

ABSTRACT

Title of dissertation: DRIVERS OF ORGANIZATIONAL MODULARITY IN
SUPPLY CHAINS – A CROSS SECTIONAL STUDY OF
U.S. MANUFACTURING INDUSTRIES

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This dissertation investigates the driving forces behind the emerging phenomenon of “organizational modularity”, by which firms create “virtual” organizations through outsourcing functions, by using contract manufacturers, by forming alliances, and by using temporary employment contracts, as they organize their activities within supply chains. Using transaction cost analysis as the overarching theoretical framework for the analysis, a number of hypotheses that relate industry structure to modularity are developed. A large scale industry-level data set is used to test the hypotheses. Statistical results show that heterogeneity of supply sources, and scale economies in focal and downstream industries, are positively associated with greater use of modular forms, whereas other factors, such as the concentration of upstream and downstream industries, are associated with less modularity. In the current outsourcing environment, these findings provide crucial insights to capture the dynamics of the prevalent modular networks.

DRIVERS OF ORGANIZATIONAL MODULARITY IN SUPPLY CHAINS –
A CROSS-SECTIONAL STUDY OF U.S. MANUFACTURING INDUSTRIES

by

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Dedicated to Two Excellent Scholars –

Professor Curtis M. Grimm

and

Professor Martin E. Dresner

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CHAPTER 1 INTRODUCTION

“There is no doubt that we are living in a modular age.”
- Garud, Kumaraswamy, and Langlois (2003), p.8

“To Be Modular or Not to Be?”
- Ketchen and Hult, 2002

“Managers facing today’s difficult environment are engaged in organizational experiments without the guidance and benefit of theories and models that would characterize the new paradigm. The experiments undertaken by organizations carry labels such as modular organization, virtual corporation ...network organization”
- Daft and Lewin, 1993, pp. i-ii

“...a modularity theory of the firm.”
- Langlois, 2002, p. 19

“I view the emergence of the modular production network as part of a historical process of industrial transformation in which nationally specific models of industrial organization co-evolve in intensifying rounds of competition, diffusion and adaptation.” (p. 451)

“In the electronics industry, at least, it is clear that the modular production network model has put a great deal of pressure on competing networks emanating from Europe and Japan.” (p. 490)
- Sturgeon, 2002

Modular Organization as a New Organizational Paradigm

A recent research stream has characterized a new industrial phenomenon by the phrase “organizational modularity” that extends beyond firm boundary issues of using “make” or “buy” alternatives to manage complex economic organizations (Sturgeon, 2002, 2003; White, 2000). *Organizational modularity* is a continuum of measuring the degree of firms’ usage of integrative, cooperative or hierarchical organizational arrangements with external business entities to minimize system-wide production and

transaction costs and increase value (Christensen, Verlinden, and Westerman, 2002; Schilling and Steensma, 2001). Manufacturing industries have been the major focus of the modularity literature. As an application of organizational modularity in the manufacturing industries, a ***modular production organization*** is a production system consisting of autonomous business entities linked by non-trivial integrative, cooperative and hierarchical governance structures with a goal of minimizing system-wide production and transaction costs and maximizing value (Daft and Lewin, 1993; Dyer, 1997; Langlois, 2002; Langlois and Robertson, 1995; Schilling and Steensma, 2001; Sturgeon, 2002; Williamson, 1991a; Zenger and Hesterly, 1997). This organizational modularity phenomenon has the potential to display an on-going paradigm shift (Best, 1990; Daft and Lewin, 1993; Sturgeon, 2002), and the impact can be as large as a Second Industrial Revolution (Achrol, 1997). Modularity researchers thus have enthusiastically called for the development of a modularity theory of the firm (Langlois, 2002; Schilling and Steensma, 2001; Tu et al. 2004).

Modularity researchers have coined several terms to describe the emergence of modular production organizations: modular network (Hoogeweegen, Teunissen, Vervest and Wagenaar, 1999), modularity-based manufacturing practices (Tu et al., 2004), modular organizational form (Schilling and Steensma, 2001), and modular production networks (Sturgeon, 2002). A parallel research stream provides several terms describing this trend to networked organization structure: virtual organizations (Daft and Lewin, 1993; Davidow and Malone, 1992; Pine II, 1993), modular organization (Schilling and Steensma, 2001; Sturgeon, 2002), network organization (or strategic network) (Gulati, 1998; Miles and Snow, 1993; Powell, 1987). In this study, we use “modular

organization” to describe the production networks that are linked by autonomous business organizations with integrative governance structures. “Organizational modularity” is used to describe the degree of an industry’s cooperative organizational arrangement.

Practices of Modular Organizations

Organizational modularity goes beyond traditional concepts concerning typical firm boundaries and encompasses multiple aspects of inter-firm arrangements. In order to achieve strategic flexibility in highly competitive markets, modular organizations often adopt inter-firm practices, including outsourcing a significant number of manufacturing activities, frequently establishing strategic alliances, and hiring a large number of short-term or temporary employees (Hitt, Keats, and DeMarie, 1998; Schilling and Steensma, 2001; Ketchen and Hult, 2002; Stratman, Roth, and Gilland, 2004; Tu et al., 2004; Van Hoek and Weken, 1998). First, contract manufacturing has become a crucial means for firms to respond to changes in the marketplace and to adjust production capacities. Recently, suppliers in several manufacturing industries, such as automobile and electronics, have begun to participate more fully in the production processes. The focal firms take charge of the most crucial coordination functions. The scope of contract manufacturing, hence, can range from the production of conventional raw materials or semi-finished parts to fully operated contract assembly operations. Secondly, strategic alliances are voluntary and cooperative long-term agreements between firms to share valuable resources (Gulati, 1998). Alliances allow firms to explore and exploit the strategic resources that are difficult to obtain through market mechanisms or vertical integration. Finally, utilizing external workforce has also become a method for firms to

achieve flexibility for employment. In addition to the conventional practice of hiring minimally skilled temporary workers, more firms are also hiring high-quality employees on a contingency basis without keeping them on the payroll as permanent workers (Schilling and Steensma, 2001).

Observers of economic organizations have pointed out that organizational modularity can be sustained in the long run (Langlois, 2002; Powell, 1987; Zenger and Hesterly, 1997). Specifically, modularity research has suggested that industrial factors, such as heterogeneity, industry concentration, technology, industrial standardization, increased competitive pressure, product innovation, pursuit for flexibility, and global supply chain management, have driven entrepreneurs to carry out organizational experiments by altering inter-firm governance structure options (Angeres, 1999; Cool and Henderson, 1998; Daft and Lewin, 1993; Bettis and Hitt, 1995; Barreyre, 1988; Garud and Munir, 2003; Hoetker, 2002; Langlois and Foss, 1999; Langlois and Robertson, 1995; Malone, Yates, and Benjamin, 1987; Schilling and Steensma, 2001; Sturgeon, 2002; Zenger and Hesterly, 1997). Firms in various manufacturing industries have transformed their industrial structures through building integrative relationships with other supply chain partners instead of utilizing market mechanisms or adopting vertical integration (Achrol, 1997; Schilling and Steensma, 2001; Sturgeon, 2002). Industries successfully implementing organizational modularity include the computer (Baldwin and Clark, 1997), electronics (Sturgeon, 2002), automobile (Hsuah 1999; Salerno, 2001), semiconductor (Machor, Mowery and Simcoe, 2002), and bicycle (Galvin and Morkel, 2001) industries.

There can also be several intangible inter-firm practices displaying organizational modularity that can be alternatives to contracts, such as trust building, relational contracting, social network relationships, etc. (Dyer, 1996; Gulati, 1998; Schilling and Steensma, 2001). This dissertation focuses on three dimensions of modularity – contract manufacturing, strategic alliance, and alternative employment arrangement, as presented in the prior discussion (Ketchen and Hult, 2002; Schilling and Steensma, 2001; Tu et al., 2004). We leave the other more intangible dimensions of organizational modularity for future research.

Implications of Modular Organizations to Supply Chain Management

Organizational modularity practices, i.e. contract manufacturing, alliance formation, and alternative employment (Schilling and Steensma, 2001), are largely associated with supply chain management (SCM) (Ketchen and Hult, 2002; Schilling and Steensma, 2001; Tu et al. 2004). A supply chain consists of many related firms, including suppliers, manufacturers, distributors, wholesalers, and retailers, that coordinate with each other through various inter-firm governance structures (Chopra and Meindl, 2001; Christopher, 1998). Firms can choose to perform all supply chain functions on their own, or coordinate these functions with other firms in the supply chain. Modular production organizations provide an additional coordination option, allowing firms to coordinate with other supply chain partners by building a hierarchical relationship, while at the same time maintaining a degree of autonomy (Daft and Lewin, 1993; Schilling and Steensma, 2001; Williamson, 1991a).

As competition has evolved to “supply chain against supply chain” (Christopher, 1998) or “network against network” (Gulati, 1998; Gulati, Nohria and Zaheer, 2000), the

understanding of organizational modularity is of crucial importance. The decisions concerning a firm's governance structures interact with those of its supply chain partners (Fine, 1998; Langlois and Robertson, 1995; Sturgeon, 2002). Utilizing modularity can result in not only the reconfiguration of a firm or a buyer-supplier relationship, but also the structure of the whole supply chain. Furthermore, the boundary-spanning nature of organizational modularity can lead to the structural reconfiguration of manufacturers and their upstream and downstream partner industries (Sturgeon, 2002; Van Hoek and Weken, 1998). Ultimately, the performance of a modular organization will be correlated with the performance of other supply chain partners.

Organization management researchers have suggested that managers are conducting the current wave of organizational innovation, including modular organizations, without the guidance of theories (Daft and Lewin, 1993). Based on our literature review, albeit the burgeoning interest in the modularity phenomenon by researchers, established management theories, e.g., Transaction Cost Economics (TCE), Resource-Based View, Strategic Network, Structure-Conduct-Performance, etc., have not yet been fully incorporated into modularity research. As stated by modularity theorists, "we cannot talk about co-evolutionary dynamics associated with the disaggregation of technical and organizational forms without reflecting upon the transaction costs and translations costs involved," (Garud, Kumaraswamy, and Langlois, 2003, p. 7). Therefore, the preceding observations motivate this dissertation to investigate organizational modularity from the perspective of TCE. This dissertation aims to establish a conceptual model that analyzes organizational modularity from both the SCM

and TCE perspectives, to develop testable hypotheses, and to conduct empirical tests for the proposed conceptual model.

Implications of Transaction Cost Economics (TCE) to Modular Organization

TCE is related to issues about the costs of transactions in the marketplace and the alignment of firm boundaries to minimize transaction costs (Williamson, 1975; 1985). TCE categorizes inter-firm governance structures with three generic modes: market mechanisms, hierarchy (or vertical integration), and a hybrid mode that displays attributes of the previous two modes (Powell, 1987; Williamson, 1985, 1995). TCE points out that in the presence of transaction costs, firms tend to build more integrative governance structures with other firms rather than use market mechanisms (Shelanski and Klein, 1995; Williamson, 1975; 1985; 1995).

Both TCE and modularity research acknowledge that economic organizations are complex systems, and modularity analysts have proposed that organizational modularity is a means to manage complex economic systems in the presence of transaction costs (Langlois, 2002; Sanchez, 1997). Organizational modularity provides an additional alternative to the conventional dichotomous make-or-buy decisions of the firm, since the dimensions of organizational modularity (i.e. contract manufacturing, alliance formation, and alternative employment) display integrative attributes of a hybrid organizational mode. We thus theorize that organizational modularity is an alternative to market mechanisms and hierarchy with respect to the firm's boundary decisions in the supply chain (Achrol, 1997; Fine, 1998; Zenger and Hesterly, 1997). Below is the highlight of this view, and full discussion will be offered in chapter 3.

This dissertation makes some fundamental TCE arguments. First, managers in a focal industry have options of using “make” (hierarchy, close-coupling, or vertical integration), “ally” (hybrid, or loose-coupling) or “buy” (market mechanisms, or decoupling) decisions when planning to organize their production system and firm or industry boundaries (Boerner and Macher, 2002; Shelanski and Klein, 1995; White, 2000; Williamson, 1995). These three options display different degrees of integration. Specifically, the “make” option is the most integrative, the “ally” option is in the middle of the governance spectrum, and the “buy” option is the least integrative. Therefore, the “ally” option, or hybrid arrangement, including long-term contracts, joint ventures and/or formal alliances, is more integrative or hierarchical than the market option. Along this line, the dimensions of organizational modularity, i.e. contract manufacturing, alliance formation, and alternative employment (Ketchen and Hult, 2002; Schilling and Steensma, 2001; Tu et al., 2004), are cooperative arrangements to coordinate activities between firms in the focal industry and other firms, and are more hierarchical and integrative governance structures in comparison to spot market mechanisms. Since the three dimensions of organizational modularity display attributes that are consistent with TCE’s hybrid governance structure based on the preceding discussion, we propose organizational modularity to be an illustration of the hybrid governance structure.

It has been observed that there are two directions of formations for modular organizations, and both adopt integrative inter-firm organizational approaches (Powell, 1987; Zenger and Hesterly, 1997). One is the infusion of market mechanisms into conventional hierarchy, as observed in most extant modularity literature. The other is the incorporation of integrative inter-firm arrangements with market mechanisms, such as

long-term buyer-supplier contracts and strategic alliances. We will discuss these two directions in the following sections.

Perspectives concerning Organizational Modularity as an Alternative to Vertical Integration

Management literature has described the modular organization as a system consisting of loosely coupled, decomposable, autonomous, interconnected, coordinated, and decentralized parts (Daft and Lewin, 1993; Williamson, 1995; Schilling and Steensma, 2001). In most of the modularity literature, researchers have argued that in the long run, vertical integration can often be replaced with separate firms connected by contracts. The pursuit of strategic flexibility can serve as the main reason to sustain modularity under heterogeneous business environments (Zenger and Hesterly, 1997; Angeres, 1999; Schilling and Steensma, 2001). Although vertical integration of supply chain functions can facilitate the coordination of manufacturing processes under relatively stable conditions, vertical integration can result in competitive disadvantages such as obsolescence and inflexibility in changing environments (Mahoney, 1992; Porter, 1980; Williamson, 1975). Additionally, high entry barriers can make vertical integration a formidable task for focal industry firm managers because of the high costs of investment (Achrol, 1997; Porter, 1980; Sanchez, 1999). In contrast, components in a modular system can leverage the advantages of codified information and standards to coordinate and communicate, and thus reduce transaction costs (Langlois and Robertson, 1995; Sturgeon, 2002). Because transaction costs between manufacturers and their suppliers could diminish in the long run, loosely coupling links can be used as a substitute of vertical integration, while the production system demonstrates higher

modularity. Modularity researchers, thus, have argued that vertically integrated organizations can oftentimes be replaced with loosely coupled modular organizations firms (Schilling and Steensma, 2001; Sturgeon, 2002).

Perspectives concerning Organizational Modularity as an Alternative to Both Vertical Integration and Market Mechanisms

As discussed earlier, the dimensions of organizational modularity display integrative attributes of the hybrid mode, so modularity is thus considered more hierarchical than pure market mechanisms (Oxley, 1999; Gulati and Singh, 1998; Williamson, 1995). To date, modularity scholars have only explained modularity as an alternative to vertical integration. For instance, Schilling and Steensma (2001) stated, “Systems are said to have a high degree of modularity when their components can be disaggregated and recombined into new configurations – possibly with new components – with little loss of functionality” (p. 1151). However, modularity researchers have provided little interpretation as to why firms might choose to utilize modularity as an alternative to both vertical integration and market mechanisms when organizing inter-firm production processes (Zenger and Hesterly, 1997). As modularity researchers pointed out, organizational modularity emerges in the integration-disintegration-reintegration cycles (Chesbrough and Kusunoki, 2001; Fine, 1998). In other words, a firm’s choice between hierarchy, modularity, and market mechanisms can be a dynamic process, and can be adjusted according to changes in the business environments.

Research Questions

The foregoing discussion on the gaps in the modularity literature, and modularity researchers' calls for a modularity theory of the firm (Langlois, 2002; Sturgeon, 2002), motivate us to investigate organizational modularity from a different angle. Specifically, we ask the following questions:

1. What are the factors that drive a manufacturing industry to use organizational modularity rather than market mechanisms in supply chains? Why do some industries display higher organizational modularity than others?
2. To what extent will these factors affect firm choice of organizational modularity?
3. Can modularity be explained by the Transaction Costs Economics theory?
4. How can supply chain management perspectives provide insights into the organizational modularity phenomenon?
5. When should firms use organizational modularity to coordinate supply chain activities in order to minimize transaction costs?

Preview of the Theoretical Framework

This dissertation provides an industry-level study and incorporates SCM and TCE perspectives to analyze the drivers of organizational modularity. We use TCE as the overarching theory to develop our conceptual model and testable hypotheses. Our intention is not to measure industry level transaction costs directly, but to examine the impacts on organizations of relevant variables that can potentially generate transaction costs. We argue that the organizational modularity of the focal manufacturing industry is a function of the attributes of the upstream and downstream supply chain industries and

of the focal industry, and that firms establish modular production organizations to account for not only production costs but also transaction costs. Supply chain attributes include the overall supply and demand heterogeneity, scale economies, and levels of concentration of upstream and downstream industries. A focal industry's attributes include the length of distribution channel, scale economies, and the level of concentration.

This dissertation attempts to make several contributions to the modularity literature. First, by applying TCE and supply chain notions, this dissertation theorizes that organizational modularity is an alternative to vertical integration and to market mechanisms. In doing so, we have re-positioned modularity in the literature. Furthermore, this dissertation contributes to the modularity literature by providing a conceptual model and empirical analyses pertaining to the driving forces behind the organizational modularity phenomenon. The complete discussion of our contributions will be offered in chapter 6.

Summary

Scholars from various research fields have viewed organizational modularity as a crucial phenomenon. The extant modularity literature views modularity as an alternative of vertical integration. In contrast, this dissertation views modularity as an alternative to both vertical integration and market mechanisms. By positioning organizational modularity in a broader theoretical framework of inter-firm governance structures, this industry-level research fills the gap in the modularity literature.

The purpose of this dissertation is to develop a model that analyzes organizational modularity from both TCE and SCM perspectives, and empirically tests the hypotheses.

This will contribute to the literature concerning the knowledge of the linkages between organizational modularity and its drivers in industrial supply chains. The findings of this study can also offer a more comprehensive theory with regard to organizational modularity that can guide managers to arrange buyer-supplier relationships.

The remaining sections of this dissertation are arranged as follows: Chapter 2 reviews empirical work on organizational modularity, with a complementary discussion of selective conceptual works. Chapter 3 provides the theory for the drivers of organizational modularity and develops testable hypotheses. Chapter 4 illustrates the measures and describes how the relevant variables are operationalized. Chapter 5 details the statistical procedures to test hypotheses and provides discussion on the testing results. Finally, the dissertation concludes with a discussion of contribution in chapter 6.

CHAPTER 2 LITERATURE REVIEW

The body of knowledge concerning organizational modularity has intersected fields such as organization management, supply chain management (SCM), operations management, strategic management, marketing management, and industrial economics. In this chapter we review the most relevant modularity studies in the foregoing areas, most of which are empirical. We also review parallel research that has applied Transaction Costs Economics (TCE) in order to analyze the interaction between inter-firm transaction attributes and the choice of governance structures.

Organization Management Literature

Organization scholars were the first to investigate the phenomenon of modular organizations (see Daft and Lewin, 1993). Their contributions focus on how technology innovation and uncertainty in business environments can affect organizational innovations, such as the formation of virtual networks and modular organizations (Argyres, 1999; Lei, Hitt and Goldhar, 1996; Sanchez, 1997; Thompson, 1967; Upton, 1997). Virtual organizations can serve as an alternative to vertical integration, especially when vertical ownership can cause diseconomies of scale and competitive disadvantages such as obsolescence due to organizational inflexibility in changing environments (Argyres, 1999).

Zenger and Hesterly (1997) have suggested that two emerging trends can change an initially integrated industrial organization. One is the infusion of hierarchy mechanisms into the market mechanisms, and the other is the infusion of market mechanisms into a hierarchy mechanism. If a firm's capacity is not sufficient, it will

have to decide whether to develop cooperative links with supply chain partners, or whether to adopt market mechanisms or vertical integration (Argyres, 1999; Zenger and Hesterley, 1997). Innovative integrative organizational governance structures, such as modular production systems, have been employed by firms as an alternative to pure market mechanisms and vertical integration (Daft and Lewin, 1993; Miles and Snow, 1987, 1993; Powell, 1987). These inter-firm integrative arrangements can link sequential supply chain echelons across firms and industries in order to vertically coordinate manufacturing processes (Argyres, 1999).

Supply Chain Management Literature

SCM researchers have found that modularity can bring forth the adjustments to supply chain structures (Towill and McCullen, 1999; Van Hoek and Weken, 1998). Modularity of product designs and supply chain processes can also redefine the divisions between supply chain stages, and transform the traditional buyer-supplier relationships (Hines and Rich, 1998; Hsuan, 1999; Van Hoek and Weken, 1998). Furthermore, the development of information technology has provided more options for managers to design virtual supply chains (Bal, Wilding and Gundry, 1999; Chandrashekar and Schary, 1999). Finally, the pursuit of strategic flexibility in terms of customization, changeover of production lines, product variety, order processing efficiency, and so forth, can be factors that drive firms to adopt organizational modularity (Bal, Wilding and Gundry, 1999; Van Hoek and Weken, 1998).

Organizational modularity can have profound impacts. Proper planning and design for a modular organization can help supply chains focus on specific supply chain functions, avoid the rigidity and inflexibility of highly integrated structures, and save

transaction costs as well as production costs (Chandrashekar and Schary, 1999; Towill and McCullen, 1999). Moreover, establishing cooperative buyer-seller relationships can strengthen a firm's competitive position (Landeros and Monczka, 1989) and result in high performance for the supply chain partners or the whole strategic alliance (Skjoett-Larse, Thernoe and Andresen, 2003; Whipple and Frankel, 2000). Specifically, inter-organizational logistics systems in flexible production networks can provide complementary capabilities for manufacturers and logistics service providers (Pfohl and Buse, 2000). Supply chain collaboration can reduce the impacts of demand and velocity fluctuation (Fine, 1998, p. 94), and integrative governance structures can be more agile, flexible and adaptive in coping with uncertainties incurred in supply chains (Vickery, Calantone, and Droge, 1999; Weber, 2002).

Several supply chain collaborative initiatives can change the scope of firms. Examples can be found in the current information sharing SCM programs, such as electronic data interchange (EDI), vender-managed inventory (VMI) and quick-response/efficient customer response (QR/ECR) solutions (Coyle, Bardi, and Langley, 1996). These organizational arrangements, as well as technology initiatives, can change the landscape of an industry and the configuration of the entire supply chain network, since integrative arrangements between supply chain members reassign the functions of different supply chain partners (Lowson, 2003; Phillips and Phillips, 1998; Van Hoek and Weken, 1998).

Another research stream has applied TCE to investigate supply management issues. Ellram (1991) suggests that a focal firm should develop integrative contractual relationships with suppliers in highly concentrated industries, so that they can assure

accessibility to inputs. Whipple, Frankel and Anselmi, (1999) also found that firms should devise hybrid-integrative organizational form to protect high relationship-specific investments, e.g. customized packaging. In sum, firms in the supply chain should implement coordination mechanisms in order to minimize the transaction costs resulted from uncertainties in inter-firm relationships, and fluctuations in order quantity, production quantity, and inventory levels.

Operations Management Literature

Operations management researchers contribute to the modularity literature with regards to the relationships between product modularity and modular manufacturing systems. Product modularity has important implication for organizational modularity. First, modularization of product and process design can create higher product variety, enhance manufacturing flexibility and facilitate manufacturing competencies (Berry and Cooper, 1999; Narasimhan, Talluri and Das, 2004). In addition, the configurations of supply chains can be strategically designed through various combinations of modularization and postponement (Ernst and Kamrad, 2000). Firms may reconfigure their production networks that correspond to the modules of the products (Ernst and Kamrad, 2000). The creation of modularity in product technology, hence, can reconfigure the design of supply chains and increase capabilities in customization (Duray et al., 2000; Ernst and Kamrad, 2000; Salvador, Forza and Rungtusanatham, 2002). Ultimately, appropriate alignment between product designs and modular organizational forms can strongly reinforce design performance and teams cooperation (Sosa, Eppinger, and Rowles, 2004).

Customization is important in driving modularity. Supply chain members are under increasing pressure to customize products and services to meet heterogeneous market needs (Pine, 1993). It is thus very critical for managers to arrange proper organizational structures that can obtain strategic flexibility in their supply chain operations (Lampel and Mintzberg, 1996). Firms have employed information and communication technology to design supply chain processes and allocate production tasks in modular organizations (Hoogeweegen et al., 1999; Tu et al., 2004). This organizational modularity can provide firms in the supply chains with accesses to complementary resources to pool capabilities for customization (Pires, 1998; Salerno, 2001).

Operations management literature has documented research concerning the performance implications of the modularity phenomenon. Ethiraj and Levinthal (2004a) use a simulation method to find the optimal level of modularity that can maximize innovation outcomes in complex organizations. Further, researchers find that modularity in the form of supply chain collaboration can enhance distribution flexibility (Daugherty and Pittman, 1995). Another research stream specifically investigates one of the major dimensions of organizational modularity, alternative employment arrangements. Researchers explore the benefits and hazards of employing temporary workers in production systems (Stratman, Roth, and Gilland, 2004).

Strategic Management Literature

Management literature has made the most extensive contribution to the understanding of the industrial evolution toward modular organization. Schilling and Steensma (2001) conducted the first extensive industry level empirical study of

organizational modularity and made a significant contribution to operationlizing organizational modularity. Organizational modularity is measured by combining three managerial dimensions; that is, contract manufacturing, alliance formation, and temporary employment. Schilling and Steensma (2001) found that combined industrial heterogeneity, from both the upstream and downstream sides, can have positive impacts on a manufacturing industry's organizational modularity. The authors did not distinguish the respective effects of input and demand heterogeneity on organizational modularity; however, they found that the heterogeneity-modularity relationship can be influenced by several complex moderating effects.

Several papers have contributed knowledge about the conditions that can drive the usage of organizational modularity. First, firms adopt organizational modularity in order to allocate their resources in the supply chains. Firms can learn about their own strength and supply chain partner capabilities through cooperative arrangements, so that they can optimize their scope of operations (Brusoni, Prencipe and Pavitt, 2001; Galunic and Eisenhardt, 2001). Furthermore, firms may utilize more hierarchical inter-firm governance structures when there are only small numbers of supply chain partners, so that they can safeguard the interdependent relationships with supply chain partners (Gulati and Singh, 1998). Also, inter-firm collaboration raises the concerns of opportunistic behaviors of supply chain participants, and hence more administrative control has to be implemented in the inter-firm exchange (Osburn et al., 1998).

Several works employed qualitative or computational approaches to study how modularity can contribute to operational performance. Modular organizational forms can enhance the exchange and combination of competitive resources between other supply

chain partners and thereby achieve greater diversification and scope economies (Helfat and Eisenhardt, 2004). Another implication associated with the combinations of complementary resources is the capability to carry out new processes and designs (Garud and Kumaraswamy, 1995; Martin and Eisenhardt, 2003). Furthermore, coordination mechanisms between firms in a modular supply chain can enhance the value of inter-firm exchange and reduce transaction costs (Baldwin and Clark, 2003; Dyer, 1997). Using a computational approach, Ethiraj and Levinthal (2004b) found that modular design and organizational modularity should be complementary to substantiate the design effectiveness.

In brief, strategy scholars have made the most significant contribution to the modularity literature by operationalizing organizational modularity and exploring the driving forces of this phenomenon. Prominent strategy theories applied in this literature include Resource-Based View (RBV) (Schilling and Steensma, 2001) and Schumpeter's (1942) Creative Destruction (Sanchez and Mahoney, 1996) theories. It appears that TCE has yet been extensively incorporated by researchers to investigate issues related to modularity.

Marketing Literature

Modularity research in the marketing management literature has suggested that organizational modularity can be an alternative to vertical integration. In particular, Achrol (1991, 1997) has observed a new business model in the U.S. emerging such that large, vertically integrated firms begin to divide their supply chain functions, such as R&D, logistics, production, or marketing, and oftentimes outsource these functions through integrative, cooperative links with supply chain partners. These links are

illustrations of modular organizational forms (Sanchez, 1999; Wilson, Weiss, and John, 1990). Moreover, the drivers of organizational modularity include greater competition, pressure to achieve flexibility, responsiveness to market demands, and pursuit of cost reductions in marketing channels (Achrol, 1997; Sanchez, 1999). Functions of the supply chain are all candidates for outsourcing and there can be numerous inter-organizational cooperative relationships to arrange modular organizational structures (Stremersch et al., 2003).

Several additional research streams related to inter-firm hybrid governance structures are very relevant to the research questions of this dissertation. Marketing provides strong empirical evidence of hybrid governance structures, even though they do not use language such as organizational modularity or modular organizations. In the following discussion, we present marketing studies applying TCE to examine how the properties of transactions affect the transaction costs and governance structure choices. Furthermore, marketing channel researchers have found that buyers and suppliers use the hybrid governance structures, e.g. alliances, joint ventures, cooperative arrangements, relational contracting, as an alternative to market mechanisms and vertical integration, to save transaction costs as well as safeguard relationships.

Marketing literature has extensively investigated various market failure issues that can lead to high transaction costs. Exchange hazards can result from various sources. The presence of opportunism can increase bargaining and monitoring costs, between channel members (Dahlstrom and Nygaard, 1999). Supply chain members may need to make greater financial or labor commitment when they conduct higher valued transactions with partners (Buvik and Andersen, 2002; Buvik and John 2000). Specific

investments between channel members can bring forth concerns about obsolete investments and inflexibility within the buyer-supplier relationship (Buvik and Andersen, 2002; Buvik and John, 2000). This asset specificity can lead to power asymmetry between channel members (Bucklin and Sengupta, 1993; Harvey and Speier, 2000). Finally, dependence of manufacturers on suppliers creates uncertainty and can result in high transaction costs (Bucklin and Sengupta, 1993; Lusch and Brown, 1996).

Empirical evidence has suggests implementation of channel integration, or inter-firm cooperation can reduce transaction costs. If we take manufacturing industries as the focal position, on the upstream supply chain side, marketing scholars have found that firms will carry out more vertical coordination and joint action in the presence of relationship-specific investments (Buvik and John 2000; Joshi and Stump, 1999). Channel members are more likely to conduct strategic integrative arrangements with suppliers if they face uncertainty from dependence on these suppliers (Johnson, 1999). Cooperation and relational contracting between manufacturers with upstream firms can reduce possession and acquisition costs (Dahlstrom and Nygaard, 1999; Noordewier, John and Nevin, 1990). Likewise, on the downstream side, interdependency and relation specific investments, and opportunism incurred in the supply chains, can lead to integrative organizational arrangements between manufacturers and retailers (Kim, 2001). Vertical contractual structures can be an effective resort to safeguard the downstream channel members from bargaining power and power imbalance incurred by the channel relationships (Dwyer and Oh, 1988; Frazier, 1999; Harvey and Speier, 2000).

Industrial Economics Literature

Most industrial economics research examining the modularity phenomenon views organizational modularity as a disintegrated structure, and the coordination mechanisms of modular organizations are substitutes for traditional, vertically integrated firms (Sturgeon, 2002; Tsang, 2003). Industrial analysts have shown that various industries, such as semiconductor (Machor, Mowery and Simcoe, 2002), electronics (Sturgeon, 2002), among others, have experienced vertical disintegration under the influences of factors such as technology, economies of scale, innovative design, product life cycle, entrepreneurial moves, etc., in the latest two decades (Brusoni and Prencipe, 2001; Christensen, Verlinden and Westerman, 2002; Cox, Mowatt and Prevezer, 2002; Galvin and Morkel, 2001; Hemmert, 1999; Kenney and Von Burg, 1999; Macher, Mowery and Simcoe, 2002; Sturgeon, 2002).

Industrial economics researchers suggest that the practices of modular production networks can lead to more disaggregated industrial landscapes (Langlois and Robertson, 1995). Modular organizations can facilitate crucial managerial variables, such as entrepreneurship (Kenney and Von Burg, 1999), vertical division of labor (Hemmert, 1999), knowledge development (Brusoni and Prencipe, 2001), and technology deployment (Christensen, Verlinden and Westerman, 2002). Through boundary-spanning arrangements with other supply chain members, firms can specialize in core competences and access the resources of other firms to reach synergies (Langlois and Robertson, 1995; Richardson, 1972; Sturgeon, 2002; Tsang, 2003).

Complementary literature in industrial economics has examined the transition from using simple market exchange mechanisms to more cooperative coordination

because of concerns with respect to transaction costs when using market mechanisms. Market mechanisms may not be able to resolve many issues of inter-firm exchanges, and market frictions are likely to occur and increase transaction costs (Williamson, 1975). Uncertainty from the external business environments can increase the cost of contracting between supply chain partners (Saussier, 2000). Relation specific investment can result in ex ante transaction costs of negotiation, and ex post costs of obsolete assets (Artz and Brush, 2000). Opportunistic behaviors, such as taking advantage of supply chain partners' investments, may cause huge losses to these partners (Oxley, 1997).

Industrial economics literature points out that firms should devise cooperative organizational forms, rather than market mechanisms, to safeguard inter-firm relationships and minimize transaction costs, since market mechanisms provide few protections to safeguard transaction hazards (Shelanski and Klein, 1995; Williamson, 1975, 1995). For example, longer contracts (Joskow, 1987; Lyons, 1996) and hierarchical structures (Oxley, 1997, 1999) can protect high asset specificity. More administrative control of the buyer-supplier relationships has been found to reduce the effect of uncertainty (Argyres, 1995). In brief, firms tend to use more hierarchical control to govern the inter-firm relationship to minimize transaction costs (Ulset, 1996).

In contrast, an alternative view suggest that, in general, firm groups in a concentrated industry may use market mechanisms to exert nontrivial influence when conducting supply chain transactions or coordinating supply chain operations (Cool and Henderson, 1998; Porter, 1980; Waldman and Jensen, 1998). The actions employed by the concentrated industry may shape the structure of not only the focal industry but the interfaces between up- and down-stream industries. Specifically, a focal industry with

high concentration may possess great bargaining power than do buyers and suppliers, and thus can take advantages of competitive pricing when coordinating its supply and demand. Examples can be found in the development of the automobile and computer industries (Langlois and Robertson, 1995; Porter, 1980). Moreover, a concentrated supplier industry is typically more able to implement supply chain transactions through monopolistic pricing mechanisms rather than longer term contracting. Likewise, because of its better position on information, demand, and pricing, a concentrated customer industry may be capable to initiate price competition rather than build longer commitment with suppliers. A prominent example is the retail industry. Emerging powerful retailers can use competitive pricing against manufacturing industries to coordinate supply and demand (Porter, 1980).

Empirical research streams have identified industry-level structural factors can be the driving forces of the firm boundaries. Two studies suggest that the levels of minimal efficient production scale can affect the degree of vertical integration (Balakrishnan and Wernerfelt, 1986; Levy, 1985). Moreover, the levels of concentration of upstream and downstream industries can affect the degree of vertical integration of the focal industry (MacDonald, 1985; Porter, 1980).

Summary

The review of relevant modularity research has indicated that organizational modularity has intersected with various research fields and the concept of modular organizations has been applied in many industries. Most of the work agrees that organizational modularity can be an alternative to vertical integration. Modularity researchers suggest organizational modularity is an emerging phenomenon that can

transform the extant industrial systems into more disintegrated ones. Modularity research also indicates that modular organizational forms can change the configurations of supply chains.

Researchers have analyzed organizational modularity from the TCE lens (Langlois and Robertson; 1995; Langlois; 1999, 2002; Sanchez, 1997, 1999; Sturgeon, 2002). On the one hand, this suggests TCE is very relevant for modularity research and has explanatory power for modularity research. On the other hand, interestingly, our literature review indicates no modularity work that views organizational modularity as an alternative to not only vertical integration but also market mechanisms.

Moreover, despite the abundant academic discussions and evidences on the increasing number of modular organizations, empirical studies that explicitly investigate organizational modularity at the industry level are few in numbers (Daft and Lewin, 1993; Schilling and Steensma, 2001). Few modularity works address which economic determinants corporations should be aware of as indicators whether to adopt organizational modularity (Daft and Lewin, 1993). In addition, modularity researchers have not incorporated theoretical notions of organizational modularity, supply chains, and TCE, simultaneously into their empirical analysis.

The preceding observations motivate this dissertation to conduct an industry-level investigation as to the drivers of organizational modularity by incorporating the constructs in organizational modularity, supply chain, and TCE research. Researchers have conducted industry-level studies to analyze the relationship between governance structures and their economic drivers (Balakrishnan and Wernerfelt, 1986; Levy, 1985; MacDonald; 1985; D'Aveni and Ravenscraft, 1994; Porter; 1980; Ravenscraft, 1983;

Schilling and Steensma, 2001). In the spirit of this stream of literature, we expect the industry level analysis can contribute to the knowledge of industrial organizational modularity.

Our review of modularity literature, and complementary research concerning inter-firm governance structures, suggests several factors that drive industries to use organizational modularity as an alternative to market mechanism. First, industrial economics studies have indicated that scale economies and industry concentration can drive an industry to be more vertically integrated (Balakrishnan and Wernerfelt, 1986; Levy, 1985; MacDonald, 1985; Porter, 1980). In addition, strategic management literature has found that combined input and demand heterogeneity has a significant impact on an industry's organizational modularity, although there is no information about the distinct impacts of the two factors (Schilling and Steensma, 2001). Moreover, supply chain management suggests that the length of distribution channels to the ultimate customer markets can cause great uncertainty and drive firms to use boundary-spanning arrangements to safeguard uncertainty (Lee, Padmanabhan, and Whang, 1997; Chopra and Meindl, 2001).

The next chapter will provide the theoretical explanations for the linkages between organizational modularity and its driving forces. Testable hypotheses will be formally developed.

CHAPTER 3 THEORY AND HYPOTHESES

The objective of this dissertation is to investigate the drivers of a manufacturing industry's organizational modularity. The unit of analysis is a manufacturing industry (U.S. Census Bureau, 1997, 2004a; Waldman and Jensen, 1998). Transaction Costs Economics (TCE) serves as the overarching theory to develop testable hypotheses. This dissertation also incorporates TCE and supply chain management (SCM) perspectives to address our research questions.

This chapter begins with a discussion of the relationships between TCE and organizational modularity. We then theorize that organizational modularity and its major dimensions; that is, contract manufacturing, alliance formation, and alternative employment arrangement (Hitt, Keats, and DeMarie, 1998; Schilling and Steensma, 2001; Ketchen and Hult, 2002; Tu et al., 2004), are consistent with TCE's hybrid governance structure. A firm thus can choose among vertical integration, market mechanisms, and modularity, to organize inter-firm relationships. The focus of this dissertation is to investigate the governance decision between market mechanisms and organizational modularity, while keeping vertical integration constant. We present a conceptual model of economic drivers of organizational modularity followed by the development of testable hypotheses.

Transaction Cost Economics and Organizational Modularity

The investigation concerning the dynamics of the current innovative modular organizational forms should reflect the transaction costs involved (Garud, Kumaraswamy, and Langlois, 2003, p. 7). Modularity scholars have applied

management theories, such as Resource-Based View (Schilling and Steensma, 2001), capability-based view (Langlois and Robertson, 1995), and Schumpeter's (1942) Creative Destruction (Sanchez and Mahoney, 1996) to analyze organizational modularity. We contend that the TCE perspective can contribute to knowledge about the organizational modularity phenomenon.

TCE is a theory used to study complex economic organization issues (Williamson, 1991a, 1991b, 1995). TCE asserts that each transaction displays distinct dimensions; i.e. uncertainty, asset specificity, frequency and complexity, which can affect the costs of carrying out the transaction. Furthermore, manager rationality is bounded with regard to uncertainty, and transactors of business exchanges, e.g. supply chain suppliers and buyers, are subject to hazards such as opportunism of parties involved in transactions. As a result, there can be conflicts or tensions when firms attempt to conduct transactions. These hazards can bring forth transaction costs - specifically, transaction costs *ex ante*, such as search costs, bargaining costs, contracting costs, and transaction costs *ex post*, such as maladaptation and misalignment (Boerner and Macher, 2002; Klein, Crawford and Alchian, 1978; Williamson, 1975, 1985, 1995). TCE scholars propose that each transaction should be carefully safeguarded with proper governance structure, so that the cost of the transaction can be minimized, if not eliminated, and the allocation of resources can be facilitated through the deliberately designed mechanism (Coase, 1937, 1988; Williamson, 1985, 1995).

TCE literature indicates that market, hybrid, and hierarchy are three generic governance modes of inter-organizational relationships (Shelanski and Klein, 1995; Williamson, 1995). These three generic governance structures demonstrate different

competences, such as coordination, and information processing mechanisms, to manage different transactions. Of the three, spot market and hierarchy are at the opposite ends of a spectrum. *Hierarchy* is defined as a “fully integrated firm, where trading parties are under unified ownership and control” (Shelanski and Klein, 1995, p. 337), while *spot market* refers to the mechanism that governs simple transactions between demand and supply through prices in the marketplace (Grover and Malhotra, 2003, p. 460; Shelanski and Klein, 1995, p. 337; Williamson, 1975). However, given the complexity of the organizations, governance structures cannot be fully analyzed with the make-or-buy dichotomy (Fine, 1998; Penrose, 1959; Powell, 1987; Richardson, 1972). There exist a great number of intermediate formats to organize the economic systems, such as long-term contracting, cooperation, alliance, or networks (Garud, Kumaraswamy, and Langlois, 2003; Tu et al., 2004; Van Hoek and Weken, 1998; Williamson, 1995) that exist between the spot market and hierarchy extremes.

Scholars of TCE have indicated that there are various “hybrid” governance structures, which are located in the spectrum between the two extremes of spot market and hierarchy governance structures (Boerner and Macher, 2002, p. 5; Shelanski and Klein, 1995, p. 337; Williamson, 1995). Examples of hybrid modes include licensing agreements, long-term supply contracts and R&D contracts (Oxley, 1999), alliances and joint ventures (Frazier, 1999; Oxley, 1999; Shelanski and Klein, 1995), relational contracting (Joskow, 1987; Palay, 1984), and bilateral organizational arrangements (Heide and John, 1990; Oxley, 1999).

In the next two sub-sections, we contend that the dimensions of modularity; that is, contract manufacturing, alliance formation, and alternative employment (Hitt, Keats,

and DeMarie, 1998; Schilling and Steensma, 2001; Sturgeon, 2002) are consistent with TCE's hybrid governance structure.

Contract Manufacturing and Alliances as the Hybrid Alternative to Market Mechanism

The first two dimensions of organizational modularity; i.e. contract manufacturing and alliances, are defined, respectively, as follows: *Contract manufacturing* refers to the contractual relationships a firm in the focal industry establishes with external manufacturing establishments, which not only can supply raw materials but can also involve the production processes and subassemblies (U.S. Census Bureau, 1997; Sturgeon, 2002). *Alliances* are voluntary contractual arrangements between separate firms involving the exchange, sharing, or joint development of products, technologies, or services, with each firm in an alliance having only limited control over the contract (Gomes-Casseres, 1996; Gulati, 1998). Examples of alliances in the manufacturing industries include decision making programs, jointly owned ventures, licensing agreements, R&D projects, marketing plans, investment programs, etc., most of which are carried out jointly by participants (Gomes-Casseres, 1996).

Contract manufacturing and alliances provide integrative organizational means to manage inter-firm exchange relationships and allocate production resources (Coase, 1937; Richardson, 1972; Williamson, 1991b). Market mechanisms may not work well, nor protect supply chain members from transaction hazards, when there are conditions in the marketplace such as changing demands, market heterogeneity, imperfect market information, power asymmetry, technology development, and so forth (Waldman and Jensen, 1998; Williamson, 1975). As TCE scholars suggest, when simple market

mechanisms do not function properly, farsighted entrepreneurs should be able to apply hierarchical contracting arrangements, rather than market mechanisms, to minimize transaction costs and optimize values (Coase, 1937, 1998; Williamson, 1995). Since both contract manufacturing and alliances are more hierarchical and integrative than market mechanisms, we consider that these two dimensions are consistent with the hybrid mode of governance. Below we present spectrums of inter-firm governance structures (Figure 3.1 and Figure 3.2) to show how these two dimensions of organizational modularity can be located on a spot market, hybrid, hierarchy spectrum.

Next, we will show that the third major dimension of organizational modularity, alternative employment arrangements, is also consistent with the hybrid governance structure, and hence that, overall, organizational modularity belongs to the hybrid governance category (Powell, 1987; Williamson, 1991b; Zenger and Hesterly, 1997).

Alternative Employment Arrangement as a Hybrid Labor Governance Structure

The labor market should be considered as a crucial supplier to an industry (Porter, 1980). In addition to acquiring labor from the spot market or employing labor directly, current business practices have adopted alternative employment arrangements (Houseman, 1999; Schilling and Steensma, 2001). These alternative employment arrangements include agency temporaries and contract laborers. The following discussion provides short summaries of the generic modes of hierarchy, spot-market and hybrid governance structures in labor organization. The subsequent section proposes an alternative employment dimension of organizational modularity that belongs to the hybrid mode of labor organization.

FIGURE 3.1

CONTRACT MANUFACTURING AS A HYBRID GOVERNANCE MODE

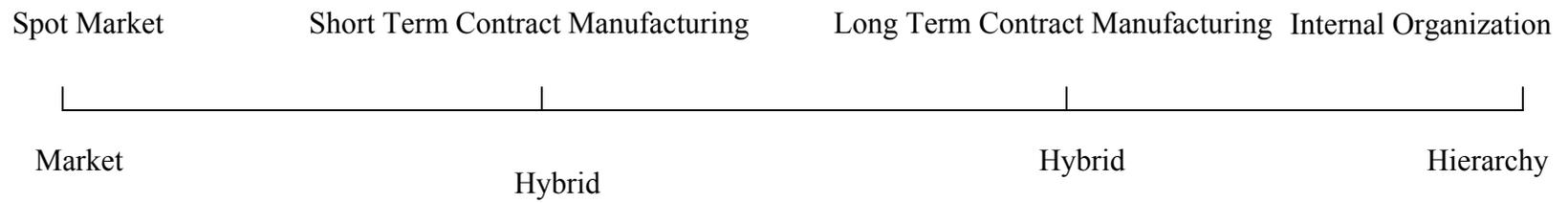
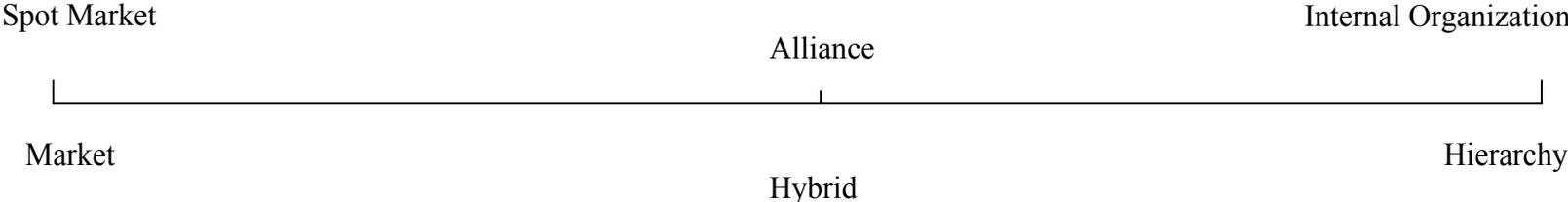


FIGURE 3.2
ALLIANCE AS A HYBRID GOVERNANCE MODE



Hierarchy Mode of Labor Management

The hierarchy mode of labor organization uses internal administrative means to govern the pricing and allocation of employment in a firm (Doeringer and Piore, 1971, pp. 1-2). Typically, workers who are considered as a hierarchy's human assets are specialized to the firm's use, and training provided for hierarchy workers is "on-the-job and firm-specific" (Osterman, 1982, p. 350; Williamson, 1985, p. 78). Workers in the hierarchy category include corporate officers and regular full-time employees (U.S. Census Bureau, 1997; Houseman, 1999).

Spot-Market Mode of Labor Management

Literature on labor management indicates two categories of labor spot markets. In the first category, firms acquire manpower directly from a pool of local labor. For manufacturing firms, these workers can perform a variety of tasks albeit with generally poorer performance as compared to regular employees (Stratman, Roth, and Gilland, 2004). Williamson (1985) calls the other category "internal spot market". In practice, the internal spot market consists of three kinds of workers - on-call workers, day laborers, and direct-hire temporaries (Houseman, 1999). These workers are hired on an as needed basis and generally perform specific projects. Their hours of work typically vary from period to period, and their assignments are oftentimes based on a short-term basis (Bureau of Labor Statistics, 1997; Houseman, 1999). Their assignments are routine, nonspecific and separable, such as data entry, warehousing, inspection procedures for production, etc. (Stratman, Roth, and Gilland, 2004; Williamson, 1985).

Workers in the spot market can move between employers without losing productivity since they typically perform standard assignments. For manufacturing firms, maintaining an employment relationship with these workers is of minimal importance. Also, firms can replace this labor without spending set-up costs. Contracting can be occasional and recurrent between labor providers and buyers, but employment can be terminated if either party is dissatisfied (Williamson, 1985, pp. 73-74 and 245).

Hybrid Mode of Labor Management

Researchers and government analysts of labor management have identified the rise in practices of alternative employment arrangements, such as agency temporaries, leased workers, independent self-employed contractors, contract companies, and others, that could transform the traditional labor organization concept (Bureau of Labor Statistics, 1997; Camuffo, 2002; Davis-Blake and Uzzi, 1993; Houseman, 1999; Kunda, Barley and Evans, 2002; Osterman, 1994, 1999; Osterman, Kochan, Locke and Piore, 2001). ***Agency temporaries*** are employees of a staffing firm (i.e. a temporary agency) that places these employees with a client firm on a short-term basis. The client firms usually direct the work of agency temporaries. ***Leased employees*** are also employees of a staffing temporary agency with longer-term contracts. ***Contract company workers*** are employees hired by a contract company. ***Independent contractors*** are self-employed and direct their own work when performing their roles, and include independent consultants and free-lance workers (Bureau of Labor Statistics, 1997; Houseman, 1999). Agency temporaries, leased employees, contract company workers, and independent contractors are more integrative into an organization's hierarchy than are workers hired on the spot labor market.

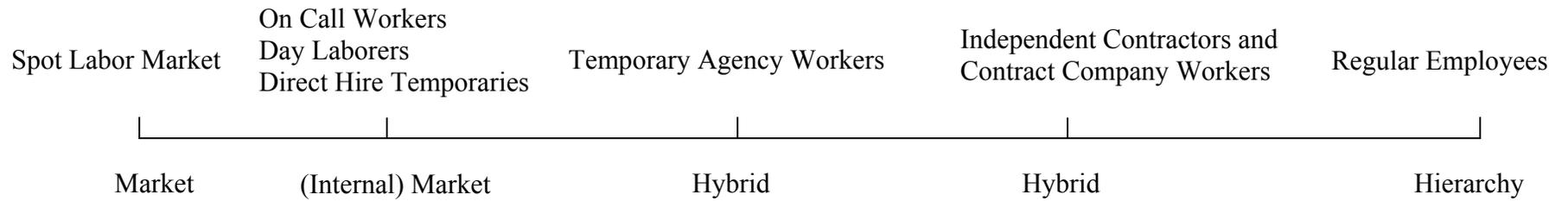
We provide a spectrum (Figure 3.3) of spot market, hybrid, and hierarchy with regard to labor management, according to TCE's generic modes of governance structures. The spectrum of the governance structures of labor markets are anchored by the left extreme point, market governance, and right extreme point, hierarchy governance. The agency temporaries, contract company workers and independent contractors, are located in the middle ground of this continuum. We thus deem these two groups of employments as hybrid modes. In our data collection, we sum up the number of the foregoing hybrid employment workers while exclude "spot market" workers to arrive at an overall alternative employment count. This conceptualization is consistent with Schilling and Steensma's (2001) "alternative work arrangements" dimension of organizational modularity.

Organizational Modularity as a Hybrid Governance Structure

Based on the preceding discussion, since the three dimensions of organizational modularity (contract manufacturing, alliances, and alternative employment arrangements) do not fit the two extremes of the conventional market-or-hierarchy options (or make-or-buy dichotomy) and display attributes of the hybrid governance mode, we thus contend that organizational modularity is consistent with TCE's hybrid governance structure (Hitt, Keats, and Demarie, 1998; Ketchen and Hult, 2002; Langlois and Robertson, 1995; Mohoney, 1992; Sturgeon, 2002; Schilling and Steensma, 2001; Williamson, 1985, 1991b, 1995). In comparison to vertical integration's internal operations and market governance's coordination through price mechanisms, organizational modularity uses various short-term or long-term contractual governances to organize inter-firm activities. These intermediate governances display attributes that are similar to both vertical

FIGURE 3.3

ALTERNATIVE EMPLOYMENT AS A HYBRID GOVERNANCE MODE



integration and market mechanisms. Also, modular organizations show attributes of the hybrid mode, such as the autonomy of system components, and the interconnections between the parts of a system (Schilling, 2000; Schilling and Steensma, 2001; Williamson, 1991b). In sum, the following figure (Figure 3.4) shows that overall organizational modularity can be located on the middle ground of the spot market, hybrid, hierarchy spectrum.

Overview of the Model and Definitions of Variables

We propose that the organizational modularity of the focal industry is a function of attributes of upstream and downstream supply chains and attributes of the focal industry. Figure 3.5 presents a conceptual model with relevant variables.

Organizational modularity was defined in chapter one. *Industry level heterogeneity* is defined as the diversity of focal industries with regards to input and demand (Allenby and Rossi, 1999, p. 57-58; Joglekar and Hamburg, 1989, p. 215; Schilling and Steensma, 2001). Diversity can be displayed through attributes of industries adjacent to the focal industry, such as transaction amounts, physical assets, strategic resources, competitive strengths, concentration level, profitability, etc. (Allenby and Rossi, 1999, p. 57-58; Joglekar and Hamburg, 1989, p. 215). Measures used in our model also include economies of scale and industry concentration. Porter (1980, p.7) defines *economies of scale* as the “declines in unit costs of a product (or operation or function that goes into producing a product) as the absolute volume per period increases.” *Industry concentration* refers to the market shared by large companies in an individual industry (Porter, 1980; Waldman and Jensen, 1998). Industry concentration indicates the role large companies play inside an individual industry (Waldman and Jensen, 1998).

FIGURE 3.4
ORGANIZATIONAL MODULARITY AS A HYBRID GOVERNANCE MODE

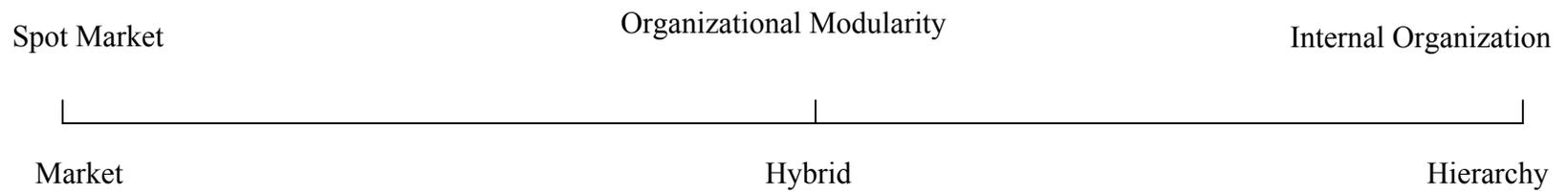
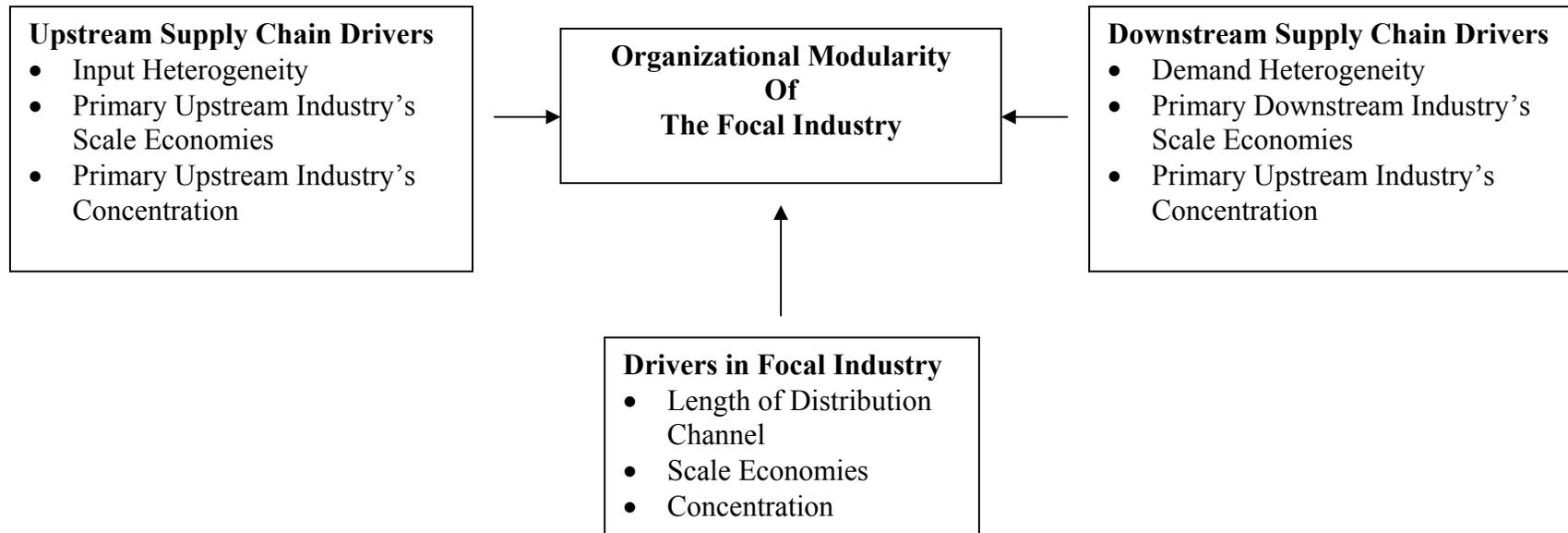


FIGURE 3.5

DRIVERS OF ORGANIZATIONAL MODULARITY



We use the overall heterogeneity measures for input and demand heterogeneity variables, while investigating the scale economies and concentration variables of *primary* upstream and downstream industries in the supply chain. A primary supply chain is linked by industries associated with physical flow of a main product category, from raw materials to industrial customers or consumer markets. Industries in primary supply chains have the highest annual exchange volumes with each other, compared to other transacting industries (Bozarth, Handfield, and Das 1998). We use the primary supply chain, instead of the entire number of possible supply chain configurations, for parsimonious reason (Barwise, 1995) since there can be numerous, if not countless, possibilities of supply chain structures considering all potential combinations of suppliers and customers of a focal industry (Chopra and Meindl, 2001; Christopher, 1998).

There are two issues our conceptual model does not attempt to address in this dissertation. First, as mentioned in chapter one, we do not measure industry level transaction costs directly, although we do examine the impacts of economic variables that can generate significant concerns of transaction costs. In addition, we do not attempt to predict which supply chain member will take initiatives to implement modularity. Our investigation concentrates on the governance choices that measure the degree of hierarchical arrangements as opposed to market mechanisms.

Fundamental Assumptions

The main interest of this dissertation is how the explanatory variables can potentially raise transaction costs, and how transaction costs can affect the degree of industrial organizational modularity. Economic factors will have impacts on the transaction costs, as well as the production costs, of firms in the supply chains. And

these costs will influence decisions in organizing inter-firm governance. As TCE scholars have suggested, farsighted entrepreneurs should be able to adopt proper contracting mechanisms to overcome potential hazards, and operate their business efficiently and effectively (Coase, 1937, 1998; Williamson, 1995, 1999). We therefore assume that managerial goals are to minimize their total costs, including transaction costs and production costs. We believe that firm behaviors will be directed by these optimization rules (Williamson, 1991b).

In the following sections, we will specify our hypotheses and explain the relationships between variables in our model.

Heterogeneity and Organizational Modularity

Heterogeneous input and demand markets in the supply chain raise concern regarding transaction costs (Waldman and Jensen, 1998). Transaction costs in homogeneous markets in the supply chain differ from heterogeneous markets in several aspects. On the input side, if the focal industry has homogeneous suppliers, standard market price systems will function at an optimal level. Changes in the fluctuation of input quantity, price, or quality, can be resolved with simple adjustments in purchasing arrangements (Porter, 1980). Switching of inputs or suppliers can be done relatively easily through market mechanisms. Moreover, on the demand side, if firms are serving homogeneous markets, using standard inputs to produce generic products and services can meet various market demands. In the presence of demand homogeneity, changes in marketing channels or locations can be easily accomplished with little switching cost. Exchanges between supply chain partners display a low degree of complexity, uncertainty, and specificity in the presence of input homogeneity (David and Han, 2004;

Williamson, 1975, 1985). However, higher degrees of input and demand heterogeneity can create transaction conditions very different from homogeneous input and demand markets, by which market mechanisms cannot prevent supply chain partners from increasing transaction costs.

From the viewpoint of the focal industry, input and demand heterogeneity can lead to complexity of supply chain functions, such as purchasing and distribution. Purchasing heterogeneous inputs through the marketplace may indicate complex procurement processes from a variety of upstream industries (Buvik and Andersen, 2002; Buvik and John, 2000; Ulset 1996). Furthermore, heterogeneity on the demand side could mean greater complexity in processing market demands for various customers and distribution channels. Using market mechanisms to coordinate supply chain functions may not be the optimal means for firms in the focal industries with heterogeneous input or demand markets, because these firms may not be able to secure necessary production inputs or distribution channels from the marketplace. Firms in the focal industries may thus incur higher transaction costs, in terms of searching, negotiation, and monitoring efforts, to coordinating greater numbers of supply chain partners on either the upstream or downstream sides (Coase, 1937; Williamson, 1985).

Furthermore, heterogeneity from the input and demand sides of the supply chain can create uncertain conditions for the focal industries. As Allenby and Rossi (1999) have stated, “As consumer preferences and sensitivities become more diverse, it becomes less and less efficient to consider the market in the aggregate” (p. 57-58). On the input side, variations in input supplies, qualities, services, prices, or combinations of preceding factors, can cause supply chain inefficiencies, such as raw materials stockpiles, input

stockouts, disruptions of production, and others (Chopra and Meindl, 2001; Pine II, 1993). In addition, technology advances from the upstream supply chain, such as R&D breakthroughs, can result in greater impacts on supplies and can bring forth new production arrangements or even new configurations of the supply chain (Fine, 1998). On the demand side, demand heterogeneity creates uncertainty resulting from changes in customer preferences, order quantities, prices, service levels, etc., of different distribution channels (Artz and Brush, 2000; Dahlstrom and Nygaard 1999; Saussier, 2000; Wernerfelt and Karnani, 1987). Since focal firms may not be able to obtain sufficient information to make optimal predictions to meet needs for the heterogeneous markets, this uncertainty might not be predicted and responded to easily (Williamson, 1975, 1985). The uncertainty of heterogeneous inputs and demands can be even higher if competitors foreclose suppliers or distribution channels from upstream or downstream industries (Boerner and Macher, 2002; Shelanski and Klein, 1995; Williamson, 1975). These hazards can translate into transaction costs for firms in the focal industry.

Higher heterogeneity from upstream and downstream supply chains can also result in more relation-specific arrangements, either tangible or intangible, between supply chain partners (Shelanski and Klein, 1995). On the input side, heterogeneous inputs can result in more specialized arrangements with different suppliers, such as specialized negotiations and greater efforts to conduct transactions (Artz and Brush, 2000). Likewise, on the demand side, heterogeneity displayed by downstream markets such as diverse channels of distribution, different and shifting customer preferences, demand quantity variance, prices, service provision requirements (e.g. customer service levels, lead times), geographical dispersion, among others, can generate pressure for

firms in the focal industry to customize production or logistics arrangements (Christopher, 1998; Lee, Padmanabhan and Whang, 1997). Focal firm customization of products, services, or distribution channels, for various downstream supply chain partners, can lead to greater transaction costs, as well as high production and logistics costs (Buvik and Andersen, 2002; Buvik and John, 2000; Coase, 1937; Dyer, 1996; Houston and Johnson, 2000; Kotha, 1995; Pine, 1993; Porter, 1985; Ulset, 1996). Aggregate switching costs can also increase if inputs or distribution channels cannot be altered or rearranged easily (Heide and John, 1990; Houston and Johnson, 2000; Monteverde and Teece, 1982; Williamson, 1975, 1985). When specific investments can no longer generate desirable outcomes, using market mechanisms without safeguards can cause higher costs of obsolescences (Williamson, 1975). Furthermore, although the use of technology and standards can facilitate the progress of the external links (Bettis and Hitt, 1995; Angeres, 1999; Zenger and Hesterly, 1997; Sturgeon, 2002), the additional investments can create higher specificity, resulting in the need for proper organizational devices as safeguards.

As compared to market mechanism that has limited safeguards for business exchanges, modular organizations adopt more hierarchical practices, such as longer-term contracting and interdependent governance structures, to safeguard the uncertainty hazards from heterogeneity, reduce transaction costs, and facilitate inter-firm coordination (Bucklin and Sengupta, 1993; Harvey and Speier 2000). Cooperative and adaptive arrangements, e.g. longer-term relational contract, joint ventures, and alliances with supply chain partners, have been identified as integrative means to enhance coordination between sequential functions in the supply chain in order to cope with

uncertainty (Buvik and Anderson, 2002; Coase, 1937; Gulati and Singh, 1998; Langlois and Robertson, 1995; Palay, 1984; Nambisan, 2002; Noordewier, John and Nevin, 1990; Shelanski and Klein, 1995; Stern and Reve, 1980). In brief, by building collaborative relationship with other supply chain partners, firms in the focal industry can use modularity to safeguard against hazards and to provide complementary strategic resources from business partners, thus reducing uncertainty (Coase, 1937; Noordewier, John and Nevin, 1990; Williamson, 1975).

In addition, uncertainty associated with demand heterogeneity can force firms to build up cooperative organizational arrangements with not only downstream channels but also upstream partners. Uncertainty displayed in demand heterogeneity will prompt firms to reconfigure their existing resources by expanding their production system boundaries through contract manufacturing (Schilling, 2000; Schilling and Steensma, 2001). Finally, through vertical coordination, modular organizations can safeguard the relation-specific investment as well as pertinent inter-firm relationships between supply chain partners facing special service level (Buvik and John, 2000, Joskow, 1987; Kim, 2001; Lyons, 1996; Oxley, 1999).

Literature has provided evidence that the integrative structure of modular organizations can save nontrivial transaction costs. On the input side, Noordewier, John, and Nevin (1990) have found that relational contracting can reduce purchasing costs. On the demand side, coordination between firms and downstream supply chain members can reduce transaction costs after integrative inter-firm relationships are established (Buvik and Andersen, 2002; Buvik and John, 2000; Williamson, 1985).

Cooperative and adaptive arrangements, e.g. vendor-management inventory systems, quick response system, JIT production, and joint logistics and marketing (Joshi and Stump, 1999), have been implemented by supply chain members to coordinate their processes (Christopher, 1998). Also, several corporations provide successful practices of organizational modularity. For instance, the B-2 bomber project (Argyres, 1999), Sun Microsystem's joint R&D programs (Garud and Kumaraswamy, 1995), and Toyota's supplier network (Dyer and Nobeoka, 2000), provide illustrations that firms can establish modular organizations with supply chain members to minimize transaction costs and create flexibility. In addition, IBM and Dell use a variety of cooperative suppliers to support their complex production and assembly systems (Baldwin and Clark, 1997; Pine, 1993; Schilling and Steensma, 2001). Facing fast changing competition, Johnson & Johnson decided to use more collaborative arrangements to link itself with many small, autonomous companies, when it recognized an increase in its market turbulence (Pine, 1993, p. 237). These arrangements have shown that organizational modularity can enhance supply chain coordination and reduce transaction costs (Langlois and Robertson, 1995).

In sum, in comparison to market mechanisms, organizational modularity is a more hierarchical organizational arrangement that can reduce transaction costs caused by input and demand heterogeneity, and facilitate the coordination of supply chain processes given heterogeneous input and demand conditions. This is consistent with the TCE literature that longer-term contracting and hierarchical governance structures have been used to safeguard firms against transaction hazards (Joshi and Stump 1999; Joskow 1987; Lyons 1996; Oxley, 1999; Ulset 1996). Thus, we propose the following hypotheses:

Hypothesis 1a: Other things being equal, the greater the input heterogeneity, the greater the level of the focal industry's organizational modularity.

Hypothesis 1b: Other things being equal, the greater the demand heterogeneity, the greater the level of the focal industry's organizational modularity.

Organizational Modularity and the Length of Industrial Distribution Channel to the Final Market in the Primary Industrial Supply Chain

Industries at different echelon of supply chains face different levels of uncertainties resulting from changing order quantities, cycle times, geographically sporadic markets, insufficient information gathered from the marketplace, different distribution channels, etc. (Achrol, 1997; Chopra and Meindl, 2001). These uncertainties can be amplified for upstream industries, i.e. the “Bullwhip” effect (Fine, 1998; Lee, Padmanabhan, and Whang, 1997). Industries at upstream supply chain may incur higher costs to buffer these variations. More specifically, a longer industrial distribution channel of a focal industry may lead to greater bullwhip effect that can translate to higher transaction costs on purchasing and marketing.

Supply chain members incur some limitations when coping with bullwhip effects. First, being upstream in a supply chain may limit firms from receiving sufficient information about the marketplace. Moreover, management is subject to bounded rationality, and firms are not able to completely predict market attributes and the future change (Chopra and Meindl, 2001; Fine, 1998). Lack of coordination, high product variation, and moves to counter the bullwhip effects by other firms in the supply chain, may further weaken abilities to align supply chain operations to meet real market demand (Lee, Padmanabhan, and Whang, 1997). As a result, the bullwhip effect may cause firms

to increase their production capacities or inventory levels to absorb the variations caused by uncertainties.

Current SCM programs, such as VMI, QR/ECR, and EDI, have been adopted to reduce the demand amplification effects in distribution channels (Coyle, Bardi, and Langley, 1996; Langlois and Robertson, 1995; Lee, So and Tang, 2000; Lee, Clark, and Tam, 1999). These information-sharing programs may enhance the integration of supply chain coordination; on the other hand, communication technology investment can increase asset specificity and interdependence (Buvik and Andersen, 2002; Buvik and John, 2000; Ulset, 1996). Supply chain members thus should build proper governance structures to safeguard these inter-organizational investments (Mahoney, 1992; Williamson, 1985).

In order to reduce the impacts of demand amplification in their distribution channels, manufacturers can adopt organizational modularity to facilitate supply chain coordination (Argyres, 1995; Buvik and John, 2000; Fine, 1998, p. 94; Oxley, 1999; Ulset, 1996). Collaborative agreements between supply chain partners, such as strategic alliances and long-term contractual relationships, can reduce the distortion of market signals through information-sharing arrangements. Richer information made available through coordination in modular structures can help firms to increase the accuracy of prediction and avoid demand amplification effects (Chopra and Meindl, 2001; Fine, 1998). More integrative arrangements can also safeguard relation-specific investments, such as communication investments, inter-organizational information technology, and EDI, among others (Fine, 1998; Noordewier, John and Nevin, 1990; Palay, 1984;). Finally, tight inter-firm governance structure can enhance performance under uncertainty

in buyer-supplier relationships (Noordewier, John and Nevin (1990). Therefore, we present the following hypothesis:

Hypothesis 2: Other things being equal, the greater the focal industry's length of distribution channel to the final customer markets in a primary supply chain, the greater the level of the focal industry's organizational modularity.

Scale Economies and Organizational Modularity

Scale Economies of the Focal Industry

Industrial structures influenced by economies of scale have implications for contracting behaviors between supply chain partners (Porter, 1980; Schumpeter, 1942). Economies of scale are crucial determinant of firm boundaries and market structure (Waldman and Jensen, 1998; Williamson, 1991a). Higher minimum efficient scales (MES) indicate manufacturers may be required to reach a larger production threshold to obtain the lowest possible unit cost. If MES is large relative to market size, high economies of scale may favor a market structure in which only a relatively small numbers of firms can operate efficiently since they possess cost advantages over other firms (Porter, 1980; Waldman and Jensen, 1998). Higher economies of scale of the focal industry not only can limit the growth of other firms in the same industry, but also can create barriers for firms trying to enter the industry (Waldman and Jensen, 1998). The advantages of large scale firms can be greater when firms possess intangible resources to run the larger scale production systems (Porter, 1980). Dependence of supply chain members on the fewer firms in the focal industry may thus develop.

Accordingly, asset specificity may be significant between low-cost focal firms and supply chain partners because of unique characteristics to facilitate or effectuate the

collaboration (Williamson, 1975). Firms on the upstream or downstream sides of the focal industry may attempt to establish integrative arrangements with the focal industry, such as contract manufacturing, to overcome entry barriers such as high investments for manufacturing systems. Smaller firms adjacent to an industry with high economies of scale may find it difficult to reach the threshold of large MES for production in a short period of time (Langlois and Robertson, 1995; Sturgeon, 2002). Switching costs can increase because of the link with large-scale and low-cost focal manufacturers (Monteverde and Teece 1982). More specifically, sophisticated production systems in the focal industry, which have already reached a higher level of plant and equipment utilization, may motivate firms in the adjacent industries to specialize in particular value chain activities, yet leverage focal firms' strength at the same time (Langlois and Robertson, 1995; Porter, 1980; Sturgeon, 2002). In addition, economies of scale of particular production processes can generate clusters inside the focal industry (Baldwin and Clark, 2000). These clusters may specialize in different stages of production, and connect with each other through integrative governance structures, such as firms do in the semiconductor industry (FSA, 2003; Baldwin and Clark, 2000; Langlois and Robertson, 1995). As a result, transaction costs in the form of asset specificity and switching costs may rise in the interfaces between focal firms and supply chain partners, and two-way safeguards could be taken to lesson the rising transaction costs.

Greater economies of scale can also be achieved through forward or backward vertically integrative moves by firms in the focal industry with large supply chain partners. Large firms with scale economies can maintain their specialized functions to reach efficiency, and build integrative links with efficient supply chain members. Thus,

these firms can avoid investing in vertical integration, minimize search costs for low cost partners (market mechanisms), and increase system efficiency simultaneously (Joglekar and Hamburg, 1989; Porter, 1980; Schumpeter, 1942; Sturgeon, 2002). Larger firms thus can build an integrated supply chain that is more efficient in the areas of transactions, production, and distribution, comparing to supply chains with different disconnected firms of various sizes (Porter, 1998). Dell provides a good example of a firm able to leverage its supply chain partners' scale economies better than its own supply chain.

The preceding discussion is consistent with organizational modularity studies that demonstrated that firms specialized in particular supply chain functions have established external integrative relationships with their supply chain partners (Best, 1994; Langlois and Robertson, 1995, Gomes-Goncerres, 1996). Thus,

Hypothesis 3: Other things being equal, the greater the focal industry's economies of scale, the greater the level of the focal industry's organizational modularity.

Scale Economies of the Upstream and Downstream Industries in the Primary Supply Chain

Scale economies can be found in supply chain functions, such as production, assembly, logistics, marketing, and others (Porter, 1980). From the perspective of the focal industry, scale economies displayed by suppliers or customers can provide cost advantages or superior expertise for these supply chain functions (Coase, 1937, 1988; Lyons, 1995, Porter, 1980). These skills employed by supply chain partners may not be easily developed or possessed by focal firms. By utilizing external strengths of efficient supply chain partners, firms in the focal industry may be able to specialize in their

particular supply chain function and help to optimize total supply chain operations at the same time (Langlois and Robertson, 1995; Sturgeon, 2002).

Large, efficient supply chain partners may help firms in the focal industry to minimize costs and optimize values for the entire production and distribution system (Coase, 1937; Langlois and Robertson, 1995; Sturgeon, 2002). On the other hand, by accessing business partners with high scale economies, the dependence of firms in the focal industries may rise, thus increasing potential transaction costs (Bozarth, Handfield, and Das 1998; Williamson, 1975, 1985). Furthermore, because of the high MES requirement, focal firms generally lack the capability to overcome high barriers to backward and forward integration (Porter, 1980; Waldman and Jensen, 1998). As a result, the existence of economies of scale in upstream and downstream firms may limit a focal firm's options in governance structures. The governance structure options can be even fewer if the firms in the focal industry are not just relatively smaller, but inefficient due to a lack of investment resources (Porter, 1980; Cool and Henderson, 1998).

For firms in the focal industry, high scale economies of the primary upstream and downstream industries have profound implications for transaction costs and total supply chain management. From the viewpoint of the focal industry, a primary upstream industry with large economies of scale is very different from a competitive supply market. Firms in the focal industry will tend to depend on a few suppliers with scale economies to gain greater efficiencies (Coase, 1937, 1988; Lyons, 1980, 1995, Porter, 1980). Furthermore, firms in the focal industry may transact with high purchasing volumes and cause even greater dependence on large-scale suppliers (Buvik and Andersen 2002; Buvik and John 2000). The dependence on suppliers with scale

economies in the upstream supply chain can result in uncertainty and the need for greater contracting efforts to guard against transaction hazards (Artz and Brush 2000; Bucklin and Sengupta, 1993; Lusch and Brown, 1996; Saussier 2000).

By the same token, in downstream industries with high scale economies, there may only be a small number of firms or channels of distribution available. The limited options for focal firms may lead to increasing dependence (Williamson, 1975, 1985). Moreover, to obtain further advantages with regard to profitability or sales performance, firms may try to concentrate high transaction volumes with large supply chain partners, and thus generate greater dependence and potential hazards (e.g., a firm supplying Walmart) (Buvik and Andersen 2002; Buvik and John 2000). In this context, switching costs may be high and result in high relation-specific commitment, i.e. asset specificity. Switching costs, together with the uncertainty incurred, may increase transaction costs accordingly (Artz and Brush, 2000; Monteverde and Teece 1982; Saussier, 2000).

Further, specific investments and cooperation efforts may be required to facilitate coordination between the focal industry and large supply chain members in order to achieve a reduction in supply chain costs (Angeres, 1999, Langlois and Robertson, 1995; Sturgeon, 2002; Zenger and Hesterly, 1997). Advanced inter-organizational information systems, such as computer-aided design (CAD), computer-aided manufacturing (CAM), flexible manufacturing systems (FMS), electronic data exchange (EDI), quick response (QR) systems, Efficient Customer Response (ECR) systems, and supply chain management (SCM) systems, have been developed to facilitate the coordination between firms in the focal industry and supply chain partners in order to reach synergistic cooperation (Malone, Yates, and Benjamin, 1987). There can be joint actions following

investments between supply chain members (Joshi and Stump, 1999). These technology investments and relationship specific arrangements can increase the asset specificity that can eventually lead to higher transaction costs and switching costs (Artz and Brush 2000; Bucklin and Sengupta 1993; Harvey and Speier 2000; Monteverde and Teece 1982; Saussier, 2000).

As opposed to using price mechanisms without safeguard, cooperative arrangements, e.g. longer-term contracts, joint ventures, or alliances, can be established between firms in the focal industry and supply chain partners. Inter-firm agreements arrangements, such as administrative control and joint actions, can be built between manufacturers and supply chain partners with superior manufacturing or distribution capacities, so that they can mitigate uncertainty in buyer-supplier relationships (Argyres, 1995; Buvik and Anderson, 2002; Dahlstrom and Nygaard 1999; Dwyer and Oh, 1988; Gulati and Singh, 1998; Houston and Johnston, 2000; Johnson, 1999; Joshi and Strump, 1999; Joskow, 1987; Lyons, 1996; Osborn and Baughn, 1990; Oxley, 1999; Ulset, 1996; Williamson, 1985). In addition, supply chain coordination can also reduce transaction costs when firms face transaction uncertainties from supply chain partners (Buvik and John, 2000; Dyer, 1997).

The effect of economies of scale from the downstream industry needs further discussion. Large downstream supply chain partners may request firms in the focal industry to provide inputs with high volume and low costs, and thus put focal firms under efficiency pressure. Firms in the focal industries may need to establish closer relationships with upstream supply chain partners to ensure low costs inputs and to steady and smooth flows toward large downstream channels (Noordewier, John and Nevin,

1990). Therefore, adopting modularity by building inter-organizational ties with supply chain partners can reduce transaction hazards and safeguard uncertainty brought forth by dependence on large firms in supply chains.

Literature has provided examples of integrative moves by manufacturers that coordinate with supply chain partners with high scale economies. Ceramics and textiles industries in Italy, and industrial groups in Denmark and Germany, are examples of cooperative mechanisms between small firms and their suppliers with economies of scale (Best, 1990; Pine II, 1993; Langlois and Robertson, 1995). The Silicon Valley in the U.S. is also a domestic illustration of the cooperation between large efficient firms (Pine II, 1993; Sturgeon, 2002).

In brief, organizational modularity provides an alternative option for firms to minimize uncertainty (Williamson, 1975). Cost-minimizing firms could consider using modular production networks as integrative and hierarchical governance structures not only to lower production costs, but also to minimize transaction costs in the supply chain. Our argument is consistent with TCE's prediction that more hierarchical coordination mechanisms may be more effective in lowering transaction costs (Osborn and Baughn, 1990) than market mechanisms (Williamson, 1985; 1991a). Thus, we conclude the above discussion with the following hypotheses:

Hypothesis 4a: Other things being equal, the greater the economies of scale of the primary upstream industry, the greater the level of the focal industry's organizational modularity.

Hypothesis 4b: Other things being equal, the greater the economies of scale of the primary downstream industry, the greater the level of the focal industry's organizational modularity.

Concentration in an Industry's Primary Supply Chain and Organizational Modularity

Concentration of the Focal Industry

High concentration can be found in oligopolistic and monopolistic industries that have several powerful firms. Highly concentrated industries typically have a different competitive status from less concentrated industries. Firms in concentrated industries may possess market powers, compared to smaller competitors and their supply chain partners (Porter, 1980). Industries with powerful firms can prevent entry threats through vertical integration. Powerful firms in highly concentrated industries can limit the number of competitors within and outside the focal industry (Waldman and Jensen, 1998). This small numbers bargaining characteristic between powerful firms and supply chain members may lead to greater opportunistic behaviors in the marketplace or transactions (Frazier, 1999; Williamson, 1975).

Potential transaction costs may exist at the interfaces between a highly concentrated focal industry and supply and customer industries. Firms in concentrated industries may try to reduce uncertainty in the marketplace through vertical integrative arrangements with their supply chain partners (Joglekar and Hamburg, 1989). The potential to lower transaction costs can motivate large firms to exercise their bargaining power to establish integrative inter-firm links with supply chain partners (Porter, 1980). Firms in concentrated industries can extend their power through integrative moves to

control suppliers or customers (Porter, 1980; Waldman and Jensen, 1998). These integrative arrangements can facilitate a powerful firm's control over complementary resources, such as R&D, marketing channels, logistics capabilities, information technologies, etc. (Gulati, 1998; Joglekar and Hamburg, 1989; Porter, 1980; Schumpeter, 1942).

Additionally, firms in adjacent upstream and downstream sides of highly concentrated industries are likely to build hierarchical governance structures rather than to implement market mechanisms. These coordinating arrangements can help suppliers and customers reduce the negative impacts due to significant bargaining power, such as opportunistic behaviors, from powerful firms, and can thus reduce costs of transacting with large firms in the concentrated industries (Williamson, 1975, 1985).

In sum, based on the preceding discussion, we contend that firms in the focal industry with high concentration can build more integrative relationships with external firms, and thus increase organizational modularity of the focal industry. We present our hypothesis as follows:

Hypothesis 5: Other things being equal, the greater the concentration of the focal industry, the greater the level of the focal industry's organizational modularity.

Concentration of the Upstream and Downstream Industries in the Primary Supply Chain

Conflicts are more likely when firms negotiate with powerful supply chain partners, such as large distributors in downstream distribution channels (Frazier and Rody 1991; Geyskens, Steenkamp, and Kumar, 1999; Johnson, 1999), and these conflicts can lead to high transaction costs (Williamson, 1975). Market mechanism works well if the upstream and downstream industries are less concentrated. However, if upstream and

downstream industries are concentrated, firms in the focal industry may have limited supply and distribution options. That is, highly concentrated supply or demand industries can lead to higher costs transacting relationships against a focal industry (Cool and Henderson, 1998; Pfeffer and Salancik, 2003; Porter, 1980; Waldman and Jensen, 1998; Williamson, 1975, 1985).

A small numbers bargaining problem can emerge when firms deal with supply chain partners in highly concentrated industries (Bozarth, Handfield, and Das 1998; Williamson, 1975, 1985). Interacting with supply chain partners in concentrated industries can generate transaction costs because of frictions in business exchanges (Frazier and Rody 1991; Geyskens, Steenkamp, and Kumar 1999). Supply chain partners in highly concentrated upstream and/or downstream industries can exert bargaining power over firms in the focal industry (Porter, 1980). Firms in the focal industry may encounter inflexibility and high switching costs when dealing with supply chain partners in concentrated industries, and thus become vulnerable (Bucklin and Sengupta, 1993; Harvey and Speier, 2000; Lusch and Brown, 1996; Monteverde and Teece, 1982).

Bargaining power displayed by supply chain partners raises the threat of opportunism and may cause substantial transaction costs (Artz and Brush, 2000; Cool and Henderson, 1998; Dahlstrom and Nygaard, 1999; Saussier, 2000; Porter, 1980; Williamson, 1985, 1995). Examples of opportunistic behaviors include unanticipated price or quality changes, distortion of demand information, threat of switching suppliers, short-notice of marketing campaigns, distortion of market and demand information, etc. (Dahlstrom and Nygaard, 1999; Gulati and Singh, 1998; Porter, 1980; Williamson, 1985). Firms may lack the capability to overcome these opportunistic behaviors through vertical

integration (Porter, 1980). Further, in a highly concentrated upstream or downstream industry, large firms may exercise power against business partners to force cooperation. Accordingly, supply chain members are exposed to greater opportunism (Artz and Brush, 2000; Dahlstrom and Nygaard, 1999; Lee, Clark, and Tam, 1999; Porter, 1980; Saussier, 2000). All these behaviors can translate into transaction costs in terms of bargaining, contracting, and monitoring activities (Artz and Brush, 2000; Dahlstrom and Nygaard, 1999; Saussier 2000). Consequently, focal firm's profitability can eventually reduced (Cool and Henderson, 1998; Dahlstrom and Nygaard, 1999).

Moreover, relational hazards can increase even more when there is power asymmetry between the focal industry and adjacent industries, where the focal industry is more competitive but the adjacent upstream and downstream industries are highly concentrated (Bucklin and Sengupta, 1993; Dahlstrom and Nygaard, 1999; Harvey and Speier 2000). Opportunism may be greater under a power imbalance (Bucklin and Sengupta 1993; Dahlstrom and Nygaard, 1999). The costs to manage the relationships between supply chain partners can be high (Artz and Brush 2000). Also, the increase in transaction costs can hurt a focal firm's profitability (Cool and Henderson, 1998; Porter, 1980). According to TCE, these hazards resulting from powerful supply chain partners require protective governance structures (Williamson, 1975).

Hierarchical linkages can be established between firms in the focal industry and firms in concentrated industries to prevent the negative impacts from bargaining power (Buvik and Anderson, 2002; Gulati and Singh, 1998; Houston and Johnston, 2000; Osborn and Baughn, 1990; Ulset, 1996). Literature has suggested that to avoid the hazards from powerful suppliers, firms in the focal industry tend to use tighter production

or distribution governance structures with supply chain partners, instead of market mechanisms (Geyskens, Steenkamp, and Kumar, 1999). For instance, formal rules and inter-firm cooperation can be established between focal firms and powerful suppliers to avoid opportunism (Dahlstrom and Nygaard, 1999; Geyskens, Steenkamp, and Kumar, 1999). Also, in order to avoid opportunism (Buvik and John, 2000; Dahlstrom and Nygaard, 1999) or conflicts (Frazier, 1999) from powerful downstream partners, more cooperative agreements should be established between industrial sellers and powerful buyers (Buvik and Anderson, 2002; Gulati and Singh, 1998; Houston and Johnston, 2000; Osborn and Baughn, 1990). So, more hierarchical mechanisms may prove be more effective in lowering transaction costs (Dyer, 1997; Osborn and Baughn, 1990).

Firms in the focal industry can also use organizational modularity's integrative arrangements with suppliers to safeguard transaction hazards from concentrated downstream industries (Williamson, 1975). Focal firms can reduce the impacts of powerful customers by establishing integrative relationships with upstream suppliers or with other manufacturing firms through information sharing, collaborative projects, or inter-firm cooperation (Porter, 1980; Wiliamson, 1975). Further, to increase their own bargaining power when interacting with powerful downstream supply chain members, focal firms might want to develop boundary-spanning arrangements with powerful suppliers to counter potential opportunism (Porter, 1980; Williamson, 1985). Focal firms, thus, can avoid becoming the captive of powerful customers who possess monopolistic power (Frazier, 1999).

In conclusion, for focal firms facing adjacent highly concentrated industries, modular production organizations' hierarchical coordination mechanisms can be effective

safeguards in lowering transaction costs (Williamson, 1985; 1991b). As firms in the focal industry attempt to conduct transactions with powerful firms in supply chains, organizational modularity can be the means to protect firms from transaction hazards, and thus minimize potential transaction costs incurred through the marketplace (Dahlstrom and Nygaard, 1999; Frazier, 1999; Gulati and Singh, 1998; Harvey and Speier, 2000). Hence, we propose the following hypotheses:

Hypothesis 6a: Other things being equal, the greater the concentration of the primary upstream industry, the greater the level of the focal industry's organizational modularity.

Hypothesis 6b: Other things being equal, the greater the concentration of the primary downstream industry, the greater the level of the focal industry's organizational modularity of the focal industry.

Summary

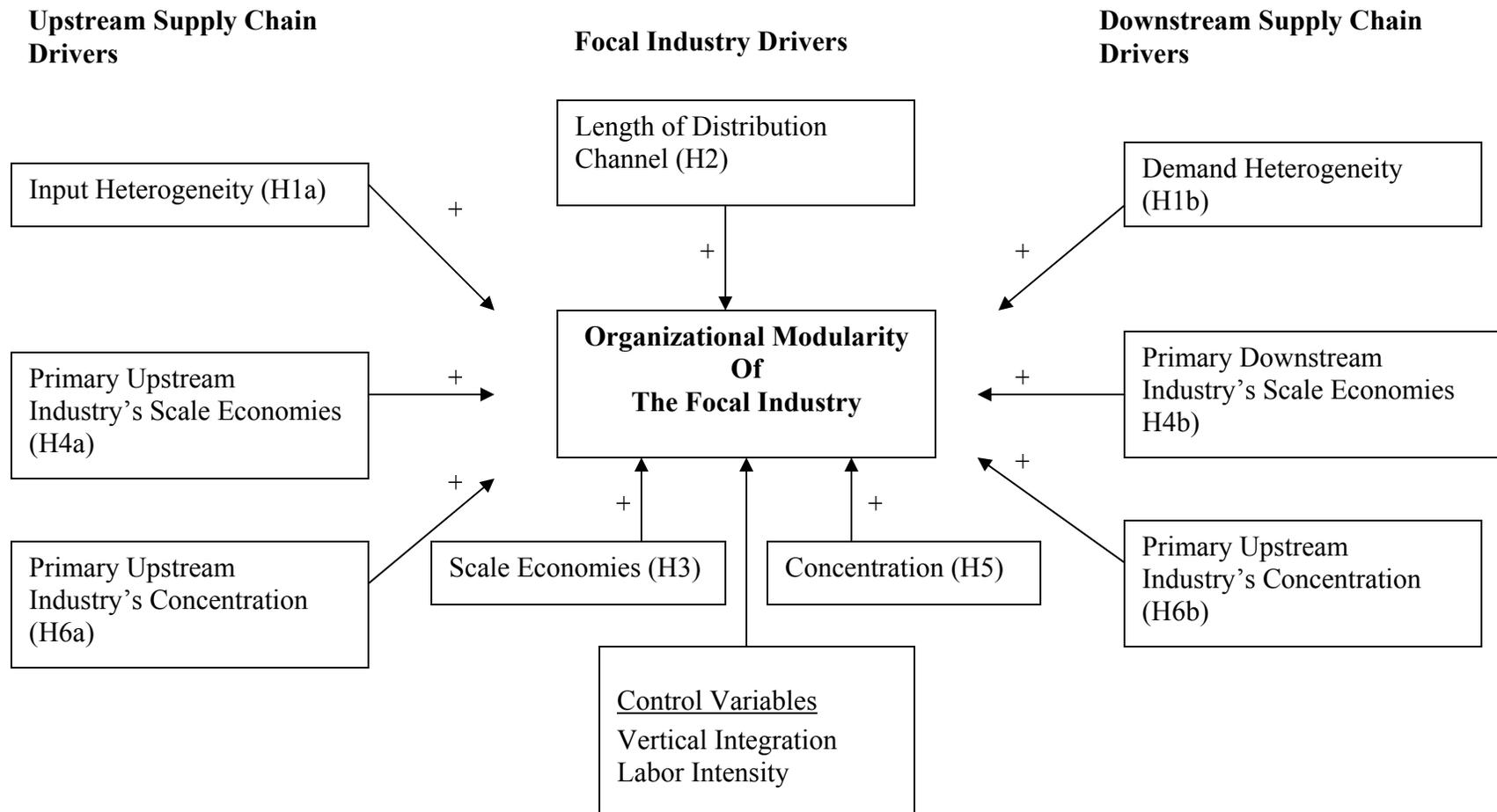
In this chapter, we have identified and defined industry level economic factors that can motivate firms to use integrative governances instead of market mechanisms. We also incorporate TCE and SCM perspectives to explore the relationships between these drivers and organizational modularity. We have indicated how our independent variables can generate transaction costs if firms merely use market mechanisms to coordinate with supply chain members. Specifically, the independent variables display different levels of opportunism, uncertainty, asset specificity, transaction frequency, transaction complexity, or combinations of the prior four dimensions that can raise the transaction costs under a market structure. We hereby incorporate the previous conceptual model (Figure 3.5) and the hypotheses and present the complete conceptual

model of the industry level drivers of a focal industry's organizational modularity (Figure 3.6). This model is our attempt to answer the call for a modularity theory of the firm (Daft and Lewin, 1993; Langlois, 2002).

Our hypotheses explain variations of organizational modularity. We theorize that firms in a focal industry will use higher modularity, i.e. more integrative organizational arrangements, to manage inter-firm relationships in the supply chain, with a goal of cost-minimization. In the next chapter, we present the data collection, industrial supply chain configurations, and the operationalization for variables pertaining to the hypotheses.

FIGURE 3.6

A CONCEPTUAL MODEL FOR DRIVERS OF ORGANIZATIONAL MODULARITY



CHAPTER 4 DATA AND OPERATIONALIZATIONS OF VARIABLES

This section presents data collection methods and operationalization employed by this dissertation. We conduct an industry level analysis regarding the drivers of organizational modularity. Based on the conceptual model in the last chapter, a model of industry level organizational modularity can be expressed in the following functional form:

$$\text{Organizational Modularity} = f(\text{Upstream Supply Chain Attributes, Downstream Supply Chain Attributes, Focal Industry Attributes}) \dots\dots\dots(4.1)$$

On the left hand side, the dependent variable is the focal industry's organizational modularity. On the right hand side are the independent variables. The upstream supply chain attributes include overall input heterogeneity, primary upstream industry's economies of scale, and primary upstream industry's concentration. The downstream supply chain attributes include overall demand heterogeneity, primary downstream industry's economies of scale, and primary downstream industry's concentration. Focal industry attributes include focal industry's length of distribution channel, focal industry's economies of scale, and focal industry's concentration.

We first present the sample we will analyze and then address the data to be collected for the measures and operationalization of the variables, followed by the methodology to test the hypotheses.

Sample and Configurations of Primary Industrial Supply Chains

Sample

The unit of analysis of this dissertation is a U.S. manufacturing industry. The 1997 version of the 6-digit North American Industry Classification System (NAICS) established by the U.S. Census Bureau (U.S. Census Bureau, 1998), is applied to define a manufacturing industry. This dissertation focuses on manufacturing industries, in that manufacturing industries have been the main focus in the organizational modularity literature (Baldwin and Clark, 1997; Langlois and Robertson, 1995; Schilling and Steensma, 2001; Sturgeon, 2002; Worren, Moore, and Cardona, 2002), and some of the constructs, such as contract manufacturing, are not pertinent to industries such as service, wholesale, retail, and transportation (Schilling and Steensma, 2001). This dissertation includes all 473 6-digit NAICS manufacturing industries. The 1997 Economic Census is the main source of the dataset.

In addition to the Economic Census, this dissertation utilizes additional 1997 data sources to conduct a cross-sectional study, as presented below. 1997 is the latest year with available data for measuring all variables.

Configurations of Primary Industrial Supply Chains

For the purpose of this study, it is imperative to identify a focal manufacturing industry and the its primary upstream and downstream industries in a industrial supply chain. This dissertation combines the information on the 1997 Economic Census and 1997 Benchmark Input-Output (IO) Accounts by the Bureau of Economic Analysis (2004) to identify the primary supplier and customer industries of a focal industry.

Researchers have utilized the IO tables to define the buying and supplying relationships between industries (Martin, 1983; Ravenscraft, 1983; Schilling and Steensma, 2001).

Most supply chain management scholars agree that typical supply chains include, from upstream toward downstream sides, raw material supply, production and operation, and wholesale and distribution stages before primary products reach customers (Bowersox and Closs, 1996, pp. 33-49; Chopra and Meindl, 2001, pp. 5-8; Christopher, 1998, p. 13; Coyle, Bardi, and Langley, 1996, pp. 8-10; Shapiro, 2001, pp. 6; Simchi-Levi, Kaminsky, and Simchi-Levi, 2000, pp. 1-4). In addition, supply chains including the general public as final users typically consist of material suppliers, manufacturers, wholesalers, retailers, and consumers (Chopra and Meindl, 2001, pp. 5-8; Coyle, Bardi, and Langley, 1996, pp. 8-10). This dissertation applies these generic supply chain models to configure industrial supply chains for 473 manufacturing industries. The main setting of upstream-focal-downstream industries discussed in Chapter 3 is largely consistent with multi-state supply chain rationale suggested by Hult, Ketchen, and Nichols (2002), Hult, Ketchen, and Slater (2004), Mentzer et al. (2001), and Porter (1980, 1985).

On the upstream side of each focal industry, the Direct Requirements Table in the 1997 Benchmark Input-Output Accounts by the Bureau of Economic Analysis is used to find all the supply industries of the focal manufacturing industry (Bureau of Economic Analysis, 2004). These supply industries are then sorted in the order of their contributions to the dollar value of focal industries' products. The supply industry with the largest contribution is considered the primary supply industry to the focal industry.

The Use Table of the 1997 Benchmark Input-Output Accounts is employed to identify the primary final users of each focal industry's products. If the primary final users cannot be identified from the Use Table, the Make Table is then employed to aid the search. A primary final user of a focal industry is the industry that uses the most of focal industry's products in terms of dollar values (Bureau of Economic Analysis, 2004). After the primary final users are found, we apply the aforementioned generic supply chain models and utilize the NAICS categorization in conjunction with its online search systems to identify the industrial channels related to the distribution of the focal industries' products (U.S. Census Bureau, 2004b). The industrial distribution channels typically consist of wholesale industries and retail industries.

Several scenarios emerge when we construct industrial supply chains. First, the primary final user may be closely related to the focal industry and mainly consume the focal industry's products. For instance, aircraft manufacturing industry (NAICS 336411) is the sole customer to aircraft engine manufacturing industry (NAICS 336412). For the similar cases, we assume that focal industries' products go directly to the final users without passing intermediate processes. On the other hand, for supply chains in which primary final users do not directly procure from focal manufacturers, we assume that the products of the focal industries will go through distribution channels prior to reaching the final users. If the primary final user is the consumer market (NAICS F01000, Personal Consumption Expenditures) or the private enterprise market (NAICS F02000, Private Fixed Investment), we use the NAICS search systems to identify the wholesale and retail industries that distribute the focal industry's products to the end customers.

Figure 4.1 illustrates the construction of the computer manufacturing industry's supply chain. The NAICS number assigned for the industry is 334111. The primary upstream industry to the computer manufacturing industry is the semiconductor industry (NAICS 334413). The primary downstream industry to the computer manufacturing industry is the computer wholesale industry (NAICS 421430). The next downstream industry in the primary supply chain is the computer retail industry (NAICS 443120). The Private Fixed Investment (NAICS F02000) is the next and final node of the primary supply chain for the computer manufacturing industry.

In order to validate all 473 industrial supply chains, three researchers participated to review the constructions of these chains. Each researcher individually applied the previous rationales to examine industrial chains. The final form of each industrial chain was determined based on the agreement of all researchers.

Dependent Variable

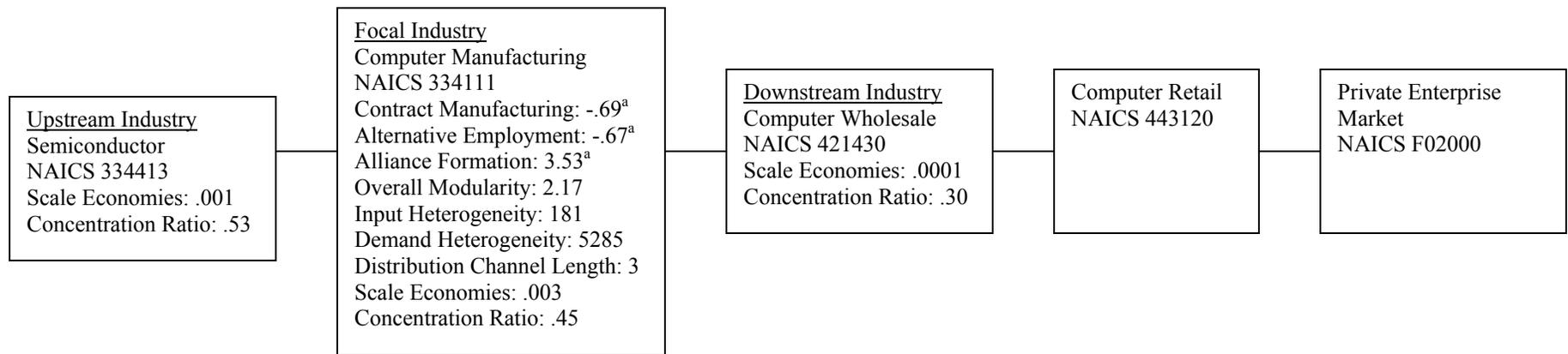
Organizational Modularity

This study follows Schilling and Steensma's (2001, p.1151) operationalization of organizational modularity. The measure of an industry's organizational modularity consists of three dimensions: contract manufacturing, alliance formation, and alternative employment.

Contract manufacturing is measured by a manufacturing industry's expenditure on contract work as a percentage of the total cost of materials. The data source is the 1997 Census of Manufacturers (Schilling and Steensma, 2001).

FIGURE 4.1

THE PRIMARY INDUSTRIAL SUPPLY CHAIN FOR THE COMPUTER MANUFACTURING INDUSTRY



a. standardized value

Alternative employment is measured by dividing the number of alternative employees by total employment in an industry in 1997 (Schilling and Steensma, 2001). The data source is the 1997 Current Population Survey (CPS) by the Bureau of Labor Statistics. The Bureau of Labor Statistics has conducted a Supplement to the February 1997 Current Population Survey to investigate the practices of alternative employment arrangements. The categories of alternative employment arrangements and definitions are as follows, with survey items inside the parentheses (Bureau of Labor Statistics, 1997; Houseman, 1999):

1. Agency temporary (PES2; PES2INS): Agency temporaries are employees of a staffing firm (i.e. temporary agency) that places them with a client firm. This placement is usually on a short-term basis, and the client firms usually direct the work of agency temporaries.
2. Leased (PES2; PES2INS): Similar to agency temporaries, leased employees are employees of a staffing firm. However, their assignments to the client firms are typically on a long-term basis.
3. Contract company workers (PES6): “Contract company workers are employed by a company that contracts out their services to a client, but the contract company directs their work” (Houseman, 1999).
4. Independent contractor (PES7; PES8IC): “Legally, independent contractors are self-employed and must direct their own work” (Houseman, 1999). Independent contractors obtain clients on their own and perform work such as independent contractors, independent consultants, or free-lance workers (BLS, 2003).

5. On-call Workers (PES4; PES4A), Day Laborer (PES5), and Direct-hire Temporary (PES1A, B, C, and D): “On-call workers are hired only on an as needed basis. Thus, while their job may not be temporary, their hours of work typically vary” (Houseman, 1999). Also, direct hire temporaries tend to be hired on a short-term basis and perform on a specific project (Houseman, 1999).

The interest of this dissertation is the alternative employment that belongs to the hybrid governance mode of transaction cost economics. On-call works, day laborers, and direct-hire temporaries are part of a spot labor market, and are thus excluded from our calculation (Houseman, 1999; Williamson, 1985). In contrast, agency temporaries, leased employees, contract company workers, and independent contractors, usually are part of inter-firm employment arrangements, and thus are considered hybrid employment arrangements. This is consistent with the alternative employment measure of Schilling and Steensma (2001).

The original industrial grouping system applied in the CPS is the 1990 Census classification system that is different from both NAICS and SIC. We utilize the Industry and Occupation Crosswalks table between NAICS 1997 and 1990 Census codes (U.S. Census Bureau, 2005a) to convert the original CPS counts into NAICS measures.

Alliance formation is measured by dividing the alliances and joint ventures counts in an industry by the number of firms in that industry to get the degree of alliance formation for 1997 (Schilling and Steensma, 2001). The data source is the Joint Venture/Alliance database in the Thompson Financial’s SDC Platinum system. The original industrial grouping system in the SDC Platinum package is the U.S. Standard Industrial Classification (SIC) system. We utilize the correspondence table between

NAICS 1997 and SIC (U.S. Census Bureau, 2005b) to convert the SIC counts into NAICS measures.

Overall modularity is operationalized through two steps. First, each of the prior three measures is standardized. Then the three standardized values for each industry are combined together with equal weight to get the measure of overall modularity for a single 6-digit NAICS industry (Schilling and Steensma, 2001).

Independent Variables

Overall input heterogeneity. To measure the input heterogeneity of a focal industry, we use the 1997 Benchmark IO tables that provide data on every commodity category input used by a focal industry. The input heterogeneity of the upstream industry is measured by counting every commodity category used by the focal industry (Schilling and Steensma, 2001).

Overall demand heterogeneity. To measure the demand heterogeneity of a focal industry, we use the 1997 Benchmark IO tables that provide data on every commodity category produced by a focal industry. Measuring the heterogeneity of demand to the focal industry requires several steps. First, we identify all commodity categories produced by a focal industry. In the next step, for each of those commodity categories, all purchasing industries of the commodity category are also identified. We count the numbers of all purchasing industries of each commodity and sum up the counts of all commodities. The resulting measure of the summation thus includes every purchasing industry for every commodity category produced by the focal industry (Schilling and Steensma, 2001).

The focal industry's length of distribution channel. We apply supply chain management expert conceptualizations of industrial supply chains to obtain a proxy of the focal industry's length of distribution channel (Bowersox and Closs, 1996; Chopra and Meindl, 2001; Christopher, 1998; Coyle, Bardi, and Langley, 1996; Shapiro, 2001; Simchi-Levi, Kaminsky, and Simchi-Levi, 2000). The distribution channel length is measured by counting the numbers of industries downstream to the focal industry in a primary supply chain.

Scale economies: minimum efficient scale (MES). We propose to use minimal efficient scale (MES) as a proxy for scale economies (Hennart and Park, 1994; Hladik, 1985). The Census Bureau has set employment size classes for industries and assigned each manufacturing establishment to one of the size classes based on the number of regular employees. In the 1997 Economic Census, there are 10 size classes for manufacturing industries, ranging from establishments with 1-4 employees to establishments with 2,500 employees or more. Also, in the past Economic Census, the Census Bureau has surveyed manufacturing establishments to obtain information about each establishment's annual dollar value of production output (products manufactured plus receipts for services rendered, U.S. Census Bureau, 1997). In addition, the Census Bureau reports the total dollar value of production output of all establishments in each size class as well as total output dollar value of the entire 6-digit NAICS industry (U.S. Census Bureau, 1997; Hladik, 1985).

This dissertation measures the scale economies of an industry by calculating the MES relative to industry output value at the 6-digit NAICS level. To calculate MES, we use the following steps to measure it. First, we calculate the sum of production output

dollar value of establishments in the median and all higher size classes. Since output dollar value in size classes below the median are typically small, we only use the production output in the median and higher classes to calculate this proxy for scale economies. Then, we divide the sum by the total number of establishments in these size classes. The MES is therefore the mean of aggregate annual output dollar value at these size classes measured in U.S. million dollars (Hennart and Park, 1994; Hladik, 1985). Finally, we divide the MES by the total output dollar value of the NAICS industry (Hennart and Park, 1994; Hladik, 1985). This is a measure of MES relative to an industry output size and can be comparable across industries. A high relative MES indicates that firms in the higher size classes share a larger percentage of production output on average and indicates larger economies of scale (Hladik, 1985).

Concentration of an industry. An industry's concentration ratio is measured by top four firms' percentage of output dollar value in a 6-digit NAICS industry (Levy, 1985; McDonald, 1985; Ravenscraft, 1983). The measures for all industries are collected from the 1997 Economic Census.

Figure 4.1 also provides the values of the relevant variable measures for the computer manufacturing industry. The organizational modularity is measured in terms of three standardized component values. The Contract Manufacturing value is -.69, the Alternative Employment value is -.67, and the Alliance Formation value is 3.53. The Overall Organizational Modularity is the sum of the previous components and thus scores 2.17. The input and demand heterogeneity measures are 181 and 5285, respectively. Additionally, the distributional channel length is three. The value of minimum efficient scale is .3 per cent. Finally, the concentration rate of top four firms is 45 per cent.

Control Variables

Vertical integration. Since we are interested in a focal firm's use of modularity as an alternative to market mechanisms, it is imperative to hold the degree of vertical integration constant. Economics and management literature has used the ratio of value added over sales as an proxy for vertical integration (Balakrishnan and Wernerfelt, 1986; Brush and Karnani, 1996; Levy, 1985; Jacobsen, 1988). We propose to use two measures, value added and dollar value of output, obtained from the 1997 Economic Census to operationalize the focal industry's vertical integration. The value added measure is derived by "subtracting the cost of materials supplies, containers, fuel, purchased electricity, and contract work from the value of shipments" (U.S. Census Bureau, 1997). We derive the focal industry's degree of vertical integration by dividing the industry's value added by the total value of shipments. The higher the measure, the more integrated the industry. This is consistent with the TCE prediction that greater vertical integration can be more efficient and perform better (Williamson, 1975).

Labor intensity. Modularity researchers have shown that the level of labor intensity can potentially affect manufacturing firms' decisions concerning using cooperative governance structures, such as outsourcing and alliances (Schilling and Steensma, 2001). To control this effect, we control labor intensity by calculating the number of employees per dollar value of production outputs for a manufacturing industry (Schilling and Steensma, 2001).

Standardization of Independent Variable Measures

After calculating the measures for independent and control variables, we standardize the values according to Schilling and Steensma (2001). We use the initial

values to calculate descriptive statistics. The measures utilized in regression analyses (to be discussed in detail in the next chapter) are standardized values.

Preview of the Methodology to Test Hypotheses

Regression techniques will be applied to test our hypotheses. Complete discussion of statistical testing procedures will be provided in the next chapter. Here we briefly lay out the construction of the regression model for organizational modularity and how hypotheses will be tested based on the regression outcomes. Specification of the regression model is as follows:

$$\begin{aligned}
 \text{Organizational Modularity} = & b_0 + b_1 \text{ Input Heterogeneity} + b_2 \text{ Demand Heterogeneity} + \\
 & b_3 \text{ Length of Distribution Channel} + b_4 \text{ Focal Industry Scale Economies} + b_5 \text{ Upstream} \\
 & \text{Scale Economies} + b_6 \text{ Downstream Scale Economies} + b_7 \text{ Focal Industry Concentration} \\
 & + b_8 \text{ Upstream Concentration} + b_9 \text{ Downstream Concentration} + b_{10} \text{ Vertical Integration} \\
 & + b_{11} \text{ Labor Intensity} + \text{error terms} \dots\dots\dots(4.2)
 \end{aligned}$$

According to Hypotheses 1a and 1b, we argue that input and demand heterogeneity will have positive impacts on a focal industry’s organizational modularity. So b1 and b2 are expected to be positive. Hypothesis 2 indicates distance from the focal industry to final markets will positively affect the focal industry’s organizational modularity, so b3 should be positive. According to Hypothesis 3, the higher the focal industry scale economies, the higher the focal industry’s organizational modularity. So we expect b4 to be positive. Hypotheses 4a and 4b suggest that if upstream and downstream industries have higher scale economies, the focal industry will have higher

modularity. So we expect b5 and b6 positive. Hypothesis 5 suggests that higher concentration in the focal industry will lead to higher organizational modularity. So b7 shall be positive. Hypotheses 6a and 6b indicate that the more concentrated the upstream and downstream industries, the higher the organizational modularity in the focal industry. So we expected b8 and b9 to be positive.

Summary

In this chapter we have presented our sample and data collection for our industry level analysis. A 6-digit NAICS manufacturing industry is the unit of analysis of this dissertation. The 1997 Economic Census is the main data source. We have specified the operationalizations of relevant variables. This dissertation applies the measure constructed by Schilling and Steensma (2001) to measure overall organizational modularity. We propose conducting regression analysis to test our hypotheses. In the next chapter, we will detail the statistical procedures of hypotheses testing and discuss results.

CHAPTER 5 METHODOLOGY AND DISCUSSION

This chapter focuses on the statistical analyses of the data detailed in chapter 4. We first report specific regression runs and results. Hypotheses and regression outcomes are compared and examined. We also discuss managerial implications and industry examples based on our findings. This chapter concludes with a discussion of research limitations and future research directions pertaining to this dissertation.

Descriptive Statistics and Correlation Coefficients

Table 5.1 presents the descriptive statistics and the correlation coefficients of the non-standardized values of all variable measures. The correlation coefficients and pertinent significances do not change for standardized values. Several correlation coefficients, in particular, those between scale economies and concentration variables, are larger than .50, similar to the coefficient between scale economies and concentration in Hennart and Park (1994). Although incorporating scale economies and concentration variables simultaneously in regression runs is not uncommon in industry level studies (see Caves, Khalilzadeh-Shirazi, and Porter, 1975; Comanor and Wilson, 1967; Hennart and Park, 1994; Khalilzadeh-Shirazi, 1974; Levy, 1985; Ravenscraft, 1983), they could suggest potential multicollinearity that can cause imprecise regression results (Greene, 2000). Therefore, the variance inflation factor (VIF) for each independent variable is further examined by utilizing SPSS statistics software (Bae and Gargiulo, 2004; Greene, 2000; Neter, Wasserman, and Kunter, 1990). The accepted threshold in the statistics and management literature is 10, and all VIF scores of the independent variables are within

TABLE 5.1
DESCRIPTIVE STATISTICS AND CORRELATION COEFFICIENTS

Variable	Mean	s.d. ^a	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Overall Modularity	-.084	1.567														
2. Contract Manufacturing	.035	.045	.652**													
3. Alternative Employment	.020	.030	.668**	.095*												
4. Alliance Formation	.064	.162	.350**	-.102*	.020											
5. Input Heterogeneity	152.186	39.380	.101*	.118*	-.052	.133**										
6. Demand Heterogeneity	2,215.019	1,737.406	.099*	.131**	.041	-.085	.535**									
7. Length of Distribution Channel	2.093	.836	-.025	-.091	.061	-.105*	-.127**	-.214**								
8. Focal Industry Scale Economies	.011	.020	.009	-.112*	-.042	.434**	-.192**	-.235**	-.126**							
9. Upstream Industry Scale Economies	.010	.017	-.091	-.101*	-.074	.211**	.029	-.068	-.151**	.136**						
10. Downstream Industry Scale Economies	.004	.009	.007	-.013	-.100*	.160**	.044	.020	-.423**	.275**	.174**					
11. Focal Industry Concentration	40.960	21.215	-.131**	-.283**	-.070	.336**	-.111*	-.332**	-.005	.593**	.084	.094*				
12. Upstream Industry Concentration	36.998	16.239	-.178**	-.135**	-.135**	.122**	.027	-.084	-.055	.149**	.591**	.084	.187**			
13. Downstream Industry Concentration	29.049	21.588	-.041	-.062	-.101*	.178**	.186**	.132**	-.484**	.138**	.130**	.526**	.217**	.142**		
14. Vertical Integration	.507	.123	.273**	.336**	.190**	-.079	.047	.098*	.028	-.154**	-.071	-.185**	-.115*	-.096*	-.035	
15. Labor Intensity	.006	.004	.257**	.372**	.223**	-.268**	-.067	.088	.116*	-.220	-.140**	-.148**	-.448**	-.160**	-.136**	.448**

a. s.d. stands for standard deviation. * p < .05; ** p < .01

the range between 1.318 and 2.188. Since no VIF exceeds 10, multicollinearity might not have a serious influence over the regression results (Bae and Gargiulo, 2004; Neter, Wasserman, and Kunter, 1990).

Statistical Procedures for Testing Hypotheses

To test the hypotheses, this dissertation follows the statistical methods documented in the econometrics and modularity literature for regression analyses (Greene, 2000; Johnston and DiNardo, 1997; Schilling and Steensma, 2001). All regression runs and heteroscedasticity tests are performed using STATA software. Here we briefly review the specification of regression models discussed in chapter 4 and then detail the statistical procedures of hypotheses testing.

Specification of the Regression Model

Based on the conceptual model in chapter 3, the model of industry level organizational modularity can be expressed in the following functional form:

$$\text{Organizational Modularity} = f(\text{Upstream Supply Chain Attributes, Downstream Supply Chain Attributes, Focal Industry Attributes}) \dots\dots\dots(5.1)$$

To the left, the dependent variable is the focal industry's organizational modularity. To the right are the independent variables. The upstream supply chain attributes include overall input heterogeneity, primary upstream industry's economies of scale, and the primary upstream industry's concentration. The downstream supply chain attributes include overall demand heterogeneity, primary downstream industry's

economies of scale, and primary downstream industry's concentration. Focal industry attributes include focal industry's length of industrial distribution channel, focal industry's scale economies, and focal industry's concentration.

In order to construct regression models consistently with past research, model specifications in multiple industry level studies are reviewed (see Cool and Henderson, 1998; Caves, Khalilzadeh-Shirazi, and Porter, 1975; Comanor and Wilson, 1967; Hennart and Park, 1994; Khalilzadeh-Shirazi, 1974; Levy, 1985; MacDonald, 1985; Ravenscraft, 1983; Schilling and Steensma, 2001). The following model specifies the regression on overall organizational modularity:

$$\begin{aligned}
 \text{Organizational Modularity} = & b_0 + b_1 \text{ Input Heterogeneity} + b_2 \text{ Demand Heterogeneity} + \\
 & b_3 \text{ Length of Distribution Channel} + b_4 \text{ Focal Industry Scale Economies} + b_5 \text{ Upstream} \\
 & \text{Scale Economies} + b_6 \text{ Downstream Scale Economies} + b_7 \text{ Focal Industry Concentration} \\
 & + b_8 \text{ Upstream Concentration} + b_9 \text{ Downstream Concentration} + b_{10} \text{ Vertical Integration} \\
 & + b_{11} \text{ Labor Intensity} + \text{error terms} \dots\dots\dots (5.2)
 \end{aligned}$$

Ordinary least squares (OLS) regression runs constitute the first step of the hypotheses tests (Schilling and Steensma, 2001). Further diagnostic regression procedures are performed if the analyses of error terms suggest heteroscedasticity. As discussed in chapter 4 (p. 69), the values of the right-hand side variables of equation 5.2 are standardized measures. Based on our predictions detailed in chapter 3, we argue that explanatory variables on the right hand side of 5.2 have positive impacts on a focal industry's organizational modularity. We thus anticipate that b1 through b9 will be

positive and significant. Furthermore, we conduct regression runs for individual components of overall modularity to explore the explanatory variables' impacts on the three dimensions of organizational modularity – contract manufacturing, alternative employment, and alliance formation (Schilling and Steensma, 2001). We next examine the properties of the error terms.

Test of Heteroscedasticity and Diagnose

Since this dissertation employs cross-sectional data sources in 1997, it is necessary to conduct tests for heteroscedasticity that is common in cross-sectional data sets (Greene, 2000; Johnston and DiNardo, 1997). More specifically, heteroscedasticity is a typical property of cross-sectional data sets where the error terms of each observation are not constant. In this dissertation, after each OLS run, White and Breusch-Pagan tests are performed for each individual regression model to test heteroscedasticity (Greene, 2000; Johnston and DiNardo, 1997). If heteroscedasticity is significant, we perform weighted least squares (WLS) regression runs to diagnose this problem (Greene, 2000; Johnston and DiNardo, 1997). Econometrics scholars suggest that while OLS coefficients are unbiased, WLS can provide more efficient results in terms of smaller coefficient standard errors. Thus WLS outcomes may be more precise for hypotheses testing (Greene, 2000; Johnston and DiNardo, 1997).

Regression Results and Tests of Hypotheses

In this section we report respective regression analyses in the following order: overall modularity, contract manufacturing, alternative employment, and alliance formation.

Model for Overall Modularity

OLS is performed to obtain a baseline model for overall modularity. In order to further account for the potential impacts of multicollinearity between scale economies variables and concentration variables, we perform additional regression runs. In Table 5.2, the second column reports the regression analysis excluding concentration variables. The third column presents the regression run without scale economies variables. In general, the coefficients in the two additional regressions are consistent with those in the full models in terms of signs and significance levels. Hence, as suggested by our prior VIF test results, the high correlation between scale economies and concentration variables appear not to cause serious effects on our regression outcomes.

Two tests for heteroscedasticity are performed for the full OLS regression. The White's test statistic is 71.798 ($p = .646$), while Breusch-Pagan test statistic is 89.592 ($p = .000$). According to the Breusch-Pagan test, heteroscedasticity is highly significant. Therefore, we performed additional WLS runs to account for heteroscedasticity. Columns 4 and 5 in Table 5.2 summarize the outcomes of the OLS and the WLS regressions for the full model. The WLS results are largely consistent with the OLS results with respect to coefficient signs and significance. In general, the WLS coefficients have smaller standard errors and the WLS model shows a higher fit (R^2), compared to the OLS model.

With reference to Table 5.2, the regression runs on overall modularity show support for several hypotheses. The coefficients of input heterogeneity are positive and significant in both the OLS (.163, $p < .05$) and the WLS (.142, $p < .05$) models; hence, hypothesis 1a is supported. In addition, the coefficients of focal industry scale economies are positive and significant in both the OLS (.293, $p < .05$) and the WLS (.321, $p < .05$)

TABLE 5.2

RESULTS OF REGRESSION ANALYSES FOR OVERALL MODULARITY AS THE DEPENDENT VARIABLE

Variable	OLS		OLS		OLS		WLS	
Constant	-.097+	(.072)	-.154*	(.070)	-.130*	(.072)	-.122*	(.069)
Input Heterogeneity	.146*	(.087)	.122+	(.085)	.163*	(.087)	.142*	(.081)
Demand Heterogeneity	.042	(.087)	.025	(.086)	.028	(.087)	.037	(.083)
Length of Distribution Channel	-.010	(.086)	-.074	(.085)	-.023	(.088)	-.064	(.079)
Focal Industry Scale Economies	.154*	(.093)			.293*	(.150)	.321*	(.146)
Upstream Industry Scale Economies	-.125	(.100)			-.051	(.121)	-.015	(.077)
Downstream Industry Scale Economies	.062	(.105)			.166+	(.114)	.157*	(.093)
Focal Industry Concentration			-.022	(.091)	-.124	(.108)	-.161+	(.102)
Upstream Industry Concentration			-.213**	(.074)	-.189*	(.090)	-.176*	(.078)
Downstream Industry Concentration			-.116+	(.085)	-.178*	(.094)	-.158*	(.086)
Vertical Integration	.324***	(.086)	.267**	(.085)	.304***	(.087)	.295***	(.079)
Labor Intensity	.280***	(.082)	.293***	(.088)	.264**	(.088)	.230**	(.087)
R ²	.118		.145		.155		.185	
F	7.011***		8.691***		6.761***		8.39***	
N	430		420		418		418	

+ p < .10; * p < .05; ** p < .01; *** p < .001; one-tailed tests. Standard errors are in parentheses.

models showing support for hypothesis 3. Finally, the coefficients of downstream industry scale economies are positive and significant in both the OLS (.166, $p < .10$) and the WLS (.157, $p < .05$) models. As a result, hypothesis 4b is supported.

The analyses of overall modularity, on the other hand, also display surprising outcomes opposite to the prediction of several hypotheses. The coefficient of focal industry concentration is negative and significant in the WLS (-.161, $p < .10$) model, which is opposite to the prediction in hypothesis 5. In addition, the coefficients of upstream industry concentration are negative and significant in both the OLS (-.189, $p < .05$) and the WLS (-.176, $p < .05$) models, thereby opposite to the prediction in hypothesis 6a. Finally, the coefficients of downstream industry concentration are negative and significant in both the OLS (-.178, $p < .05$) and the WLS (-.158, $p < .05$) models, opposite to the prediction in hypothesis 6b.

Next we examine individual components of overall modularity in order to get more insights as to how modularity drivers impact each dimension of organizational modularity.

Model for Contract Manufacturing

OLS is performed to obtain a baseline model for contract manufacturing. Furthermore, we test for heteroscedasticity. The White's test statistic is 71.543 ($p = .654$), while the Breusch-Pagan test statistic is 116.023 ($p = .000$). According to the Breusch-Pagan test, heteroscedasticity is highly significant. Therefore, we perform additional WLS runs to account for heteroscedasticity. Table 5.3 summarizes the outcomes of the OLS and WLS regressions. The WLS results are largely consistent with the OLS results with respect to coefficient signs and significance. In general, the WLS

coefficients have smaller standard errors, while the model as a whole demonstrates a higher fit (R^2), compared to the OLS model.

TABLE 5.3
RESULTS OF REGRESSION ANALYSES FOR CONTRACT
MANUFACTURING AS THE DEPENDENT VARIABLE

Variable	OLS		WLS	
Constant	-.027	(.045)	-.029	(.042)
Input Heterogeneity	.119*	(.054)	.115**	(.045)
Demand Heterogeneity	-.026	(.054)	-.049	(.052)
Length of Distribution Channel	-.118*	(.055)	-.101*	(.046)
Focal Industry Scale Economies	.091	(.094)	.077	(.070)
Upstream Industry Scale Economies	-.063	(.076)	-.063	(.060)
Downstream Industry Scale Economies	.061	(.071)	.054	(.062)
Focal Industry Concentration	-.190**	(.068)	-.182***	(.056)
Upstream Industry Concentration	-.047	(.056)	-.063+	(.044)
Downstream Industry Concentration	-.094+	(.059)	-.071+	(.052)
Vertical Integration	.215***	(.055)	.154***	(.040)
Labor Intensity	.224***	(.055)	.248***	(.052)
R^2	.232		.262	
F	11.117***		13.07***	
N	418		418	

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; one-tailed tests. Standard errors are in parentheses.

With respect to contract manufacturing, regression outcomes in Table 5.3 show support for the hypothesis pertaining to input heterogeneity. The coefficients of input heterogeneity are positive and significant in both the OLS (.119, $p < .05$) and the WLS (.115, $p < .05$) models. This result is consistent with the modularity regression with

respect to input heterogeneity. However, regression analyses of contract manufacturing also display unexpected outcomes, opposite to the prediction of several hypotheses. The coefficient of demand heterogeneity is negative and significant in both the OLS ($-.118$, $p < .05$) and the WLS ($-.101$, $p < .05$) models, opposite to the expectations of hypothesis 1b. The coefficients of focal industry concentration are negative and significant in both the OLS ($-.190$, $p < .01$) and the WLS ($-.182$, $p < .001$) models, opposite to the prediction from hypothesis 5. Additionally, the coefficient of upstream industry concentration is negative and significant in the WLS ($-.063$, $p < .10$) model, opposite to the prediction of hypothesis 6a. Finally, the coefficients of downstream industry concentration are negative and significant in both the OLS ($-.094$, $p < .10$) and the WLS ($-.071$, $p < .10$) models, opposite to the prediction in hypothesis 6b.

Model for Alternative Employment

OLS is performed to obtain a baseline model for alternative employment. Additionally, the result of the White's test statistic on heteroscedasticity is 90.150 ($p = .145$), while the Breusch-Pagan test statistic is 440.084 ($p = .000$). According to the Breusch-Pagan test, heteroscedasticity is highly significant. Therefore, we performed additional WLS runs to account for heteroscedasticity. Table 5.4 summarizes the outcomes of both the OLS and the WLS regressions. The WLS results are largely consistent with the OLS results with respect to coefficient signs and significance. In general, WLS coefficients have smaller standard errors and the model displays a higher fit (R^2), compared to the OLS model.

Based on Table 5.4, in terms of alternative employment, regression runs provide results consistent with the prediction of several hypotheses. The coefficients of demand

heterogeneity are positive and significant in both the OLS (.102, $p < .05$) and the WLS (.124, $p < .01$) models. In addition, the coefficients of focal industry concentration are positive and significant in both the OLS (.088, $p < .10$) and the WLS (.082, $p < .10$) models.

TABLE 5.4
RESULTS OF REGRESSION ANALYSES FOR ALTERNATIVE
EMPLOYMENT AS THE DEPENDENT VARIABLE

Variable	OLS		WLS	
Constant	-.031	(.046)	-.030	(.041)
Input Heterogeneity	-.090+	(.055)	-.069+	(.045)
Demand Heterogeneity	.102*	(.058)	.124**	(.049)
Length of Distribution Channel	.045	(.056)	.017	(.047)
Focal Industry Scale Economies	-.064	(.073)	-.026	(.060)
Upstream Industry Scale Economies	.030	(.079)	-.019	(.048)
Downstream Industry Scale Economies	-.002	(.058)	-.036	(.038)
Focal Industry Concentration	.088+	(.068)	.082+	(.058)
Upstream Industry Concentration	-.124*	(.058)	-.073+	(.048)
Downstream Industry Concentration	-.073	(.061)	-.074+	(.047)
Vertical Integration	.076+	(.053)	.056+	(.043)
Labor Intensity	.178**	(.058)	.140**	(.053)
R ²	.094		.115	
F	4.128***		5.16***	
N	448		448	

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; one-tailed tests. Standard errors are in parentheses.

The analyses on alternative employment also display surprising outcomes, opposite to the predictions of several hypotheses. The coefficients of input heterogeneity

are negative and significant in both the OLS (-0.090 , $p < .10$) and the WLS (-0.069 , $p < .10$) models, opposite to the prediction of hypothesis 1a. In addition, the coefficients of upstream industry concentration are negative and significant in both the OLS (-0.124 , $p < .05$) and the WLS (-0.073 , $p < .10$) models, opposite to the predictions from hypothesis 6a. Finally, the coefficient of downstream industry concentration is negative and significant in the WLS (-0.074 , $p < .10$) model, opposite to the prediction in hypothesis 6b.

Model for Alliance Formation

OLS is performed to obtain a baseline model for alliance formation. Tests for heteroscedasticity indicate that it may be prevalent. The White's test statistic is 208.779 ($p = .000$), while the Breusch-Pagan test statistic is 404.456 ($p = .000$); i.e., both tests are significant. Therefore, we performed WLS runs to account for heteroscedasticity. Table 5.5 summarizes the outcomes of the OLS and the WLS regressions. The WLS results largely display consistency with the OLS results. In general, the WLS coefficients have smaller standard errors and the model as a whole displays a higher fit (R^2), compared to the OLS model.

According to Table 5.5, regression runs on alliance formation show support for several hypotheses. The coefficients of input heterogeneity are positive and significant in both the OLS ($.208$, $p < .001$) and the WLS ($.192$, $p < .001$) models. This results support hypothesis 1a. In addition, the coefficients of focal industry scale economies are positive and significant in both the OLS ($.413$, $p < .001$) and the WLS ($.390$, $p < .001$) models. This result confirms hypothesis 3. Finally, the coefficient of downstream industry scale economies is positive and significant in the WLS ($.071$, $p < .10$) models. This result provides support for hypothesis 4b. However, the analyses for alliance formation also

display surprising outcomes opposite to the predictions of one hypothesis. The coefficients of downstream heterogeneity are negative and significant in both the OLS ($-.084$, $p < .05$) and the WLS ($-.072$, $p < .05$) models, opposite to the prediction of hypothesis 6b.

TABLE 5.5
RESULTS OF REGRESSION ANALYSES FOR ALLIANCE FORMATION AS
THE DEPENDENT VARIABLE

Variable	OLS	WLS
Constant	-.033 (.030)	-.035 (.028)
Input Heterogeneity	.208*** (.037)	.192*** (.033)
Demand Heterogeneity	-.084* (.038)	-.072* (.036)
Length of Distribution Channel	.016 (.037)	.028 (.032)
Focal Industry Scale Economies	.413*** (.049)	.390*** (.040)
Upstream Industry Scale Economies	.005 (.053)	-.007 (.049)
Downstream Industry Scale Economies	.021 (.038)	.071+ (.053)
Focal Industry Concentration	.003 (.045)	.003 (.039)
Upstream Industry Concentration	-.033 (.038)	-.022 (.034)
Downstream Industry Concentration	.026 (.041)	.026 (.040)
Vertical Integration	.025 (.035)	.019 (.030)
Labor Intensity	-.138*** (.039)	-.094** (.030)
R ²	.296	.327
F	16.631***	19.22***
N	448	448

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; one-tailed tests. Standard errors are in parentheses.

Brief Summary of Hypotheses Tests

We provide several tables to summarize the regression results and hypotheses tests. Tables 5.6 and 5.7 combine the foregoing regression results from the OLS and WLS regressions, respectively. Table 5.8 reports the significant coefficients in regression models for overall modularity, contract manufacturing, alternative employment, and alliance formation models, together with pertinent variables and hypotheses. This summary table may offer more detailed insights as to how determinants affect each modularity dimensions. Table 5.9 highlights hypotheses supported by regression results.

In sum, hypothesis 1a is supported, particularly for contract manufacturing and alliance formation. In addition, hypothesis 3 is supported, especially for alliance formation. Hypothesis 4b is supported, particularly in the regression on alliance formation. Lastly, we also found unexpected results with regards to hypotheses 1b, 2, 5, and 6. We now turn to the discussion of these results and pertinent implications.

Discussion of Hypotheses Testing Results and Managerial Implications

In this part of the dissertation, we examine our findings in conjunction with past literature. Managerial implications and examples of the supported hypotheses follow. Brief explanations for surprising outcomes of hypotheses 5 and 6 are also offered.

Hypotheses 1a – Input Heterogeneity

Hypothesis 1a suggested that input and demand heterogeneity, respectively, can drive firms to utilize organizational modularity. The regression results supported hypothesis 1a, in particular for contract manufacturing and alliance formation. When

TABLE 5.6

OLS RESULTS OF REGRESSION ANALYSES FOR THE DRIVERS OF ORGANIZATIONAL MODLARITY

	Overall Modularity		Contract Manufacturing		Alternative Work Arrangements		Alliance Formation	
Constant	-.130*	(.072)	-.027	(.045)	-.031	(.046)	-.033	(.030)
Input Heterogeneity	.163*	(.087)	.119*	(.054)	-.090+	(.055)	.208***	(.037)
Demand Heterogeneity	.028	(.087)	-.026	(.054)	.102*	(.058)	-.084*	(.038)
Length of Distribution Channel	-.023	(.088)	-.118*	(.055)	.045	(.056)	.016	(.037)
Focal Industry Scale Economies	.293*	(.150)	.091	(.094)	-.064	(.073)	.413***	(.049)
Upstream Industry Scale Economies	-.051	(.121)	-.063	(.076)	.030	(.079)	.005	(.053)
Downstream Industry Scale Economies	.166+	(.114)	.061	(.071)	-.002	(.058)	.021	(.038)
Focal Industry Concentration	-.124	(.108)	-.190**	(.068)	.088+	(.068)	.003	(.045)
Upstream Industry Concentration	-.189*	(.090)	-.047	(.056)	-.124*	(.058)	-.033	(.038)
Downstream Industry Concentration	-.178*	(.094)	-.094+	(.059)	-.073	(.061)	.026	(.041)
Vertical Integration	.304***	(.087)	.215***	(.055)	.076+	(.053)	.025	(.035)
Labor Intensity	.264**	(.088)	.224***	(.055)	.178**	(.058)	-.138***	(.039)
R ²	.155		.232		.094		.296	
F	6.761***		11.117***		4.128***		16.631***	
N	418		418		448		448	

+ p < .10; * p < .05; ** p < .01; *** p < .001; one-tailed tests. Standard errors are in parentheses.

TABLE 5.7

WLS RESULTS OF REGRESSION ANALYSES FOR THE DRIVERS OF ORGANIZATIONAL MODULARITY

	Overall Modularity		Contract Manufacturing		Alternative Work Arrangements		Alliance Formation	
Constant	-.122*	(.069)	-.029	(.042)	-.030	(.041)	-.035	(.028)
Input Heterogeneity	.142*	(.081)	.115**	(.045)	-.069+	(.045)	.192***	(.033)
Demand Heterogeneity	.037	(.083)	-.049	(.052)	.124**	(.049)	-.072*	(.036)
Length of Distribution Channel	-.064	(.079)	-.101*	(.046)	.017	(.047)	.028	(.032)
Focal Industry Scale Economies	.321*	(.146)	.077	(.070)	-.026	(.060)	.390***	(.040)
Upstream Industry Scale Economies	-.015	(.077)	-.063	(.060)	-.019	(.048)	-.007	(.049)
Downstream Industry Scale Economies	.157*	(.093)	.054	(.062)	-.036	(.038)	.071+	(.053)
Focal Industry Concentration	-.161+	(.102)	-.182***	(.056)	.082+	(.058)	.003	(.039)
Upstream Industry Concentration	-.176*	(.078)	-.063+	(.044)	-.073+	(.048)	-.022	(.034)
Downstream Industry Concentration	-.158*	(.086)	-.071+	(.052)	-.074+	(.047)	.026	(.040)
Vertical Integration	.295***	(.079)	.154***	(.040)	.056+	(.043)	.019	(.030)
Labor Intensity	.230**	(.087)	.248***	(.052)	.140**	(.053)	-.094**	(.030)
R ²	.185		.262		.115		.327	
F	8.39***		13.07***		5.16***		19.22***	
N	418		418		448		448	

+ p < .10; * p < .05; ** p < .01; *** p < .001; one-tailed tests. Standard errors are in parentheses.

TABLE 5.8

SUMMARY OF REGRESSION RUNS ON OVERALL MODULARITY AND THREE COMPONENTS

Variables (modularity Drivers)	Significant Coefficients on Regression Results				Hypothesis
	Modularity	Contract Manufacturing	Alternative Employment	Alliance Formation	
Input Heterogeneity	+	+	-	+	H1a
Demand Heterogeneity			+	-	H1b
Length of Distribution Channel		-			H2
Focal Industry Scale Economies	+			+	H3
Upstream Industry Scale Economies					H4a
Downstream Industry Scale Economies	+			+	H4b
Focal Industry Concentration	-	-	+		H5
Upstream Industry Concentration	-	-	-		H6a
Downstream Industry Concentration	-	-	-		H6b

TABLE 5.9**SUMMARY OF HYPOTHESES TESTING ON OVERALL ORGANIZATIONAL MODULARITY**

Variables (modularity Drivers)	Results	Hypothesis	Testing Results
Input Heterogeneity	positive and significant	H1a	Supported
Demand Heterogeneity	--	H1b	
Length of Distribution Channel	--	H2	
Focal Industry Scale Economies	positive and significant	H3	Supported
Upstream Industry Scale Economies	--	H4a	
Downstream Industry Scale Economies	positive and significant	H4b	Supported
Focal Industry Concentration	negative and significant in the WLS regression	H5	
Upstream Industry Concentration	negative and significant	H6a	
Downstream Industry Concentration	negative and significant	H6b	

input supply displays high levels of heterogeneity, firms in the focal industry may use organizational modularity as opposed to market mechanisms to coordinate supply chain activities. This evidence coincides with the Transaction Cost Economics (TCE) prediction that firms are more likely to establish cooperative organizational with supply sources when heterogeneous inputs may lead to complex supply chain activities (Noordewier, John, and Nevin, 1990; Buvik and Andersen, 2002; Buvik and John, 2000; Schilling and Steensma, 2001; Williamson, 1985).

Our findings provide guidelines to firms to adjust inter-firm arrangements in the presence of various supply sources. According our model and analysis, input heterogeneity is a key determinant for the industry modularity. Managers should examine the extant input heterogeneity level or monitor the evolvement of input heterogeneity, so that they can examine the organizational modularity of an industry and the structure of its pertinent supply chain. Envisioning increasing input heterogeneity, purchasing firms may institute modular organizations with supply chain partners in order to accommodate to the likely structural shift of the industry. By acknowledging the impact of input heterogeneity and adjusting their inter-firm governance structures, firms can better position themselves within an industry and in the supply chain. Eventually, better alignment between firm and industry organizational forms may lead to higher performance (Porter, 1980; Waldman and Jensen, 1998). This view is also consistent with Schilling and Steensma (2001).

Several manufacturing industries render examples supporting our findings pertaining to the relationships between input heterogeneity and modularity. Firstly, in the electronics manufacturing industry, the supply for production inputs comes with a high

variety of material sources and displays high heterogeneity. As a result, an increasing number of original equipment manufacturers (OEMs) outsource manufacturing to other electronic manufacturing service (EMS) providers, or electronics contract manufacturers (CMs), to organize heterogeneous inputs (Sturgeon, 2002). For instance, Motorola has contracted out significant portions of its operations to Jabil Circuit, an EMS provider. This prevalent contract manufacturing strategy has thus increased the organizational modularity in the electronics industry (Lee and Hoyt, 2001; Sturgeon, 2002). Secondly, in the automobile industry, the production of cars requires thousands of materials, parts, and subassemblies. Among large automakers, Toyota's supplier network might be the most well-known example to streamline the management of complex and heterogeneous supplies. Specifically, Toyota establishes a modular network with a goal to manage an array of inputs and complex inbound logistics activities (Dyer and Nobeoka, 2000). Another example can be found in the bicycle industry where outsourcing of materials or sub-assemblies is common in the presence of a high level of heterogeneous inputs (Randall and Ulrich, 2000). Finally, prominent corporations or industrial cooperative programs apply organizational modularity to process a variety of supply sources. Industry examples include IBM, and Sun Microsystem, and with industrial cooperative programs such as the B-2 bomber project (Argyres, 1999; Baldwin and Clark, 1997; Garud and Kumaraswamy, 1995; Pine, 1993; Schilling and Steensma, 2001).

Hypothesis 3 – Focal Industry Scale Economies

Hypothesis 3 proposed that higher scale economies will lead firms in the focal industry to use more modular organizational forms. The regression analyses support

hypothesis 3, in particular for alliance formation. The results suggest that manufacturers with high economies of scale may actively utilize intermediate governance structures to coordinate supply chain activities. Organization management researchers predict that large-scale firms may align the supply chain structures with more hierarchical buyer-supplier arrangements (Best, 1990; Gomes-Goncerres, 1996; Joshi and Stump 1999; Joskow 1987; Langlois and Robertson, 1995; Lyons 1996; Oxley, 1999; Ulset 1996). Our findings are consistent with this view.

According to our discovery, managers can examine their industry scale economies to forecast industry modularity evolution over time. High economies of scale may drive firms within an industry to arrange multiple intermediate governance structures with suppliers and customers rather than use market mechanisms. Accordingly, the overall industry modularity and related supply chain configuration may shift. Firms monitoring the level of their industry scale economies may align their inter-firm governance choices with the emerging industry modular structure. As a result, the advance alignment between firm and industry modularity may better account for costs related to production, transactions, and supply chain operations (Sturgeon, 2002; Waldman and Jensen, 1998).

Two prominent manufacturing industries provide evidence supporting our findings. First, in the aircraft industry, manufacturing firms, such as Boeing and Airbus, demonstrates significant scale economies in aircraft production. The large manufacturing scale of this industry has motivated aircraft makers and their suppliers and buyers to arrange cooperative relationships. In particular, contract manufacturing has become a significant way to coordinate aircraft manufacturing supply chains (Argyres, 1999;

Waldman and Jensen, 1998). Additionally, in the computer industry, Dell extensively uses cooperative links, including contract manufacturing, logistics alliances with supply chain experts (e.g., UPS and Fedex), and alternative employment (outsourcing service manpower) to substantiate Michael Dell's "virtual integration" vision (Magretta, 2001). Finally, we believe that this outcome can help explain the emerging global modular networks. For examples, prominent low-cost, large-scale firms, such as Hewlett-Packard (H-P), and Dell, have instituted alliances or outsourced manufacturing processes to overseas contract manufacturers in mainland China (Dean and Tam, 2005).

Hypothesis 4b –Downstream Scale Economies

Hypothesis 4b propose that greater degrees of downstream scale economies may drive firms in a focal industry to use greater organizational modularity. The regression results support hypothesis 4b, in particular for alliance formation. These findings may shed light on the inter-firm arrangements between focal manufacturers and downstream partners. To put it specifically, manufacturers may consider instituting organizational modularity to organize their interface with large-scale supply chain partners. Our view is consistent with the TCE reasoning that focal firms may be motivated to establish more hierarchical arrangement with downstream partners because of the nontrivial dependence on large-scale customers (Osborn and Baughn, 1990; Williamson, 1985; 1991b).

Our findings indicate that managers should analyze customer industry scale economies to predict the industry modular configuration. High scale economies in the downstream industry may trigger a potential shift in both industry organization and supply chain outlook that may lead to more intermediate coordination mechanisms in

supply chains, compared to market mechanisms or vertical integration. Industry modularity may thus increase. Therefore, customer industry scale economies may impact not only on supply chain cost efficiencies but also the industry structures. By foreseeing the changing modularity of the industry supply chain configuration, managers may proactively apply modularity in governance choices by establishing cooperative arrangement with supply chain members. As discussed previously, this better alignment may lead to competitive advantages (Porter, 1980; Sturgeon, 2002; Waldman and Jensen, 1998).

The preceding discussion can be further supported by the following examples. In the semiconductor industry, large downstream chip-packaging and testing service providers have motivated microchip manufacturers to implement strong ties with them because of the significant scale economies in chip-packaging and testing processes (FSA, 2003). In the computer industry, H-P, which has its own radio frequency identification (RFID) initiatives, establishes RFID partnerships with Walmart, a well-known large size, low-cost retailer, to facilitate the combined supply chain operations (Sullivan, 2004). In the soft drink manufacturing industry, Pepsico, Inc. maintained a strong alliance relationship with Taco Bell after these two firms dissolve their former “hierarchy” structure. In doing so Pepsico may leverage scale economies pertaining to the geographical expansion of Taco Bell stores (Manning, Rodriguez, and Ghosh, 1999).

Additionally, hypotheses 3 and 4b may be jointly viewed to make a synergy argument when both the focal industry and downstream industries display scale economies. Using the semiconductor industry as an example again, low-cost, large-scale semiconductor manufacturers (e.g. Taiwan Semiconductor Manufacturing Company and

United Microelectronics Corporation) build cooperative relationships with their downstream low-cost, large-scale chip-packaging and testing firms. The global electronics manufacturing network also provides an illustration of cooperative links initiated by large-scale, low-cost firms lodged in different supply chain stages (Fujimoto, 2003; Langlois and Robertson, 1995; Sturgeon, 2002, 2003).

Hypothesis 5 and 6 – Concentration in the Focal Industry and Upstream and Downstream Industries

Hypothesis 5 argues that focal industry scale economies lead to higher level of organizational modularity. Hypotheses 6a and 6b suggest that upstream and downstream concentration will cause focal industry firms to employ more modular organizational forms. Surprisingly, according to the regression outcomes, higher concentration in the focal industry, and in up- and down-stream industries, leads to lower overall modularity.

The latest modularity research has clearly suggested that industry concentration may lead to lower transaction costs and result in greater reliance on market mechanisms. Lead firms in concentrated industries may develop technical standards across industries and supply chain links that can ultimately help formalize market transactions and minimize coordination costs (Gereffi, Humphrey, and Sturgeon, 2005; Schilling and Steensma, 2001, Sturgeon, 2002, 2003). In addition, lead firms in supply chains are more likely to institute inter-firm information technologies (IT). Thanks to established international standards, supply chain members can use prevalent communication means to coordinate with lead firms in concentrated industries (Gereffi, Humphrey, and Sturgeon, 2005; Sturgeon, 2002, 2003). The standardization and IT investments led by

large firms may reduce relation-specific investments and mutual dependence between supply chain partners. Consequently, business exchanges can be performed by using the formalized, arms-length mechanism (Sturgeon, 2003). Greater use of market mechanisms will reduce industry modularity.

Moreover, highly concentrated industries typically have smaller number of firms. Transaction frequencies within a concentrated industry and along its supply chains may be relatively fewer vis-à-vis more competitive industries (Williamson, 1975, 1985). Additionally, the competition between lead firms may be more stable than competitive industries (Waldman and Jensen, 1998). As a result, the interface between concentrated industries and suppliers and customers may display lower levels of frequencies and uncertainties. Transaction costs are thus reduced and in favor of market mechanisms, lowering industry organizational modularity.

The Structure-Conduct-Performance perspective in the industrial organization (IO) literature provides a prediction in line with our findings. IO researchers suggest that a concentrated industry may favor competitive pricing rather than longer term contracting to coordinate their supply and demand (Porter, 1980; Waldman and Jensen, 1998). The fewer contracting activities between supply chain members, therefore, translate to lower organizational modularity.

Limitations and Future Research

While our findings can offer insights into the driving forces behind the organizational modularity phenomenon, several limitations remain. First, as an emerging research area, organizational modularity can be observed through multiple established

theories (Langlois and Robertson, 1995; Sturgeon, 2002). This dissertation employs TCE theory as the overarching theory to examine organizational modularity. Whereas our regression results indicate that our conceptual model has explanatory power, our theoretical framework solely concentrates on the transaction costs minimization aspect of the firm-boundary decision. Most certainly, firm decisions regarding operational scope are based on not only transaction costs but also other factors, such as production costs, competitive strategies, regulations, etc. (Penrose, 1959; Porter, 1980; Waldman and Jensen, 1998). However, prominent theories in the strategy literature have not yet been thoroughly grounded into empirical modularity studies to test current predictions of this “paradigm shift” (Sturgeon, 2002). Researchers interested in this area may consider utilizing such theoretical lenses as Structure-Conduct-Performance, Resource-Based View, Strategic Network, or Evolution Economics, to act as guidelines to generate research questions and develop hypotheses. Ultimately, the theory-driven research on modularity may be able to answer research questions pertaining to the financial and operational impacts of modular organizations (Swamidass and Newell, 1987). These questions have yet to be addressed empirically by the extant modularity literature (Ethiraj and Levinthal, 2004b).

The next limitation pertains to the measure of the overall organizational modularity applied in this dissertation. In their seminal operationalization, Schilling and Steensma (2001) combine three components to measure organizational modularity. Each component is equally weighed. However, no specific unit can be identified and clearly interpreted with this complex construct. In addition, while the correlation coefficients between modularity components are not high, as reported in both Schilling and Steensma

(2001) and this dissertation, the non-zero correlations may suggest that contract manufacturing, alternative employment, and alliance formation practices may overlap or could be traded off. Future modularity research may explore other operationlization strategies that determine distinct weights for each component. For instance, an alternative to Schilling and Steensma's (2001) method is performing factor analysis to obtain a composite modularity score. Moreover, researchers can test different combinations of components to see if the regression results change. A further study on the unit of modularity is also in order.

Furthermore, Schilling and Steensma (2001) pointed out that organizational modularity can be operationalized more broadly (pp. 1150-1151). Although their measure for organizational modularity has been recognized by operations management researchers (Ethiraj and Levinthal, 2004a; Tu et al., 2004), a more encompassing organizational modularity measure beyond the three extant components might be necessary to fully reflect this complex construct. In other words, studies employing the Schilling and Steensma (2001) methodology might leave certain features of organizational modularity unexplored. Future research may follow Schilling and Steensma's (2001) instructions to develop a broader organizational modularity measure that includes not only tangible contracting components but also intangible governance structures such as trust, reputation, and inter-firm social capitals.

Accordingly, for future modularity research, researchers should perform disaggregate level studies to identify a broader set of dependent and independent variables and develop pertinent measures. While this dissertation employed the latest available, multiple sources to construct an cross-industry data set, objective data sources

are still limited to capture all details of organizational modularity. For instance, the alliance formation component does not distinguish the R&D, production, or marketing alliances within an industry. Management literature has documented a variety of hybrid governance structures, e.g. franchising, licensing, outsourcing, etc., that may lead to higher modularity (see Boerner and Macher, 2002). These specific data on extensive organizational modularity measure, including tangible inter-firm links and intangible links, may be only available through disaggregate data collection. To obtain richer information on inter-firm arrangements, disaggregate level investigations are in order. According to our literature review, Worren, Moore, and Cardona (2002) is the only firm level, empirical study developing scale for the “modular structure” construct. However, the Worren, Moore, and Cardona (2002) scale only contains limited information for modularity components. With this observation, we propose that different level of research, such as industry specific, firm level, or firm specific studies, should investigate inter-firm relationships in detail. Data collection methods, such as survey and case studies, can be applied to overcome the limitations of archival data sources mentioned previously, and thus complement the extant industry level research

The prior limitations may jointly lead to the contrary results of regression runs on disaggregate modularity components. Specifically, we obtain unexpected results for distribution channel length in the contract manufacturing regression, for input heterogeneity in the alternative employment regression, and for demand heterogeneity in the alliance formation regression. Perhaps future modularity research could correct the problem by both applying an alternative theoretical lens and developing alternative operationizations.

Also, future research may need to track the relevant data streams over time to account for the limitations of our cross-sectional data. Ideally, a study about industry level organizational modularity should examine current trends; however, the latest available data sources containing all relevant modularity measures prevent us from conducting a longitudinal investigation beyond 1997. We anticipate that this limitation can be overcome in the near future with the forthcoming publication of more current data.

An interesting issue not yet studied in the literature relates to the two-way reinforcement between modularity and its driving forces (Schilling and Steensma, 2001). More specifically, as organizations adopt hybrid governances to coordinate business processes, firms may become better able to develop greater product customization, which can eventually lead to more heterogeneous demand, and in turn to a greater variety of supply sources. These structural changes might take time to occur. Accordingly, cross-sectional data set is limited to account for the lag effects of the simultaneity between drivers and modularity. Thus, as discussed previously, a time series analysis may be necessary for investigating these two-way reinforcement. Future research might employ longitudinal data for investigating this potential interchange between modularity and its relevant drivers.

Another direction for future research pertains to unexplored factors that moderate the relationship between and modularity and its determinants. Management researchers have shown that decision making concerning inter-firm governance structure, e.g. organizational modularity, can be very complex. There can be additional variables that indirectly reinforce or lessen the motivation associated with inter-firm governance structures decisions (Leiblein, Reuer, Dalsace, 2002; Leiblein and Miller, 2003; Schilling

and Steensma, 2001). These moderating variables may include information technologies (IT), product modularity, industry employment policies, communication and manufacturing standards, etc. (Sturgeon, 2002). Using IT as an example, manufacturers may use inter-organizational information systems or internet connectivity as a coordination alternative to contracts. Several papers have provide researchers with abundant discussion on these potential moderating effects which could lead to potential testable hypotheses (see Zenger and Hesterly, 1997; Malone, Yates, and Benjamin, 1987; Sturgeon, 2002). With more modularity drivers identified, there are promising opportunities for researchers to investigate the interaction between modularity drivers and potential moderators.

Lastly, another data limitation is lack of data for contractors, suppliers, buyers, etc., in foreign countries. In the current context of global outsourcing and international alliance formation, the emerging modular networks can oftentimes develop to a global scope. This dissertation only analyzes the modularity practices of U.S. manufacturing industries. In this sense, our data set may underestimate the impacts of modularity drivers. As more organizations extend to international operations, incorporating both international and domestic aspects of modular practices may better capture the impacts of driving forces on modularity. To better reflect this reality, we suggest modularity researchers use alternative research methods to investigate how the drivers affect modularity choices of both domestic and non-U.S. firms.

Summary

In this chapter we have presented data analysis procedures and statistical findings.

Regression runs strongly support our hypotheses regarding input heterogeneity, focal industry scale economies, and downstream industry economies. The discussion of managerial implications may provide guidance for firms in adopting outsourcing strategies with supply chain partners. The discussion on limitation and future research may direct researchers to further investigate the modularity phenomenon. In the next chapter, we will conclude this dissertation with succinct reviews and discussion on contributions.

CHAPTER 6 CONCLUSIONS

This first part of the conclusions summarizes major components of the dissertation. Discussion of the contributions of this dissertation follows.

Summary of Theoretical Framework, Methodology, and Findings

This dissertation examines the recent phenomenon of organizational modularity. Nowadays, many manufacturing firms no longer act as isolated and independent entities. Instead, businesses adopt organizational modularity as a strategy to coordinate supply chain networks. Modularity provides strategic flexibility by using integrative inter-firm arrangements, such as contracting manufacturing, alternative employment, and alliances. The purpose of this dissertation is to investigate the drivers of organizational modularity in supply chains. The drivers this dissertation explored include input and demand heterogeneity, length of industrial distribution channels, scale economies, and industry concentration.

Using transaction cost analysis as the overarching theoretical framework for the analysis, a number of hypotheses that relate industry structure to modularity are developed in an industrial supply chain context. A conceptual model of the drivers of organizational modularity summarizing pertinent hypotheses is also presented. A large scale industry-level data set from public sources is used to test the hypotheses. Statistical results show that heterogeneity of supply sources and scale economies in focal and downstream industries, are positively associated with greater use of modular organizational forms. Other factors, such as the concentration of upstream and downstream industries, are associated with less modularity.

Contributions

This dissertation has made several contributions to the modularity literature on the theoretical, methodological, and empirical fronts. Our first contribution pertains to a new perspective of organizational modularity. By applying Transaction Cost Economics (TCE) as an overarching theory, this dissertation views organizational modularity as a “hybrid” or intermediate governance structure to coordinate supply chain activities. Past modularity literature has viewed organizational modularity as an alternative of vertical integration; this dissertation, however, views organizational modularity as an alternative to not only vertical integration but also market mechanisms. Through our TCE-based theoretical development, this dissertation has thus re-positioned modularity in the pertinent economic organization literature.

Secondly, this dissertation applies a cross-discipline approach to integrate research streams on economic organizations. We incorporate findings from such fields as strategic management, logistics, supply chain management, marketing, and economics. This extensive literature review leads us to examine the organizational modularity phenomenon in the supply chain context. We believe that research questions associated with the development of modular organizational forms are fundamental supply chain management issues. This view has not been explicitly acknowledged, particularly, in strategy, operations, and even in supply chain literature.

In addition, this dissertation develops a model of the drivers of organizational modularity based on the TCE view. We incorporate the rational views of Mentzer et al. (2001) and Porter (1980, 1985) to construct the conceptual model in a supply chain setting. To be more specific, we have a focal manufacturing industry with its

primary supplier and customer industries. This model makes it clear that the driving forces of organizational modularity come not only from within the focal industry, but also from upstream and downstream industries in the supply chain. Our conceptual model answers the call for an overall theory of organizational modularity that has been cited in modularity literature (Langlois, 2002).

The fourth contribution of this dissertation is the development of variable measurements and the configuration of industry level primary supply chains. Based on statistical analyses of our data set, this dissertation provides the first empirical evidence on an extensive set of modularity drivers. Future works on organizational modularity may build research on our variable operationlization and data collection techniques.

Finally, we explore the implications for managers by combining industry evidence with our research findings. The theoretical framework allows managers to capture critical determinants of firm-boundary decisions to safeguard contracting relationships. In addition, our findings may provide managers with guidelines for the adoption of organizational modularity as an alternative to instituting buyer-supplier relationships. Extant modularity research has contributed knowledge to practitioners in terms of the strategic flexibility implications (Schilling and Steensma, 2001). In contrast, this dissertation emphasizes that supply chain members can potentially utilize organizational modularity to minimize nontrivial transaction costs. This emphasis, together with former contributions, adds value to the body of modularity literature.

REFERENCES

- Achrol, Ravi S. (1991), "Evolution of the Marketing Organization: New Forms for Turbulent Environments," *Journal of Marketing*, Vol. 55, No. 4, pp. 77-93.
- Achrol, Ravi S. (1997), "Changes in the Theory of Interorganizational Relations in Marketing: Toward a Network Paradigm," *Journal of the Academy of Marketing Science*, Vol. 25, No. 1, pp. 56-71.
- Allenby, Greg M. and Peter E. Rossi (1999), "Marketing Models of Consumer Heterogeneity," *Journal of Econometrics*, Vol. 89, No. 1/2, pp. 57-78.
- Argyres, Nicholas S. (1995), "Technology Strategy, Governance Structure and Interdivisional Coordination," *Journal of Economic Behavior and Organization*, Vol. 28, No. 3, pp. 337-358.
- Argyres, Nicholas S. (1999), "The Impact of Information Technology on Coordination: Evidence from the B-2 "Stealth" Bomber," *Organization Science*, Vol. 10, No. 2, pp. 162-180.
- Artz, Kendall W. and Thomas and Brush (2000), "Asset Specificity, Uncertainty and Relational Norms: an Examination of Coordination Costs in Collaborative Strategic Alliances," *Journal of Economic Behavior and Organization*, Vol. 41, No. 4, pp. 337-362.
- Bae, Jonghoon and Martin Gargiulo (2004), "Partner Substitutability, Alliance Network Structure, and firm Profitability in the Telecommunications Industry," *Academy of Management Journal*, Vol. 47, No. 6, pp. 843-859.
- Bal, Jay, Richard Wilding, and John Gundry (1999), "Virtual Teaming in the Agile Supply Chain," *International Journal of Logistics Management*, Vol. 10, No. 2, pp. 71-82.
- Balakrishnan, Srinivasan and Birger Wernerfelt (1986), "Technical Change, Competition and Vertical Integration," *Strategic Management Journal*, Vol. 7, No. 4, pp. 347-359.
- Baldwin, Carliss Y., and Kim B. Clark (1997), "Managing in an Age of Modularity," *Harvard Business Review*, Vol. 75, No. 5, pp. 84-94.
- Baldwin, Carliss Y. and Kim B. Clark (2000), *Design Rules. Volume 1: The Power of Modularity*, Cambridge, MA: MIT Press.
- Baldwin, Carliss Y. and Kim B. Clark (2003), "Where Do Transactions Come From? A Perspective from Engineering Design," peer-reviewed research paper presented in 2003 Academy of Management Conference.

- Barreyre, P. Y. (1988), "The Concept of 'Impartition' Policies: A Different Approach to Vertical Integration Strategies," *Strategic Management Journal*, Vol. 9, No. 5, pp. 507-520.
- Barwise, Patrick (1995), "Good Empirical Generalizations," *Marketing Science*, Vol. 14, No. 3, Part 2 of 2, pp. g29-g35.
- Best, Michael H. (1990), *The New Competition: Institutions of Industrial Restructuring*, Cambridge, Massachusetts: Harvard University Press.
- Bettis, Richard A. and Michael A. Hitt (1995), "The New Competitive Landscape," *Strategic Management Journal*, Vol. 16, No. 7 (special issue), pp. 7-19.
- Boerner, Christopher S. and Jeffrey Macher (2002), "Transaction Cost Economics: An Assessment of Empirical Research in the Social Sciences," working paper.
- Bowersox, Donald J. and David J. Closs (1996), *Logistical Management: the Integrated Supply Chain Process*, McGraw-Hill.
- Bozarth, Cecil, Robert Handfield, and Ajay Das (1998), "Stages of Global Sourcing Strategy Evolution: an Exploratory Study," *Journal of Operations Management*, Vol. 16, No. 2/3, pp. 241-255.
- Brush, Thomas and Aneel Karnani (1996), "Impact of Plant Size and Focus on Productivity: An Empirical Study," *Management Science*, Vol. 42, No. 7, pp. 1065-1081.
- Brusoni, Stefano, and Andrea Prencipe (2001), "Unpacking the Black Box of Modularity: Technologies, Products and Organizations," *Industrial and Corporate Change*, Vol. 10, No. 1, pp. 179-205.
- Brusoni, Stefano, Andrea Prencipe, and Keith Pavitt (2001), "Knowledge Specialization, Organizational Coupling, and the Boundaries of the Firm: Why Do Firms Know More Than They Make?" *Administrative Science Quarterly*, Vol. 46, No. 4, pp. 597-621.
- Bucklin, Louis P. and Sanjit Sengupta (1993), "Organizing Successful Co-Marketing Alliances," *Journal of Marketing*, Vol. 57, No. 2, pp. 32-46.
- Bureau of Economic Analysis (2004), *Interactive Access to Input-Output Accounts Data*, http://www.bea.gov/bea/industry/iotables/prod/table_list.cfm?anon=4061.
- Bureau of Labor Statistics (1997), *Contingent Worker and Alternative Employment*, <http://www.bls.census.gov/cps/contwkr/contwkr.htm>
- Buvik, Arnt and Otto Andersen (2002), "The Impact of Vertical Coordination on Ex Post Transaction Costs in domestic and International Buyer-Seller Relationships," *Journal of*

International Marketing, Vol. 10, No. 1, pp. 1-24.

Buvik, Arnt and George John (2000), "When Does Vertical Coordination Improve Industrial Purchasing Relationships," *Journal of Marketing*, Vol. 64, No. 4, pp. 52-64.

Camuffo, Arnaldo (2002), "The Changing Nature of Internal Labor Markets," *Journal of Management and Governance*, Vol. 6, No. 4, pp. 281-294.

Caves, Richard E., Javad Khalilzadeh-Shirazi, and Michael E. Porter, (1975) "Scale Economies in Statistical Analyses of Market Power," *The Review of Economics and Statistics*, Vol. 57, No. 2, pp. 133-140.

Chandrashekar, Ashok and Philip B. Schary (1999), "Toward the Virtual Supply Chain: The Convergence of IT and Organization," *International Journal of Logistics Management*, Vol. 10, No. 2, pp. 27-39.

Chesbrough, Henry W. and Ken Kusunoki (2001), "The Modularity Trap: Innovation, Technology Phase Shifts and the Resulting Limits of Virtual Organizationa," in Nonaka, Ikujiro and David J. Teece (eds) (2001), *Managing Industrial Knowledge*, Sage: London, ch. 10.

Chopra, Sunil and Peter Meindl (2001), *Supply Chain Management: Strategy, Planning, and Operation*, Upper Saddle River, New Jersey: Prentice Hall.

Christensen, Clayton M., Matt Verlinden, and George Westerman (2002), "Disruption, Dis-Integration, and the Dissipation of Differentiability," *Industrial and Corporate Change*, Vol. 11, No. 5, pp. 955-993.

Christopher, Martin (1998), *Logistics and Supply Chain Management*, 2nd Ed. London: Financial Times.

Coase, Ronald H. (1937), "The Nature of the Firm," *Econometrica*, November.

Coase, Ronald H. (1988), "The Nature of the Firm: Influence," *Journal of Law, Economics, and Organization*, Vol. 4, No. 1, pp. 33-47.

Comanor, William S. and Thomas A. Wilson (1967), "Advertising Market Structure and Performance," *The Review of Economics and Statistics*, Vol. 49, No. 4, pp. 423-440.

Cool, Karel and James Henderson (1998), "Power and Firm Profitability in Supply Chains: French Manufacturing Industry in 1993," *Strategic Management Journal*, Vol. 19, No. 10, pp. 909-926.

Cox, Howard, Simon Mowatt, and Martha Prevezer (2002), "The Firm in the Information Age: Organizational Responses to Technological Change in the Processes Foods Sector," *Industrial and Corporate Change*, Vol. 11, No. 1, pp. 135-158.

Coyle, John J., Edward J. Bardi, and C. John Langley Jr. (1996), *The Management of Business Logistics*, St. Paul, MN: West Publishing Company.

D'Aveni, Richard A. and David J. Ravenscraft (1994), "Economies of integration versus bureaucracy costs: does vertical integration improve performance?" *Academy of Management Journal*, Vol. 37, No. 5, pp. 1167-1206.

Daft, Richard L. and Arie Y. Lewin (1993), "Where Are the Theories for the "New" Organizational Forms? An Editorial Essay," *Organization Science*, Vol. 4, No. 4, pp. i-iv.

Dahlstrom, Robert and Arne Nygaard (1999), "An Empirical Investigation of Ex Post Transaction Costs in Franchised Distribution Channels," *Journal of Marketing Research*, Vol. 36, No. 2, pp. 160-170.

Daugherty, Patricia J. and Paul H. Pittman (1995), "Utilization of Time-Based Strategies – Creating Distribution Flexibility/Responsiveness," *International Journal of Operations and Production Management*, Vol. 15, No. 2, pp. 54-60.

David, Robert J. and Shin-Kap Han (2004), "A Systematic Assessment of the Empirical Support for Transaction Cost Economics," *Strategic Management Journal*, Vol. 25, No. 1, pp. 39-58.

Davis-Blake, Alison and Brian Uzzi (1993), "Determinants of Employment Externalization: A Study of Temporary Workers and Independent Contractors," *Administrative Science Quarterly*, Vol. 38, No. 2, pp. 195-223.

Davidow, William H. and Michael S. Malone (1992), *The Virtual Corporation: Customization and Instantaneous Response in Manufacturing and Service – Lessons from the World's Most Advanced Companies*, New York: HarperCollins Publishers.

Dean, Jason and Pui-Wing Tam (2005), "The Laptop Trail," *Wall Street Journal*, June 9, p. B1.

Doeringer, P. and M. J. Piore (1971), *Internal Labor Markets and Manpower Analysis*, Lexington, Massachusetts: Heath.

Duray, Rebecca, Peter T. Ward, Glenn W. Milligan, and William L. Berry (2000), "Approaches to Mass Customization: Configurations and Empirical Validation," *Journal of Operations Management*, Vol. 18, No. 6, pp. 605-625.

Dwyer, F. Robert and Sejo Oh (1988), "A Transaction Cost Perspective on Vertical Contractual Structure and Interchannel Competitive Strategies," *Journal of Marketing*, Vol. 52, No. 2, pp. 21-34.

Dyer, Jeffrey H. (1996), "Does Governance Matter? Keiretsu Alliances and Asset

Specificity as Sources of Japanese Competitive Advantage,” *Organization Science*, Vol. 7, No. 6, pp. 649-666.

Dyer, Jeffrey H. (1997), “Effective Interfirm collaboration: How Firms Minimize Transaction Costs and Maximize Transaction Value,” *Strategic Management Journal*, Vol. 18, No. 7, pp. 535-556.

Dyer, Jeffrey H. and Kentaro Nobeoka (2000), “Creating and Managing a High-performance Knowledge-sharing Network: the Toyota Case,” *Strategic Management Journal*, Vol. 21, No. 3, pp. 345-367.

Ellram, Lisa M. (1991), “Supply Chain Management: The Industrial Organisation Perspective,” *International Journal of Physical distribution and Logistics Management*, Vol. 21, No. 1, pp. 13-22.

Ernst, Ricardo and Bardia Kamrad (2000), “Evaluation of Supply Chain Structures through Modularization and Postponement,” *European Journal of Operational Research*, Vol. 124, No. 3, pp. 495-510.

Ethiraj, Sendil K. and Daniel Levinthal (2004a), “Modularity and Innovation in Complex Systems,” *Management Science*, Vol. 40, No. 2, pp. 159-173.

Ethiraj, Sendil K. and Daniel Levinthal (2004b), “Bounded Rationality and the Search for Organizational Architecture: An Evolutionary Perspective on the Design of Organizations and Their Evolvability,” *Administrative Science Quarterly*, Vol. 49, No. 3, pp. 404-437.

Fine, Charles H. (1998), *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, Reading, MA: Perseus Books.

Frazier, Gary L. (1999), “Organizing and managing Channels of Distribution,” *Journal of the Academy of Marketing Science*, Vol. 27, No. 2, pp. 226-240.

Frazier, Gary L. and Raymond C. Rody (1991), “The Use of Influence Strategies in Interfirm Relationships in Industrial Product Channels,” *Journal of Marketing*, Vol. 55, No. 1, pp. 52-69.

FSA (Fabless Semiconductor Association) (2003), *Effective Management of Outsourced Operations: Contending with the New Dynamics and Volatility in the Electronics Supply Chain*, <http://www.fsa.org/publications/supplychain/index.asp>.

Fujimoto, Hisao (2003), “Collaborative Networking in a Multi-Stage Industrial Channel,” *International Journal of Physical Distribution and Logistics Management*, Vol. 33, No. 3, pp. 229-235.

Galunic, D. Charles and Kathleen M. Eisenhardt (2001), “Architectural Innovation and

- Modular Corporate Forms,” *Academy of Management Journal*, Vol. 44. No. 6, pp. 1229-1249.
- Galvin, Peter and Andre Morkel (2001), “The Effect of Product Modularity on Industry Structure: The Case of the World Bicycle Industry,” *Industry and Innovation*, Vol. 8, No. 1, pp. 31-47.
- Garud, Raghu and Arun Kumaraswamy (1995), “Technological and Organizational Designs for Realizing Economies of Substitution,” *Strategic Management Journal*, Vol. 16, Special issue, pp. 93-109.
- Garud, Raghu and Kamal Ahmed Munir (2003), “Breaking Apart to Break Through: The Case of Polaroid’s SX-70 Camera”, working paper.
- Garud, Raghu, Arun Kumaraswamy, and Richard N. Langlois (2003), *Managing in the Modular Age: Architectures, Networks, and Organizations (eds.)*, Malden, MA: Blackwell Publishers.
- Gereffi, Gary, John Humphrey, and Timothy Sturgeon (2005), “The Governance of Global Value Chains,” *Review of International Political Economy*, Vol. 12, No. 1, pp. 78-104.
- Geyskens, Inge, Jan-Benedict E.M. Steenkamp and Nirmalya Kumar (1999), “A meta-Analysis of Satisfaction in Marketing Channel Relationships,” *Journal of Marketing Research*, Vol. 36, No. 2, pp. 223-238.
- Gomes-Casseres, Benjamin (1996), *The Alliance Revolution: The new Shape of Business Rivalry*, Cambridge, Massachusetts: Harvard University Press.
- Greene, William H. (2000), *Econometric Analysis*, 4th ed., Upper Saddle River, New Jersey: Prentice-Hall.
- Grover, Varun and Manoj K. Malhotra (2003), “Transaction Cost Framework in Operations and Supply Chain Management Research: Theory and Measurement,” *Journal of Operations Management*, Vol. 21, No. 4, pp. 457-473.
- Gulati, Ranjay (1998), “Alliances and Networks,” *Strategic Management Journal*, Vol. 19, No. 4, pp. 293-317.
- Gulati, Ranjay, Nitin Nohria, and Akbar Zaheer (2000), “Strategic Networks,” *Strategic Management Journal*, Vol. 21, No. 3, pp. 203-215.
- Gulati, Rajay and Harbir Singh (1998), “The Architecture of Cooperation: Managing Coordination Costs and Appropriation Concerns in Strategic Alliances,” *Administrative Science Quarterly*, Vol. 43, No. 4, pp. 781-814.

- Harvey, Michael and Cheri Speier (2000), "Developing an Inter-Organization Relational management Perspective," *Journal of Marketing Channels*, Vol. 7, No. 4, pp. 2000.
- Helfat, Constance E. and Kathleen M. Eisenhardt (2004), "Inter-Temporal Economies of Scope, Organizational Modularity, and the Dynamics of Diversification," *Strategic Management Journal*, Vol. 25, No. 13, pp. 1217-1232.
- Hemmert, Martin (1999), "'Intermediate Organization Revisited' Revisited: a Framework for the Vertical Division of Labor in Manufacturing and the Case of the Japanese Assembly Industries," *Industrial and Corporate Change*, Vol. 8, No. 3, pp. 487-517.
- Hennart, Jean-Francois and Young-Ryeol Park (1994), "Location, Governance, and Strategic Determinants of Japanese Manufacturing Investment in the United States," *Strategic Management Journal*, Vol. 15, No. 6, pp. 419-436.
- Hines, Peter and Nick Rich (1998), "Outsourcing Competitive Advantage: the Use of Supplier Associations," *International Journal of Physical distribution and Logistics Management*, Vol. 28, No. 7, pp. 524-546.
- Hitt, Michael A, Barbara W. Keats, and Samuel M. DeMarie (1998), "Navigating in the New Competitive Landscape: Building Strategic Flexibility and Competitive Advantage in the 21st Century," *Academy of Management Executive*, Vol. 12, No. 4, pp. 22-42.
- Hladik, Karen J. (1985), *International Joint Ventures: An Economic Analysis of U.S.-Foreign Business Partnerships*, Lexington: D.C. Heath and Company.
- Hoetker, Glenn (2002), "Do Modular Products Lead to Modular Organizations," working paper.
- Hoogeweegen, Martijn R., Wim J.M. Teunissen, Peter H.M. Vervest, and Rene W. Wagenaar (1999), "Modular network Design: Using Information and Communication Technology to Allocate production Tasks in a Virtual Organization," *Decision Sciences*, Vol. 30, No. 4, pp. 1073-1103.
- Houseman, Susan N. (1999), *A Report on Temporary Help, On-Call, Direct-Hire Temporary, Leased, Contract Company, and Independent Contractor Employment in the United States*, U.S. Department of Labor.
- Hsuan, Juliana (1999), "Impacts of Supplier-Buyer Relationships on Modularization in New Product Development," *European Journal of Purchasing and Supply Management*, Vol. 5, pp. 197-209.
- Hult, G. Tomas, David J. Ketchen, Jr., and Ernest L. Nichols, Jr. (2002), "An Examination of Cultural Competitiveness and Order Fulfillment Cycle Time within Supply Chains," *Academy of Management Journal*, Vol. 45, No. 3, pp. 577-586.

Hult, G. Tomas, David J. Ketchen, Jr., and Stanley F. Slater (2004), "Information Processing, Knowledge Development, and Strategic Supply Chain Performance," *Academy of Management Journal*, Vol. 47, No. 2, pp. 241-253.

Jacobsen, Robert (1988), "The Persistence of Abnormal Returns," *Strategic Management Journal*, Vol. 9, No. 5, pp. 415-430.

Joglekar, Prafulla and Morris Hamburg (1989), "Industry Concentration and Allocation of Resources to Basic Research," *Management Science*, Vol. 35, No. 2, pp. 208-225.

Johnson, Jean L. (1999), "Strategic Integration in Industrial distribution channels: Managing the Interfirm Relationship as a Strategic Asset," *Journal of the Academy of Marketing Science*, Vol. 27, No. 1, pp. 4-18.

Johnston, Jack and John DiNardo (1997), *Econometric Methods*, 4th edition, New York: The McGraw-Hill Companies.

Joshi, Ashwin W. and Rodney L. Stump (1999), "The Contingent Effect of Specific Asset Investments on Joint Action in manufacturer-Supplier Relationships: An Empirical Test of the moderating Role of Reciprocal Asset Investments, Uncertainty, and Trust," *Journal of the Academy of Marketing Science*, Vol. 27, No. 3, pp. 291-305.

Joskow, Paul L. (1987), "Contract duration and Relationship-Specific Investments: Empirical Evidence from Coal Markets," *The American Economic Review*, Vol. 77, No. 1, pp. 168-185.

Kenney, Martin and Urs von Burg (1999), "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128," *Industrial and Corporate Change*, Vol. 8, No. 1, pp. 67-103.

Ketchen, David J. and G. Tomas M. Hult (2002), "To Be Modular or Not to Be? Some Answers to the Question," *Academy of Management Executive*, Vol. 16, No. 2, pp. 166-168.

Khalilzadeh-Shirazi, Javad (1974), "Market Structure and Price-Cost Margins in United Kingdom Manufacturing Industries," *The Review of Economics and Statistics*, Vol. 56, No. 1, pp. 67-76.

Kim, Jooheon (2001), "Distribution channel Selection of Foreign-Owned Firms in the Korean Market: Combining the Transactions Cost Approach and the Functional Approach," *Journal of Marketing Channels*, Vol. 8, No. 3/4, pp. 49-64.

Klein, Benjamin, Robert A. Crawford, and Armen A. Alchian (1978), "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process," *Journal of Law and Economics*, Vol. 21, October, pp. 297-326.

- Kunda, Gideon, Stephen R. Barley, and James Evans (2002), "Why Do Contractors Contract? The Experience of Highly Skilled Technical Professionals in a Contingent Labor Market," *Industrial and Labor Relations Review*, Vol. 55, No. 2, pp. 174-305.
- Lampel, Joseph and Henry Mintzberg (1996), "Customizing Customization," *Sloan Management Review*, Vol. 38, No. 1, pp. 21-30
- Landeros, Robert and Robert M. Monczka (1989), "Cooperative Buyer/Seller Relationships and a Firm's Competitive Posture," *Journal of Purchasing and Materials Management*, Vol. 25, No. 3, pp. 9-18.
- Langlois, Richard N. (2002), "Modularity in Technology and Organization," *Journal of Economic Behavior and Organization*, Vol. 49, No. 1, pp. 19-37.
- Langlois, Richard N. and Nicolai J. Foss (1999), "Capabilities and Governance: The Rebirth of Production in the Theory of Economic Organization," *Kyklos*, Vol. 52, No. 2, pp. 201-218.
- Langlois, Richard N. and Paul L. Robertson (1995), *Firms, Markets and Economic Change: A Dynamic Theory of Business Institutions*, New York: Routledge.
- Leiblein, Michael J. and Douglas J. Miller (2003), "An Empirical Examination of Transaction- and Firm-Level Influences on the Vertical Boundaries of the Firm," *Strategic Management Journal*, Vol. 24, No. 9, pp. 839-859.
- Leiblein, Michael J., Jeffrey J. Reuer, and Frederic Dalsace (2002), "Do Make or Buy Decisions Matter? The Influence of Organizational Governance on Technological Performance," *Strategic Management Journal*, Vol. 23, Issue 9, pp. 817-833.
- Lee, Hau L., V. Padmanabhan, and Seungjin Whang (1997), "The Bullwhip Effect in Supply Chains," *Sloan Management Review*, Vol. 38, No. 3, pp. 93-102.
- Lee, Hau L., Kut C. So, and Christopher S. Tang (2000), "The Value of Information Sharing in a Two-Level Supply Chain," *Management Science*, Vol. 45, No. 5, pp. 626-643.
- Lee, Ho Geun, Theodore Clark, and Kar Yan Tam (1999), "Research Report. Can EDI Benefit Adopters?" *Information Systems Research*, Vol. 10, No. 2, pp. 186-195.
- Lei, David, Michael A. Hitt, and Joel D. Goldhar, (1996), "Advanced manufacturing Technology: Organizational Design and Strategic Flexibility," *Organization Studies*, Vol. 17, No. 3, pp. 501-523.
- Levy, David T. (1985), "The Transaction Cost Approach to Vertical Integration: An Empirical Examination," *The Review of Economics and Statistics*, Vol. 67, No. 3, pp. 438-445.

- Lowson, Robert H. (2003), "How Supply Network Operations Strategies Evolve: Composition, Competitive Priorities and Customisation," *International Journal of Physical Distribution and Logistics Management*, Vol. 33, No. 1, pp. 75-91.
- Lusch, Robert F. and James R. Brown (1996), "Interdependency, Contracting, and Relational Behavior in Marketing Channels," *Journal of Marketing*, Vol. 60, No. 4, pp. 19-38.
- Lyons, Bruce (1980), "A New Measure of Minimum Efficient Plant Size in UK Manufacturing Industry," *Economica*, Vol. 47, No. 1, pp. 19-34.
- Lyons, Bruce R. (1995), "Specific Investment, Economies of Scale, and the Make-or-Buy Decision: A Test of Transaction Cost Theory," *Journal of Economic Behavior and Organization*, Vol. 26, No. 3, pp. 431-443.
- Lyons, Bruce R. (1996), "Empirical Relevance of Efficient Contract Theory: Inter-Firm Contracts," *Oxford Review of Economic Policy*, Vol. 12, No. 4, pp. 27-52.
- MacDonald, James M. (1985), "Market Exchange or Vertical Integration: An Empirical Analysis," *The Review of Economics and Statistics*, Vol. 67, No. 2, pp. 327-331.
- Macher, Jeffrey T., David C. Mowery, and Timothy S. Simcoe (2002), "e-Business and Disintegration of The Semiconductor Industry Value Chain," *Industry and Innovation*, Vol. 9, No. 3, pp. 155-181.
- Mahoney, Joseph T. (1992), "The Choice of Organizational form: Vertical Financial Ownership Versus Other Methods of Vertical Integration," *Strategic Management Journal*, Vol. 13, No. 8, pp. 559-584.
- Malone, Thomas W., Joanne Yates, and Robert I. Benjamin (1987), "Electronic Markets and Electronic Hierarchies," *Communications of the ACM*, Vol. 30, No. 6, pp. 484-497.
- Magretta, Joan (2001), "The Power of Virtual Integration: an Interview with Dell Computer's Michael Dell," *Harvard Business Review*, product number: 7907.
- Manning, Chris, Mauricio Rodriguez, and Chinmoy Ghosh, (1999), "Devising a Corporate Facility Location Strategy to Maximize Shareholder Wealth," *The Journal of Real Estate Research*, Vol.17, No. 3, pp. 321-340.
- Martin, Stephen (1983), "Vertical Relationships and Industrial Performance," *The Quarterly Review of Economics and Business*, Vol. 23, No. 1, pp. 6-18.
- Martin, Jeffrey A. and Kathleen Eisenhardt (2003), "Cross-business Synergy: Recombination, Modularity and the Multi-business Team," working paper.

Mentzer, John T., Willaim DeWitt, James S. Keebler, Soonhong Min, Nancy W. Nix, Carlo D. Smith, and Zach Zacharia (2001), "Defining Supply Chain Management," *Journal of Business Logistics*, Vol. 22, No. 2, pp. 1-25.

Monteverde, Kirk and David J. Teece (1982), "Supplier Switching Costs and Vertical Integration in the Automobile Industry," *The Bell Journal of Economics*, Vol. 13, No. 1, pp. 206-213.

Nambisan, Satish (2002), "Designing Virtual Customer Environments for New Product Development: Toward a Theory," *Academy of Management Review*, Vol. 27, No. 3, pp. 392-413.

Narasimhan, Ram, Srinivas Talluri, and Ajay Das (2004), "Exploring Flexibility and Execution Competencies of Manufacturing Firms," *Journal of Operations Management*, Vol. 22, No. 1, pp. 91-106.

Neter, J., W. Wasserman, and M.H. Kunter (1990), *Applied Linear Statistical Models: Regression, Analysis of Variance, and Experimental Design*, 3rd ed., Homewood, IL: Irwin.

Noordewier, Thomas G., George John, and John R. Nevin (1990), "Performance outcomes of Purchasing Arrangements in Industrial Buyer-Vendor Relationships," *Journal of Marketing*, Vol. 54, No. 4, pp. 80-93.

Osborn, Richard N. and C. Christopher Baughn (1990), "Forms of Interorganizational Governance for Multinational Alliances," *Academy of Management Journal*, Vol. 33, No. 3, pp. 503-519.

Osterman, Paul (1982), "Employment Structures within Firms," *British Journal of Industrial Relations*, Vol. 20, No. 3, pp. 349-361.

Osterman, Paul (1994), "How Common is Workplace Transformation and Who Adopts It?" *Industrial and Labor Relations Review*, Vol. 47, No. 2, pp. 173-188.

Osterman, Paul (1999), *Securing Prosperity, The American Labor Market: How it has Changed and What to Do About It*, Princeton, NJ: Princeton University Press.

Osterman, P., T. A. Kochan, R.M. Locke, and M.J. Piore (2001), *Working in America: A Blueprint for the New Labor Market*, Cambridge, Massachusetts: MIT Press.

Oxley, Joanne E. (1997), "Appropriability Hazards and Governance in Strategic Alliances: A Transaction Cost Approach," *The Journal of Law, Economics, and Organization*, Vol. 13, No. 2, pp. 387-409.

Oxley, Joanne E. (1999), "Institutional Environment and the Mechanisms of Governance: the Impact of Intellectual Property Protection on the Structure of Inter-Firm Alliances,"

Journal of Economic Behavior and Organization, Vol. 38, No. 3, pp. 283-309.

Palay, Thomas M. (1984), "Comparative Institutional Economics: The Governance of Rail Freight Contracting," *The Journal of Legal Studies*, Vol. 13, June, pp. 265-287.

Penrose, Edith (1959), *The Theory of the Growth of the Firm*, 3rd edition, New York: Oxford University Press.

Pfohl, Hans-Christian and Hans Peter Buse (2000), "Inter-Organizational Logistics Systems in Flexible Production Networks: An Organizational Capabilities Perspective," *International Journal of Physical Distribution and Logistics Management*, Vol. 30, No. 5, pp. 388-408.

Pfeffer, Jeffrey and Gerald R. Salancik (2003), *The External Control of Organizations: A Resource Dependence Perspective*, Stanford, California: Stanford University Press.

Phillips, Diane M. and Jason Keith Phillips (1998), "A Social Network Analysis of Business Logistics and Transportation," *International Journal of Physical Distribution and Logistics Management*, Vol. 28, No. 5, pp. 328-348.

Pine II, B. Joseph (1993), *Mass Customization*, Boston, Massachusetts: Harvard Business School Press.

Pires, Silvio R. I. (1998), "Managerial Implications of the Modular Consortium Model in a Brazilian Automotive Plant," *International Journal of Operations and Production Management*, Vol. 18, No. 3, pp. 221-232.

Porter, Michael E. (1980), *Competitive Strategy: Techniques for Analyzing Industries and Competitors*, New York: The Free Press.

Porter, Michael E. (1985), *Competitive Advantage: Creating and Sustaining Superior Performance*, New York: The Free Press.

Powell, Walter W. (1987), "Hybrid Organizational Arrangements: New Form or Transitional Development?" *California Management Review*, Vol. 30, No. 1, pp. 67-87.

Ravenscraft, David J. (1983), "Structure-Profit Relationships at the Line of Business and Industry Level," *The Review of Economics and Statistics*, Vol. 65, No. 1, pp. 22-31.

Richardson, G. B. (1972), "The Organisation of Industry," *Economic Journal*, Vol. 82, No. 327, pp. 883-896.

Salerno, Mario Sergio (2001), "The Characteristics and the Role of Modularity in the Automotive Business," *International Automotive Technology and Management*, Vol. 1, No. 1, pp. 92-107.

Salvador, F., C. Forza, and M. Rungtusanatham (2002), "Modularity, Product Variety, Production Volume, and Component Sourcing: Theorizing Beyond Generic Prescriptions," *Journal of Operations Management*, Vol. 20, No. 5, pp. 549-575.

Sanchez, Ron (1997), "Preparing for an Uncertain Future: Managing Organizations for Strategic Flexibility," *International Studies of Management & Organization*, Vol. 27, No. 2, pp. 71-94.

Sanchez, Ron (1999), "Modular Architectures in the Marketing Process," *Journal of Marketing*, Vol. 63, Special Issue, pp. 92-111.

Sanchez, Ron and Joseph T. Mahoney (1996), "Modularity, Flexibility, and Knowledge Management in Product and Organization Design," *Strategic Management Journal*, Vol. 17, Winter Special Issue, pp. 63-76.

Saussier, Stephane (2000), "Transaction Costs and Contractual Incompleteness: the Case of Electricite de France," *Journal of Economic Behavior and Organization*, Vol. 42, No. 2, pp. 189-206.

Schilling, Melissa A. (2000), "Toward A General Modular systems Theory and Its Application to Interfirm Product Modularity," *Academy of Management Review*, Vol. 25, No. 2, pp. 312-234.

Schilling, Mellissa A. and H. Kevin Steensma (2001), "The Use of Modular Organizational Forms: An Industry-Level Analysis," *Academy of Management Journal*, Vol. 44, No. 6, pp. 1149-1168.

Schumpeter, Joseph A. (1942), *Capitalism, Socialism, and Democracy*, New York: Harper & Brothers Publishers.

Shapiro, Jeremy F. (2001), *Modeling the Supply Chain*, California: Duxbury/Pacific Grove.

Shelanski, Howard A. and Peter G. Klein (1995), "Empirical Research in Transaction Cost Economics: A Review and Assessment," *The Journal of Law, Economics and Organization*, Vol. 11, No. 2, pp. 335-361.

Simchi-Levi, David, Philip Kaminsky, and Edith Simchi-Levi (2000), *Designing and Managing the Supply Chain – Concepts, Strategies, and Case Studies*, McGraw-Hill.

Skjoett-Larse, Tage, Christian Thernoe, and Claus Andresen (2003), "Supply Chain Collaboration: Theoretical Perspectives and Empirical Evidence," *International Journal of Physical Distribution and Logistics Management*, Vol. 33, No. 6, pp. 531-549.

Sosa, Manuel E., Steven D. Eppinger, and Craig M. Rowles (2004), "The Misalignment of Product Architecture and Organizational Structure in Complex Product Development,"

Management Science, Vol. 50, No. 12, pp. 1674-1689.

Stern, Louis W. and Torger Reve (1980), "Distribution Channels as Political Economies: a Framework for Comparative Analysis," *Journal of Marketing*, Vol. 44, No. 3, pp. 52-64.

Stratman, Jeff K., Aleda V. Roth, and Wendell G. Gilland (2004), "The Deployment of Temporary Production workers in Assembly Operations: A Case Study of the Hidden Costs of Learning and Forgetting," *Journal of Operations Management*, Vol. 21, No. 6, pp. 689-707.

Stremersch, Stefan, Allen M. Weiss, Benedict G. C. Dellaert, and Ruud T. Frambach (2003), "Buying Modular Systems in Technology-Intensive Markets," *Journal of Marketing Research*, Vol. 40, No. 3, pp. 335-350.

Sturgeon, Timothy J. (2002), "Modular Production Networks: a New American Model of Industrial Organization," *Industrial and Corporate Change*, Vol. 11, No. 3, pp. 451-496.

Sturgeon, Timothy J. (2003), "What really Goes on in Silicon Valley? Spatial Clustering and dispersal in Modular Production Networks," *Journal of Economic Geography*, Vol. 3, No. 2, pp. 199-225.

Sullivan, Laurie (2004), "Wal-Mart Tests RFID with Eight Suppliers," *InformationWeek*, May 3rd, p. 28.

Swamidass, Paul M. and William T. Newell (1987), "Manufacturing Strategy, Environmental Uncertainty and Performance: A Path Analytic Model," *Management Science*, Vol. 33, No. 4, pp. 509-524.

Thompson, James D. (1967), *Organizations in Action: Social Science Bases of Administrative Theory*, New York: McGraw-Hill.

Towill, Denis R. and Peter McCullen (1999), "The Impact of Agile Manufacturing on Supply Chain Dynamics," *International Journal of Logistics Management*, Vol. 10, No. 1, pp. 83-96.

Tsang, Denise (2003), "Influence of American Models: The Evolution of Corporate Network in the European PC Industry, working paper.

Tu, Qiang, Mark A. Vonderembse, T. S. Ragu-Nathan, and Bhanu Ragu-Nathan (2004), "Measuring Modularity-Based Manufacturing Practices and Their Impact on Mass Customization Capability: A Customer-Driven Perspective," *Decision Sciences*, Vol. 35, No. 2, pp. 147-168.

Ulset, Svein (1996), "R&D Outsourcing and Contractual Governance: An Empirical Study of Commercial R&D Projects," *Journal of Economic Behavior and Organization*,

Vol. 30, No. 1, pp. 63-82.

Upton, David M. (1997), "Process Range in Manufacturing: An Empirical Study of Flexibility," *Management Science*, Vol. 43, No. 8, pp. 1079-1092.

U.S. Census Bureau (1997), *1997 Economic Census*, <http://www.census.gov/epcd/www/econ97.html#1997>.

U.S. Census Bureau (1998), *1997 NAICS Codes and Titles*, <http://www.census.gov/epcd/naics/naicscod.txt>

U.S. Census Bureau (2004a), *Manufacturing, Mining, and Construction Statistics*, www.census.gov/mcd

U.S. Census Bureau (2004b), *1997 Economic Census: Summary Statistics for United States – 1997 NAICS Basis*, <http://www.census.gov/epcd/ec97/us/US000.HTM>.

U.S. Census Bureau (2005a), *Industry and Occupation Crosswalks*, <http://www.census.gov/hhes/www/ioindex/ioindex.html>

U.S. Census Bureau (2005b), *The North American Industry Classification System*, <http://www.census.gov/epcd/www/naics.html>

Van Hoek, Remko I. and Harm A.M. Weken (1998), "The Impact of Modular Production on the Dynamics of Supply Chains," *The International Journal of Logistics Management*, Vol. 9, No. 2, pp. 35-50.

Vickery, Shawnee, Roger Calantone, and Cornelia Droge (1999), "Supply Chain Flexibility: An Empirical Study," *The Journal of Supply Chain Management*, Vol. 35, No. 3, pp. 16-24.

Waldman, Don E. and Elizabeth J. Jensen (1998), *Industrial Organization: Theory and Practice*, Reading, Massachusetts: Addison-Wesley.

Weber, Mary Margaret (2002), "Measuring Supply Chain Agility in the Virtual Organization," *International Journal of Physical Distribution and Logistics Management*, Vol. 32, No. 7, pp. 577-590.

Wernerfelt, Birger and Aneel Karnani (1987), "Competitive Strategy under Uncertainty," *Strategic Management Journal*, Vol. 8, No. 2, pp. 187-194.

Whipple, Judith Schmitz, Robert Frankel, and Kenneth Anselmi (1999), "The Effect of Governance Structure on Performance: A Case Study of Efficient Consumer Response," *Journal of Business Logistics*, Vol. 20, No. 2, pp. 43-62.

Whipple, Judith M. and Robert Frankel (2000), "Strategic Alliance Success Factors," *The*

Journal of Supply Chain Management, Vol.36, No.3, pp. 21-28.

White, Steven (2000), "Competition, Capabilities, and the Make, Buy, or Ally Decisions of Chinese State-owned Firms," *Academy of Management Journal*, Vol. 43, No. 3, pp. 324-341.

Williamson, Oliver E. (1975), *Markets and Hierarchies: Analysis and Antitrust Implications*, New York: The Free Press.

Williamson, Oliver E. (1985), *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*, New York: The Free Press.

Williamson, Oliver E. (1991a), "Comparative Economic Organization: The Analysis of Discrete Structural Alternatives," *Administrative Science Quarterly*, Vol. 36, No. 2, pp. 269-296.

Williamson, Oliver E. (1991b), "Strategizing, Economizing, and Economic Organization," *Strategic Management Journal*, Vol. 12, Special Issue, pp. 75-94.

Williamson, Oliver E. (1995), *The Mechanisms of Governance*, New York: Oxford University Press.

Williamson, Oliver E. (1999), "Strategy Research: Governance and Competence Perspectives," *Strategic Management Journal*, Vol. 20, No. 12, pp. 1087-1108.

Wilson, Lynn O., Allen M. Weiss, and George John (1990), "Unbundling of Industrial Systems," *Journal of Marketing Research*, Vol. 27, No. 2, pp. 123-138.

Worren, Nicolay, Karl Moore, and Pablo Cardona (2002), "Modularity, Strategic Flexibility, and Firm Performance: A Study of the Home Appliance Industry," *Strategic Management Journal*, Vol. 23, No. 12, pp. 1123-1140.

Zenger, Todd R. and William S. Hesterly (1997), "The Disaggregation of Corporations: Selective Intervention, High-Powered Incentives and Molecular Units," *Organization Science*, Vol. 8, No. 3, pp. 209-222.