A Virtual Integration Theory of Improved Supply-Chain Performance

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ABSTRACT: Organizing and maintaining a competent and flexible supply chain is a major challenge to manufacturers in today's increasingly competitive and uncertain environments. Virtual integration represents the substitution of ownership with partnership by integrating a set of suppliers through information technology (IT) for tighter supply-chain collaboration. From the systems and control perspectives, this study develops a theory of virtual integration with an empirical model to examine the role that virtual integration plays in facilitating manufacturers to achieve greater manufacturing flexibility and comparative cost advantage. Based on a survey of Taiwanese manufacturing firms, our results show that environmental uncertainty tends to motivate manufacturers to increase their manufacturing flexibility, with both virtual integration and supplier responsiveness playing a vital enabling role. The results demonstrate the importance of supplier responsiveness for manufacturers to gain manufacturing flexibility and comparative cost advantage in supply-chain operations. En-

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vironmental uncertainty, thus, might first appear as a threat to a manufacturer, but with the help of IT and more responsive suppliers, such a threat could be transformed into a competitive edge, as reflected in the manufacturer's higher levels of manufacturing flexibility and comparative cost advantage.

KEY WORDS AND PHRASES: competitive advantage, environmental uncertainty, interorganizational information systems, structural equation modeling, supply-chain management.

THE STUDY OF MANUFACTURING FLEXIBILITY has long been a central theme in the information technology (IT) and operations management literature [7, 20, 37, 67, 78], as it is an important capability to survive in hyper-competitive industries [22]. Many studies have examined the impacts of the external environment on firms' manufacturing strategies, organizational characteristics, and technology adoption practices [7, 52, 74], which all are ways to achieve higher manufacturing flexibility. Virtual integration allows a firm to substitute ownership with partnership by integrating a set of suppliers through IT for tighter collaborative operation execution and process planning and control [19, 47]. Vertical integration has been proposed as a useful governance structure for countering environmental uncertainty through reduced price uncertainty and lower transaction costs, but it also can result in low flexibility and incur additional administrative and production costs associated with required adaptability [11, 39, 41]. In contrast, market transactions and outsourcing have also been recognized as an alternative for firms to achieve manufacturing flexibility by leveraging production capacity, shortening the learning curve, reducing risks, and expanding the firm's resource base through collaboration with qualified suppliers [35]. Although interfirm collaboration seems to satisfy a firm's adaptation needs in a dynamic environment [36, 39], it may actually be more costly than vertical integration. We propose virtual integration as an alternative governance mechanism, which can achieve both manufacturing flexibility and cost advantage by increasing internal and external control.

Virtual integration is similar to *vertical quasi-integration in lean supply,* which offers the benefits that it was assumed vertical integration should provide [6, 18, 36]. Clemons et al. [19] argue that the combination of reduction of coordination cost and transaction risk will lead to partnership outsourcing, and thus the emergence of electronic hierarchies, rather than market outsourcing; the same results are also suggested by the theoretic work of Malone et al. [42]. Outsourcing may reduce the influences of environmental uncertainty facing firms, but it can also generate a new demand for ensuring flexible, smooth, and well-coordinated operations with suppliers [27, 71]. Consequently, the management of external suppliers becomes an important source of firm competitiveness [61], and IT-enabled integration probably is the most effective and efficient mechanism [40].

This study develops and tests hypotheses regarding the relationships between virtual integration and flexibility and cost advantage in uncertain environments. We contribute to the literature by theorizing and empirically testing the critical role of virtual integration in mediating the effect of environmental uncertainty and in enabling supplier responsiveness in a supply chain, and the resultant manufacturing flexibility and cost advantage of the buyer. Our empirical findings corroborate our theoretical model, highlighting the importance of virtual integration in supply-chain operations.

Theoretical Background and Model

THE STUDY OF FLEXIBILITY HAS BEEN CRITICIZED as lacking a substantial theoretical foundation [23]. Yet several preliminary theoretical works still provide us with insights into the relationship between environmental uncertainty and flexibility (e.g., [72]).

Flexibility at the Firm Level

The *open systems view* suggests that a manufacturer seeks to handle uncertainty as an input from its environment and then generates flexibility as a competitive advantage in the environment [23]. (See Figure 1.) A manufacturer's adaptability represents its insensitivity to the control influences originated from its environment: manufacturing flexibility is a way to achieve control [72]. For example, Sanchez [57] suggests that a manufacturer with resources and coordination flexibility is better prepared for an uncertain future and enjoys the benefits of flexibility in competition.

The primary source of environmental uncertainty facing manufacturers is demand volatility, which tends to be distorted and amplified along a supply chain, a phenomenon commonly called the *Forrester effect* or the *bullwhip effect* [38]. The bullwhip effect might be caused by a manufacturer's behaviors responding to demand forecast updating, order batching, price fluctuations, and rationing and shortage gaming [38].

Another source of environmental uncertainty facing firms is industry clockspeed, which also tends to be amplified along a supply chain [25]. *Clockspeed amplification* describes the fact that manufacturers face a remarkable decline in the price/performance ratio and compression of product life cycle as they are situated closer to the consumer end of the supply chain [46]. As the rates of change in an industry increase—especially changes in technology, consumer preferences, and competition—so does the clockspeed of the industry. To compete, firms in such an industry need to adjust the speed of their internal operations to meet the accelerating external clockspeed [46].

Flexibility can provide firms with greater ability to adapt to or accommodate environmental uncertainty [20, 31]. *Manufacturing flexibility,* defined as a firm's ability to develop new products, handle a mix of products, and adjust production according to demands effectively, can enhance a manufacturer's performance in meeting its end customers' requirements speedily, which encompasses those areas where flexibility can directly impact a manufacturer's ability to serve customers. These include product flexibility, volume flexibility, mix flexibility, launch flexibility, and responsiveness to target markets [37, 71]. The underlying rationale connecting manufacturing flexibility

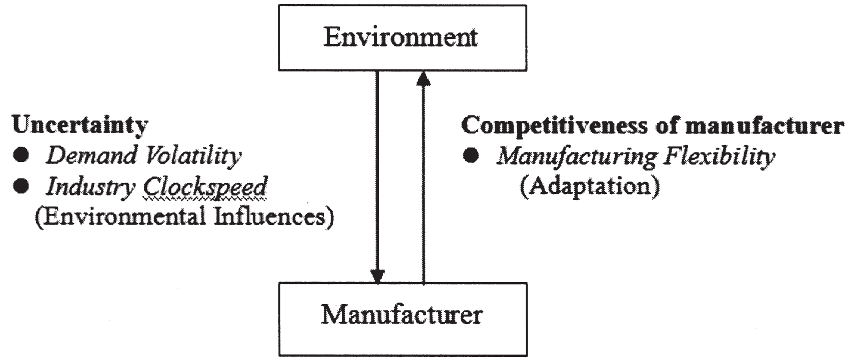

Figure 1. The Manufacturer as a Controlled, Autonomous System

with environmental uncertainty is obvious, because the environment affects a firm's manufacturing strategy and its subsequent design and investment in operational technology, thereby shaping its manufacturing capabilities [74]. Regardless of whether the firm is proactively or defensively investing in greater manufacturing flexibility, it may design its organization to function more organically and invest in flexible technologies for accommodating uncertainty [57, 67]. Thus, this study holds that manufacturers are able and motivated to increase their flexibility in responding to uncertain environments [13].

> *Hypothesis 1 (The Uncertainty–Flexibility Hypothesis): The greater the environmental uncertainty faced by a manufacturer, the greater will be its manufacturing flexibility.*

Flexibility at the Supply-Chain Level

As demand volatility and industry clockspeed increase, which tend to be amplified along the supply chain, a manufacturer can hardly compete effectively by only focusing on internal flexible manufacturing competencies alone [78], and constructing and maintaining a flexible and competent supply chain becomes critical. Supply-chain integration, which makes the chain agile by obtaining timely feedback from suppliers, becomes an important way for a manufacturer to deal with environmental influences. Because all systems are hierarchical in nature, any system can be considered as a subsystem in some supersystem [1]. A focal manufacturer and its suppliers, therefore, are subsystems in their supply-chain system with self-referential interaction patterns. (See Figure 2.) In such a system, a change in one element usually is coupled with changes elsewhere, and these changes may create influences that go back to the initial element [1, 23, 75]. The focal manufacturer can be viewed not only as a *controlled system* but also an *autonomous system,* framing a *dual control perspective* [23]. On one hand, a focal manufacturer within a supply chain seeks to resist or adapt to the threats from the external environment by enhancing flexibility. On the other hand, being an autonomous system, the supply chain evolves and seeks to absorb

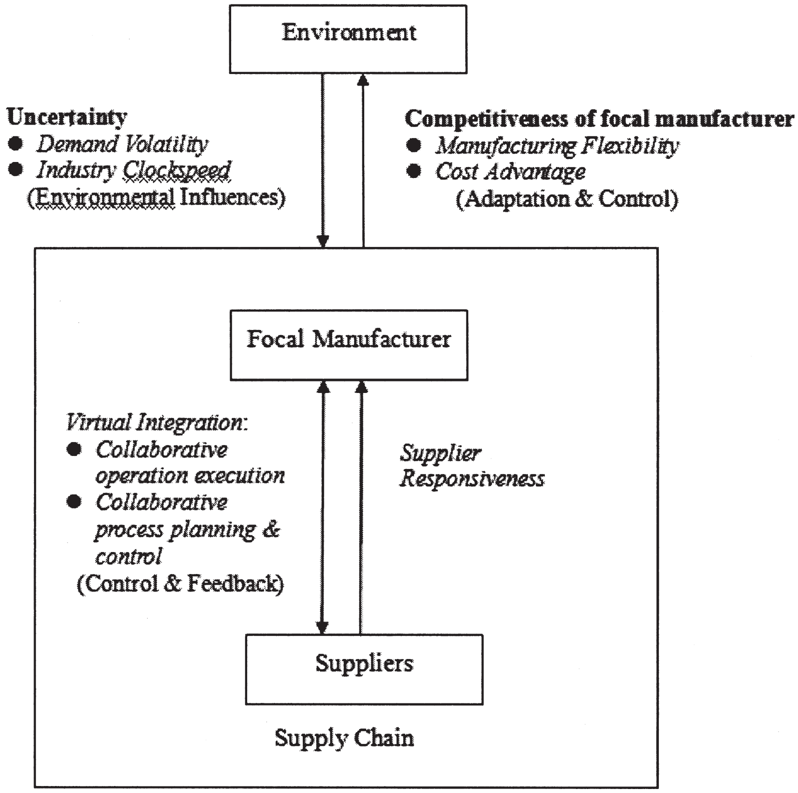

Figure 2. A Controlled-Flexibility Framework of a Supply Chain

environmental disturbances to create new orders. Therefore, the focus of our analysis is directed toward the dimensions of a supply chain that can help the chain maintain its identity by accommodating or counteracting threatening fluctuations [23]. High flexibility within the supply chain corresponds to the extensive coordination and control capacities of the manufacturer with respect to its suppliers. We propose that two critical supply-chain characteristics influence supply-chain flexibility: virtual integration and supplier responsiveness, as depicted in Figure 2.

Virtual Integration in Supply Chains

From the dual control perspective [23], the internal flexibility offered by a controlled system focuses on creating a hierarchical composition of loosely coupled subsystems to facilitate its adaptability. A supply chain's subsystems possess some unique properties of stability to realize effective independent reactions, which keep disturbances local. So the supply-chain system as a whole will be less sensitive to local environmental changes. In the case of an autonomous system, the external flexibility is created for enhancing its capacity to influence environment. Vertical integration is an example of changing external structures for input or demand uncertainty control [23]. However, vertical integration also may create inflexible structures at the risk of losing asset value and firm capabilities as circumstances change [66, 72]. To achieve both internal and external flexibility, virtual integration will enable a manufacturer to gain more control over the environment without having to exert ownership control over its suppliers.

Virtual integration here captures the extent to which trading partners use IT to implement two aspects of vertical coordination and control in the supply chain: *collaborative operation execution* and *collaborative process planning and control* [47]. Collaborative operation execution refers to the extent to which IT facilitates common operations between supply-chain partners, such as purchasing, production, and logistics operations, while collaborative process planning and control represents the extent to which IT is used to support collaborative decision making and performance control by the partners. With greater information processing and communication capabilities, as well as better control and feedback mechanisms provided by IT, trading partners are able to achieve greater interfirm collaboration without common ownership [9, 16]. Because IT can facilitate timely interfirm joint decision making and coordination, its proper applications should give manufacturers greater ability to manage their supply-chain operations, and control and coordinate with suppliers [31, 43].

Virtual integration creates an ability on the part of the firm to effect better process control and also to manage demand volatility better [43], allowing manufacturers to substitute "information for inventory" and thereby improving resource utilization for both manufacturers and suppliers [24, 54, 73]. Thus, virtual integration can be seen as a strategy to reduce the influences of environmental uncertainty by improving interfirm information processing, coordination, and control [28, 43]. Consequently, it is suggested that virtual integration will be more likely to be observed when firms operate in uncertain environments.

> *Hypothesis 2 (The Environmental Uncertainty Hypothesis): The greater the environmental uncertainty faced by a manufacturer, the greater will be the extent to which it is virtually integrated with its suppliers.*

Supplier Responsiveness in Supply Chains

Supplier responsiveness is a local adaptation concept, reflecting the extent to which a supplier meets customer requirements in procurement and supply operations [15]. Manufacturers try to increase their control through collaboration with suppliers to make them more responsive, thereby also making the manufacturers responsive to environmental changes. The ability of manufacturers to control suppliers will increase when the manufacturers adopt practices such as operational collaboration and relationship building. Consequently, it is expected that manufacturers will apply more such practices for tighter coordination with their suppliers under a more uncertain environment, leading to greater supplier responsiveness.

> *Hypothesis 3 (The Uncertainty–Supplier Hypothesis): The greater the environmental uncertainty faced by a manufacturer, the greater will be the degree of its suppliers' responsiveness.*

To deal with process-oriented problems (e.g., throughput variance control), suppliers have to coordinate with buyers to obtain information concerning demand patterns, inventory buffers, and production capacity. To ensure proper interfirm performance control and operational integration, knowledge embedded in the working practices of supply-chain partners also needs to be sufficiently shared [30]. Virtual integration can be regarded as an integration mechanism for partners to exchange information for effective interfirm learning and mutual adaptation [60]. Of course, the tacit nature of knowledge prohibits its direct translation into digital form, but the transferability of tacit knowledge between supply-chain partners can nonetheless be improved through frequent interactions facilitated by IT. Because joint actions and planning and resource sharing are all information-intensive activities requiring substantial interfirm coordination, learning, and adaptation, virtual integration should be useful in increasing trading partners' capabilities for handling such activities. With integrated information systems (IS) to synchronize material flows, suppliers can more dynamically react to messages from their customers and adjust to customer requests [63]. An electronically integrated supply chain allows the suppliers to have greater downstream visibility, thus giving them greater ability to meet downstream manufacturers' varying market conditions.

Hypothesis 4 (The Supplier Responsiveness Hypothesis): The greater the degree that a manufacturer is virtually integrated with its suppliers, the greater will be the extent of its suppliers' responsiveness.

Supply-Chain Competitiveness

Flexibility is the most important capability against environmental uncertainty, but it may also require much cost for a firm to realize this capability. Manufacturing flexibility and cost advantage are two major competitive goals for manufacturers to pursue [75]. Fisher [26] proposes that supply-chain management actually manages two distinct costs: *physical costs* (e.g., manufacturing, transport, and cycle stock cost) and *market mediation costs* (e.g., safety stock, markdowns, and lost sales). Market mediation costs predominate in uncertain environments, as the matching of supply and demand is more difficult [26, 33]. A manufacturer may perform well in handling physical costs, but it needs to coordinate with its suppliers to reduce market mediation costs by controlling uncertain market environments. Hence, for creating cost advantage as well as manufacturing flexibility, virtual integration and supplier responsiveness are two important enablers within the supply-chain system [31].

The major advantage that virtual integration can bring about for managing a supply chain is enhanced visibility [2]. With seamless information channels connected to suppliers, and thus a high level of supply-chain visibility, manufacturers can more easily track variations in production, product quality, inventory levels, and delivery capability of suppliers. By receiving such information in a more timely way, manufacturers can plan and adjust their own operations more rapidly, and thereby achieve greater adaptability to any unexpected events caused by suppliers. On the other hand, by providing suppliers with timely information regarding their own changes of plan, manufacturers also allow their suppliers to adjust themselves to such changes more rapidly. Besides, virtual integration is critical to the implementation of certain manufacturing practices regarded as important in increasing manufacturing flexibility. For example, van Hoek [69] empirically demonstrates the important role of IT in facilitating postponed manufacturing. This study holds that a manufacturer's manufacturing flexibility should be significantly affected by the extent to which its processes and decision-making activities are electronically linked with its suppliers.

Hypothesis 5 (The Manufacturing Flexibility Hypothesis): The greater the degree that a manufacturer is virtually integrated with its suppliers, the greater will be its manufacturing flexibility.

Virtual integration also can help manufacturers achieve a low-cost advantage in terms of efficient resource utilization in production and supply-chain operations [17, 32]. Through appropriate IT investments and usage, supply-chain costs can be lowered, speed of feedback and error correction can be increased, agility of supply-chain operations can be improved, and relationships between trading partners can be enhanced. As such, existing bottlenecks in the supply chain can be removed and variability of production flows leveled. According to the *theory of swift, even flow,* improvements in procurement/production processes can, in turn, lead to better manufacturing performance such as reduced production cost [59]. Thus, with virtual integration, the performance of a manufacturer's production function and supply-chain operations can be greatly improved, due to the elimination of waste in time, inventory, and transportation [24, 44].

Hypothesis 6 (The Cost Advantage Hypothesis): The greater the degree that a manufacturer is virtually integrated with its suppliers, the greater will be its cost advantage compared to competitors.

A manufacturer, as a component system in a loosely coupled system, is influenced by its suppliers based on some patterns of interaction. Supplier responsiveness, as one of the manufacturer's flexible manufacturing resources [53], may significantly affect how quickly the manufacturer can react to new market conditions. Thus, with effectively coordinated and responsive suppliers, a manufacturer can avoid many operational problems, including the delay of orders, lower quality, high in-transit process inventories, long customer lead times, and product obsolescence [47, 61]. Consequently, we believe that supplier responsiveness should have beneficial effects on a manufacturer's manufacturing flexibility.

Hypothesis 7 (The Supplier–Flexibility Hypothesis): The greater the degree of responsiveness of a manufacturer's suppliers, the greater will be its manufacturing flexibility.

Moreover, many studies have demonstrated that supplier responsiveness is an important determinant of buyers' purchasing performance. For example, Stanley and Wisner [64] suggest that a supplier's service quality can directly affect the quality performance of its buyers' purchasing function. Of course, the quality performance of a buyer's purchasing function can, in turn, impact its operational performance considerably. Because industrial firms on average spend more than half of every sales dollar on purchased products, supplier responsiveness should have significant impact on the cost structure of manufacturers [68]. Indeed, more responsive suppliers allow their buyers to react to market changes more rapidly, thus reducing the risk of producing outdated products or holding devalued inventories. Thanks to supplier responsiveness, early identification and resolution of production problems can be more easily achieved, giving manufacturers greater ability to contain their costs.

Hypothesis 8 (The Supplier–Cost Advantage Hypothesis): The greater the degree of responsiveness of a manufacturer's suppliers, the greater will be its cost advantage compared to competitors.

Table 1 provides a summary of the hypotheses, including the name, antecedent, and outcome of each hypothesis.

Methodology

Survey Procedure

A CROSS-SECTIONAL MAIL SURVEY WAS ADMINISTRATED for collecting data from randomly selected large and medium-sized manufacturing firms in Taiwan. A draft survey was developed largely based on measures that were identified in the literature as suitable for the current study. After compiling an English-language version of the questionnaire, the survey items were first translated into Chinese by a bilingual research associate. The survey items were verified and refined for translation accuracy by a management information systems (MIS) professor and two senior doctoral students. The Chinese version of the draft was then pretested with 18 senior managers (including purchasing, operation, sales, marketing, and IS managers, and CEOs) for face and content validity, resulting in modifications of the wording of some survey items. We randomly selected 980 manufacturing firms from the Year 2000 directory of the *Top 5000 Largest Firms in Taiwan,* published by China Credit Information Services Ltd., and then the final version of the survey was distributed to the senior operations manager of these firms. Because the operation function plays a critical role in any manufacturing firm and its senior managers should also have a good understanding of the conditions in both sales and manufacturing, we believe that senior operations managers should be the most knowledgeable and reliable informants within a company to answer our survey.

Sample

After one follow-up mailing, 153 surveys were returned in total, with 149 having completed data available for subsequent analysis, yielding an effective response rate of 15.2 percent. Although the response rate is not high, it is still acceptable and comparable to other studies in supply-chain management (e.g., [56, 65]). We present the

Table 1. Summary of Hypotheses

Hypothesis name	Antecedent	Outcome
Uncertainty–flexibility hypothesis (H1)	Environmental uncertainty	Manufacturing flexibility
Environmental uncertainty hypothesis (H2)	Environmental uncertainty	Virtual integration
Uncertainty–supplier hypothesis (H3)	Environmental uncertainty	Supplier responsiveness
Supplier responsiveness hypothesis (H4)	Virtual integration	Supplier responsiveness
Manufacturing flexibility hypothesis (H5)	Virtual integration	Manufacturing flexibility
Cost advantage hypothesis (H6)	Virtual integration	Cost advantage
Supplier–flexibility hypothesis (H7)	Supplier responsiveness	Manufacturing flexibility
Supplier–cost advantage hypothesis (H8)	Supplier responsiveness	Cost advantage

All the hypotheses postulate a positive relationship.

characteristics of the responding firms in Table 2. As the production value of the computer and electronics industry has contributed one-third of Taiwan's gross domestic product, 34.2 percent of the respondents are from this industry. Metal, textile, and automobile industries are around 10 percent in the sample. In addition, 46 percent of the responding firms have assets of less than NT$1.2 billion, but firms with fewer than 100 employees are scarce. Around 43 percent of the responding firms have over 500 employees. Therefore, the sample consists of medium-sized to large firms in Taiwan but with more medium-sized firms than large ones. The average number of years in the informants' current position is 4.3. The informants also averaged 13.4 years in the firm. This indicates that informants are sufficiently knowledgeable to answer the survey.

We conducted two statistical analyses to ensure the absence of nonresponse bias [5]. We first compared the responding and nonresponding firms in terms of company assets and number of employees. These are available from the 2002 *Common Wealth Magazine,* and no significant differences between the two groups were found based on the independent sample *t*-test ($p = 0.17$ and 0.32, respectively). Then, the respondents were divided in half based on the dates of return. The comparison on company assets and employee numbers between the two groups again showed no significant differences based on the independent sample *t*-test ($p = 0.13$ and 0.12, respectively). Accordingly, nonresponse bias should not be a problem in this study.

Table 2. Demographic Characteristics of the Responding Firms (n = 149)

	Percentage of firms
Industry	
Automobile	8.7
Chemical	4.0
Computer and electronics	34.2
Food	4.7
Machine and tool	8.1
Mental	15.4
Textile	10.7
Others	14.2
Total assets (NT$)	
Less than $0.8 billion	26.2
$0.8–$1.2 billion	20.1
$1.3–$2 billion	12.1
$2.1–$3 billion	13.4
$3.1–$5 billion	11.4
$5.1–$8 billion	5.4
$8.1–$10 billion	1.3
Over $10 billion	9.4
No response	0.7
Number of employees	
Fewer than 100	2.0
101–500	53.7
501–1,000	20.1
1,001–3,000	15.4
Over 3,000	8.1
No response	0.7

Measures

Environmental Uncertainty (EU)

Demand volatility and industry clockspeed are the two main sources of environmental uncertainty encountered by companies in which the supply chain operates. Demand volatility reflects the variability and unpredictability of market demand. The rate of decline in price and the freshness of the product line have been suggested to have influences on industry clockspeed [45, 46]. We adopted items reflecting these two sources of environmental uncertainty from Mendelson and Pillai [46] and van Hoek [69].

Virtual Integration (VI)

We use prior literature on supply-chain integration as the basis for developing measurement items corresponding to IT-based interfirm integration activities. The measurement items cover two aspects of interfirm collaboration: operation execution and process planning and control, including order tracking, market information sharing, production capacity coordination, inventory level coordination, support for material or component design, and support for quality control [4, 29, 47, 49].

Supplier Responsiveness (SR)

We operationalized supplier responsiveness based on Carr and Smeltzer [15] by assessing the extent to which a manufacturer perceives its suppliers as responsive to its purchasing requirements. The focal aspects measured include material quality, material delivery, material price, and flexibility in volume changes.

Manufacturing Flexibility (MF)

A consensus is still lacking regarding how manufacturing flexibility should be properly operationalized and numerous approaches have been proposed [7, 51]. The authors focus on measuring different aspects of manufacturing flexibility relevant to the effectiveness of supply chains. Such an approach has been suggested in prior studies [8, 71]. Based on these works, we assess five important aspects of manufacturing flexibility: product flexibility, volume flexibility, mix flexibility, launch flexibility, and responsiveness to target markets. We operationalized product flexibility as a manufacturer's ability to develop or modify product designs rapidly. Volume flexibility is a manufacturer's ability to operate efficiently at different levels of output. Mix flexibility is a manufacturer's ability to produce a widely varied product mix simultaneously. Launch flexibility is a manufacturer's ability to launch new product designs into production speedily. Responsiveness to target markets is a manufacturer's ability to respond to the needs of its target markets. This could also be considered as an overall assessment of the manufacturer's ability to satisfy market demands.

Cost Advantage (CA)

Cost advantage was operationalized based on Beamon [8] and Scannel et al. [58] by assessing the extent to which a manufacturer's cost performance is comparable to that of its major competitors in the following aspects: production cost, inventory cost, and distribution cost. Because the major cost dimensions relevant to supply-chain management are simultaneously measured, we believe that this variable should be indicative of the resource utilization and operational performance of the supply chain.

Results

WE CONDUCTED THE DATA ANALYSIS IN TWO PARTS—measurement analysis and hypothesis testing. Following Anderson and Gerbin's [3] two-step approach, the measures were subjected to confirmatory factor analysis (CFA) and reliability tests to ensure that desirable measurement properties of the scales were present. Then, a structural equation model (SEM) was constructed for hypothesis testing. The software package that we used for the statistical analyses was EQS for Windows.

Measurement Model

We first used CFA [10] to validate the measures [12]. Table 3 gives the results. The model fit for CFA was reasonable, with a χ^2 of 338.97 (degrees of freedom [df] = 199), a root mean square error (RMSE) of 0.07, and a comparative fit index (CFI) of 0.90. All loadings are of a reasonable magnitude and are significant at $p < 0.01$. This pattern of strong loadings provided preliminary evidence of scale validity. Further, the construct reliabilities were in a reasonable range, between 0.74 and 0.95. Except for environmental uncertainty, the average variance extracted (AVE) of the remaining constructs was greater than 0.5. In general, these results suggest acceptable unidimensionality, internal consistency, and adequate reliability for these measures.

As shown in Table 4, none of the correlations between the constructs was sufficiently high to jeopardize discriminant validity. To provide further evidence, we ran an additional series of CFAs to assess discriminant validity. Where possible, for each pair of the constructs, the fit of the CFA model with the interconstruct correlation constrained to unity was compared with the fit of an unconstrained CFA model. χ^2 difference tests indicated that in each case, the unconstrained model provided a significantly more accurate representation of the data, further demonstrating sufficient discriminant validity among the constructs.

Structural Model

As shown in Figure 3, the overall model fit index CFI (0.90) and the χ^2 degrees of freedom ratio (1.70) show that our proposed model fits the data acceptably and the nonnormed fit index (NNFI) is only slightly below the recommended 0.90 threshold at 0.88. Also, except for virtual integration, the variance explained (R^2) by the other three endogenous variables is reasonable ($R^2 \geq 0.20$), so most of the endogenous variables are reasonably explained by the factors proposed in the study. So, we conclude that the overall model fit is acceptable and the path estimates can be used for hypothesis testing. Figure 3 shows that only the path from virtual integration to cost advantage, that is, the Cost Advantage Hypothesis (H6), fails to be significant at the 0.05 level.

Discussion

FOLLOWING THE ELECTRONIC HIERARCHY CONCEPT of Malone et al. [42] and the "move to the middle" hypothesis [19], this study investigates the importance of IT-enabled virtual integration in supply-chain performance. The model is based on the

Table 3. Measurement Model: Confirmatory Factor Analysis Results

Construct indicators	Loadings (t)	Reliability[1]	AVE
Environmental uncertainty		0.74	0.45
(EU1) The extent of demand variability	0.87 (10.03***)		
(EU2) The unpredictability of demand volume	0.45 (5.39***)		
(EU3) The rate of decline in product price	0.38 (4.20***)		
(EU4) The rate of new product obsoleteness	0.58 (5.62***)		
Virtual integration[2] (relying on interorganizational information systems and Internet applications to)		0.95	0.70
(VI1) Trace orders	0.74 (10.20***)		
(VI2) Exchange product price and market information	0.81 (12.11***)		
(VI3) Implement quality control on purchased goods	0.77 (11.73***)		
(VI4) Collaborate on the aspects of new material and component testing periodically	0.85 (12.37***)		
(VI5) Coordinate production plan with each other	0.82 (11.86***)		
(VI6) Coordinate inventory level with each other	0.75 (10.97***)		
Supplier responsiveness (the extent to which the suppliers fulfill the requirements of)		0.79	0.49
(SR1) Material quality	0.43 (6.44***)		
(SR2) Material delivery	0.57 (7.28***)		
(SR3) Material price	0.34 (4.66***)		
(SR4) Volume flexibility	0.52 (6.67***)		

Cost advantage		0.86	0.61
(CA1) Production cost	0.52 (7.35***)		
(CA2) Inventory cost	0.54 (7.77***)		
(CA3) Distribution cost	0.62 (9.63***)		
Manufacturing flexibility		0.90	0.65
(MF1) Put new product designs into production quickly	0.76 (13.47***)		
(MF2) Operate efficiently at different levels of output	0.60 (10.00***)		
(MF3) Develop or modify new product designs	0.73 (11.79***)		
(MF4) Produce a wide variety of product mix simultaneously	0.52 (7.72***)		
(MF5) Respond to market demand on time	0.59 (9.07***)		
RMSEA	0.07		
Bentler's CFI	0.90		
Chi-square/df ratio	338.97/199 = 1.70		
Bentler and Bonett's NNFI	0.88		

Notes: [1] Composite reliability. [2] There is a supplementary question that asked respondents to indicate the ratio they used in the following different interorganizational information systems (IOS): XML-based business-to-business (B2B) systems, WWW (e.g., portal), EDI, FTP, e-mail, and others. *** indicates significant at the $p < 0.01$ level.

Table 4. Descriptive Analysis and Correlations

Variable	Mean	Standard deviation	Median	1	2	3	4
1. Environmental uncertainty	3.2	0.73	3.3				
2. Virtual integration	3.3	0.82	3.3	0.16**			
3. Supplier responsiveness	3.6	0.56	3.5	0.14	0.33***		
4. Cost advantage	3.5	0.65	3.7	0.07	0.19**	0.35***	
5. Manufacturing flexibility	3.8	0.69	3.8	0.27***	0.32***	0.29***	0.34***

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

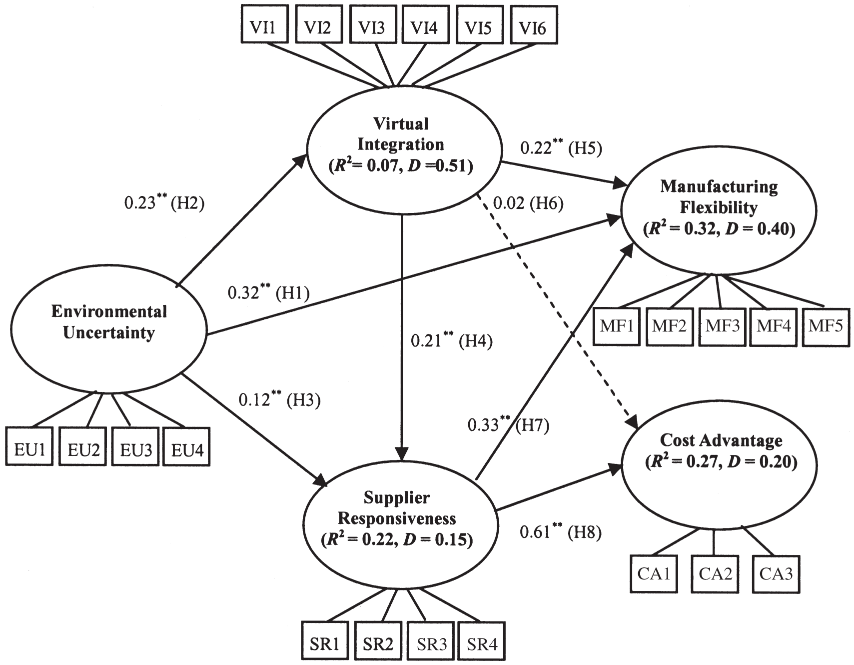

Figure 3. Structural Equation Model with Path Estimates
Notes: The model was estimated with the covariance between the error variances of manufacturing flexibility and cost advantage being freely estimated. The covariance, however, is not significant and thus is not shown in the figure. Except for the path from virtual integration to cost advantage, the paths are significant at the 0.05 level. The result shows the importance of virtual integration in mediating environmental uncertainty into greater supplier responsiveness and supply-chain performance characterized by manufacturing flexibility and cost advantage of the buyers. RMSEA: 0.07; Bentler's CFI = 0.90; χ^2/df: 340.13/200 = 1.70; Bentler and Bonet's NNFI: 0.88. ** $p < 0.05$, one-tailed test. D is error variance.

dual control perspective [23], theorizing the mediating effect of virtual integration between environmental uncertainty and supply-chain performance.

Results

Environmental Effects

The Uncertainty-Flexibility Hypothesis (H1) and the Uncertainty-Supplier Hypothesis (H3) suggest that uncertain environments tend to motivate both buyers and suppliers to search for responsiveness and flexibility in the supply-chain context. H1 points out that manufacturers are likely to implement technologies and mechanisms for facilitating flexible manufacturing operations, in addition to IT. Although Pagell and Krause's [50] study shows no significant association between environmental uncertainty and operational flexibility of manufacturers at the shop floor level, our results show otherwise. Further, with greater environmental uncertainty, H3 suggests that manufacturers will collaborate more tightly with their suppliers in order to make them more responsive to environmental changes. The two main sources of environmental uncertainty (i.e., demand volatility and industry clockspeed) are two important drivers for motivating firms to implement IT-based supply-chain integration mechanisms, as indicated by the Environmental Uncertainty Hypothesis (H2). Our results therefore suggest that having flexible manufacturing operations, integrating electronically with suppliers, and developing responsive suppliers all are ways for manufacturers to deal with uncertain environments.

Virtual Integration Effects

Our results fail to support the Cost Advantage Hypothesis (H6). The results indicate that virtual integration is unlikely to contribute to manufacturers' cost advantage directly. Nonetheless, it is important for influencing both supplier responsiveness and manufacturing flexibility, as suggested by the Supplier Responsiveness Hypothesis (H4) and the Manufacturing Flexibility Hypothesis (H5). The latter hypothesis indicates that the improvement in a manufacturer's flexibility is likely to be observed when it exchanges timely product/process information with suppliers through interorganizational IS. Such information exchange enabled by IT, as suggested by H4, also makes the suppliers responsive to the buyer dynamic requests, indicating that IT-enabled integration is a useful mechanism for enhancing supplier responsiveness to changing environments. Although the Cost Advantage Hypothesis (H6) asserts that virtual integration can provide manufacturers with the capability for achieving greater cost advantage, it is not supported by our data. However, because supplier responsiveness is beneficial to manufacturers for gaining cost advantage, as suggested by the Supplier–Cost Advantage Hypothesis (H8), virtual integration still can positively impact manufacturers' cost indirectly. Thus, virtual integration should be useful for manufacturers in gaining comparative cost advantage, but such an effect is largely achieved through the help of responsive suppliers.

Mediating Effects

Virtual integration and supplier responsiveness are the two mediating variables in our model. The combination of the Environmental Uncertainty Hypothesis (H2) and Manufacturing Flexibility Hypothesis (H5) suggests that when operating in uncertain environments, manufacturers tend to use IT to integrate with their suppliers for manufacturing flexibility. H2 and the Supplier Responsiveness Hypothesis (H4) together also imply that the uncertainty experienced by manufacturers can be transformed into supplier responsiveness through tighter supply-chain coordination and control supported by a high level of virtual integration. Given that the Supplier–Flexibility Hypothesis (H7) suggests a positive effect of supplier responsiveness on manufacturing flexibility, it together with the Supplier–Cost Advantage Hypothesis (H8) shows that virtual integration can still impact both manufacturing flexibility and cost advantage indirectly.

Implications

Our findings suggest that IT-enabled integration should be an integral part of manufacturing firms' supply-chain management efforts, especially for supplier development and involvement, while responsive suppliers are critical for both manufacturing flexibility and cost advantage under uncertain environments. This implies that the communication channels enabled by IT can be beneficial to supply-chain coordination, resulting in greater mutual adaptability between trading partners when facing unexpected events [14]. Consequently, virtual integration should be valued as an important strategy for mitigating and accommodating environmental uncertainties in supply-chain management. Of course, no matter what types of supply-chain management programs a firm chooses to implement, it still needs the cooperation of suppliers in delivering quality materials and components in the right amounts at the right time. Thus, complementary to such programs is the responsiveness of suppliers. With greater supplier responsiveness enabled by virtual integration, a firm can raise its own ability to counter external influences with greater flexibility. Indeed, supplier responsiveness appears to be the most significant factor in affecting cost advantage in our model, suggesting its critical role in improving buyer performance [61] and that IT-based integration is a powerful instrument for realizing such an effect. Even though IT might not be the only means for improving supply-chain performance, managers should realize its importance in such an endeavor. Firms lagging behind in the investment of interorganizational IS could put themselves at competitive disadvantage, especially as the development of IT has been so rapid and many firms are striving to take fuller advantage of the technologies.

Conclusions

THIS STUDY CONTRIBUTES TO THE LITERATURE by building a theoretical model in which virtual integration plays a pivotal role in generating two dimensions of supply-chain performance—manufacturing flexibility and comparative cost advantage.

Contributions

Theoretically, this study sets a foundation for a theory of virtual integration for improved supply-chain performance under environmental uncertainty. We argue that environmental uncertainty might first appear as a threat to the firm, but with proper supply-chain practices and IT that support efficient and flexible supply-chain coordination, such a threat can be transformed into competitive edge via higher levels of manufacturing flexibility and comparative cost advantage. Except for the direct effect of virtual integration on cost advantage, the data are supportive of the rest of the hypotheses proposed in our model.

Our empirical evidence also demonstrates the importance of the supply-chain system concept: a manufacturer and its suppliers can form a loosely coupled system governed by IT to enhance supplier responsiveness, leading to greater manufacturing flexibility. We also suggest comparative cost advantage is the other important advantage obtained by a virtually integrated supply-chain system. But, such advantage is hardly gained by a firm alone when it pursues greater manufacturing flexibility at the same time. In fact, having a set of responsive suppliers is very important for improving a manufacturer's supply-chain performance. By invoking the concept of fit as mediation [70], our results confirm that manufacturers tend to integrate electronically with their suppliers in order to have their supply-chain operations fit their environments, resulting in more responsive suppliers and better supply-chain performance. The evidence also seems to support the "move to the middle" hypothesis [19] that supply-chain firms can use IT to achieve better vertical coordination without ownership control, forming a vertical structure close to an electronic hierarchy instead of a market of arm's-length transactions. Through tight electronic integration with suppliers and their resultant responsiveness, manufacturing flexibility and comparative cost advantage appear to be something that manufacturers can feed back to counteract the environmental influences, providing preliminary support to the dual control perspective [23].

Limitations

This study has several limitations. First, because we adopted the single-informant approach from the manufacturer's perspective, respondent bias is possible. Second, we used perceptual measures, which might not accurately reflect the objective or real relationships among the theoretical constructs examined. The perceptions of managers largely determine their actions and decisions, so such a limitation might not be so serious. Nonetheless, further development and validation of the measures utilized here are needed. Third, many other interorganizational factors, such as trust, commitment, power, and dependence, have been shown to influence interorganizational IS adoption and the attainment of strategic flexibility by business partners [55, 77]. This might explain the low explanatory power of environmental uncertainty on virtual integration. These factors as well as other supply-chain management practices and technologies might also have significant implications on dimensions of supply-chain performance, but were not incorporated in the current study (e.g., [21, 34, 48]). Fourth, the response rate of the survey may appear somewhat low. Even though the possibility of nonresponse bias was checked and ruled out statistically, the representativeness of the sample, and thus the generalizability of the results, could still be limited.

Future Research

For future research, we offer the following suggestions. First, we did not explicitly distinguish the ways virtual integration could be implemented to improve supplier responsiveness [31]. We examined the possibly differential effects of IT on enhancing supplier responsiveness and on increasing the buyer's control capability over suppliers in combination with one another in this study. Future research can clarify such differential effects of virtual integration and other facilitating and hindering factors affecting supply-chain effectiveness. Second, this study focuses on manufacturing flexibility and cost in supply chains. Future research may extend our model to include transaction cost and risk considerations [19, 62, 76]. Third, because the purpose of the study was not to identify a comprehensive set of variables that affect the application of electronic integration and supply-chain performance, many other factors might generate flexibility-enhancing effects [31] or influence the motivation and requirement of the firm to utilize IT for interfirm integration [62]. Some of them served as intervening variables in our theoretical arguments. But we did not explicitly incorporate them in our model, which was specified in a somewhat reduced form. The effect of feeding back greater flexibility and cost efficiency into the manufacturers' market environments was not explicitly investigated either. Constructing and testing a model taking fuller account of the control-flexibility framework or conducting a longitudinal study should be a valuable direction for future theory development. Fourth, the control-flexibility perspective is inherently functional. A qualitative or interpretative research design might help us gain a fuller understanding of the internal works of supply chains responsible for flexibility generation. Fifth, because we attempted to obtain general results, we did not control for possible confounding effects of industries. Future research may examine the differences between supply-chain management and flexibility-enhancing practices adopted in different industries and compare their effects across industries. Further, although businesses appear to be taking advantage of advanced software applications and the Internet for interfirm communication, incompatible technologies are still hindering seamless communication and common visibility across organizational boundaries. The developments in languages such as XML and in technical dictionaries, such as RosettaNet, may provide a partial solution to the problem. Also, an increasing number of vendors are offering supply-chain management software, which makes supply-chain integration easier. However, these developments also make a firm's supply-chain strategies more imitable, thus reducing its chances of obtaining sustainable competitive advantage through IT. Future study may take a microeconomic approach to analyze the effect of electronic supply-chain integration on market performance and industry structure, possibly at the level of chain-to-chain competition. Finally, interorganizational IS enable more efficient interfirm coordination and control, but it is the internal IS that provide the basis for a firm to operate as an extended enterprise. Consequently, the alignment of a firm's internal IS with interorganizational systems should have a profound impact on the firm's coordination capabilities and visibility along the supply chain. Future research may take a capability or competence view to assess the implications of such alignment on supply-chain flexibility and performance.

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References

1. Ackoff, R.L. *Creating the Corporate Future: Plan or Be Planned For.* New York: John Wiley and Sons, 1981.

2. Allem, S. Full pipeline visibility of Compaq's supply chain. *Taiweb* (2000), 46–55.

3. Anderson, J.C., and Gerbin, D.W. Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103,* 3 (1988), 411–423.

4. Angeles, R., and Nath, R. Partner congruence in electronic data interchange (EDI)-enabled relationships. *Journal of Business Logistics, 22,* 2 (2001), 109–127.

5. Armstrong, J.S., and Overton, T.S. Estimating non-response bias in mail surveys. *Journal of Marketing Research, 14,* 3 (1977), 396–402.

6. Bakos, J.Y. Information links and electronic marketplaces: The role of interorganizational information systems in vertical markets. *Journal of Management Information Systems, 8,* 2 (Fall 1991), 31–52.

7. Beach, R.; Muhlemann, A.P.; Price, D.H.R.; Paterson, A.; and Sharp, J.A. A review of manufacturing flexibility. *European Journal of Operational Research, 122,* 1 (2000), 41–57.

8. Beamon, B.M. Measuring supply chain performance. *International Journal of Operations & Production Management, 19,* 3 (1999), 275–292.

9. Bensaou, M., and Venkatraman, N. Inter-organizational relationships and information technology: A conceptual synthesis and a research agenda. *European Journal of Information Systems, 5,* 2 (1996), 84–91.

10. Bentler, P.M. *EQS Structural Equations Program Manual.* Encino, CA: Multivariate Software, 1995.

11. Blois, K.J. Vertical quasi-integration. *Journal of Industrial Economics, 20,* 3 (1972), 253–272.

12. Bollen, K.A. *Structural Equations with Latent Variables.* New York: Wiley, 1989.

13. Brandyberry, A.; Rai, A.; and White, G.P. Intermediate performance impacts of advanced manufacturing technology systems: An empirical investigation. *Decision Sciences, 30,* 4 (1999), 993–1020.

14. Buvik, A., and Gronhaug, K. Inter-firm dependence, environmental uncertainty, and vertical coordination in industrial buyer–seller relationships. *Omega, 28,* 4 (2000), 445–454.

15. Carr, A.S., and Smeltzer, L.R. An empirical study of the relationships among purchasing skills and strategic purchasing, financial performance, and supplier responsiveness. *Journal of Supply Chain Management, 36,* 3 (2000), 40–54.

16. Chatfield, A.T., and Yetton, P. Strategic payoff from EDI as a function of EDI embeddedness. *Journal of Management Information Systems, 16,* 4 (Spring 2000), 195–224.

17. Christopher, M., and Towill, D.R. Supply chain migration from lean and functional to agile and customized. *Supply Chain Management, 5,* 4 (2000), 206–213.

18. Clemons, E.K., and Row, M.C. Limits to interfirm coordination through information technology: Results of field study in consumer packaged goods distribution. *Journal of Management Information Systems, 10,* 1 (Summer 1993), 73–95.

19. Clemons, E.K.; Reddi, S.P.; and Row, M.C. The impact of information technology on the organization of economic activity: The "move to the middle" hypothesis. *Journal of Management Information Systems, 10,* 2 (Fall 1993), 9–35.

20. Correa, H.L., and Slack, N. Framework to analyze flexibility and unplanned change in manufacturing systems. *Computer Integrated Manufacturing Systems, 9,* 1 (1996), 57–64.

21. Cox, A. Understanding buyer and supplier power: A framework for procurement and supply competence. *Journal of Supply Chain Management, 37,* 2 (2001), 8–15.

22. D'Aveni, R. *Hypercompetition: Managing the Dynamics of Strategic Maneuvering.* New York: Free Press, 1994.

23. De Leeuw, A.C.J., and Volberda, H.W. On the concept of flexibility: A dual control perspective. *Omega, 24,* 2 (1996), 121–139.

24. Dudley, L., and Lasserre, P. Information as a substitute for inventories. *European Economic Review, 33,* 1 (1989), 67–88.

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

26. Fisher, M.L. What is the right supply chain for your product? *Harvard Business Review, 75,* 2 (1997), 105–116.

27. Flynn, B.B., and Flynn, E.J. Information-processing alternatives for coping with manufacturing environment complexity. *Decision Sciences, 30,* 4 (1999), 1021–1052.

28. Forster, P.W., and Regan, A.C. Electronic integration in the air cargo industry: An information processing model of on-time performance. *Transportation Journal, 40,* 4 (2001), 46–61.

29. Frohlich, M.T., and Westbrook, R. Arcs of integration: An international study of supply chain strategies. *Journal of Operations Management, 19,* 2 (2001), 185–200.

30. Germain, R.; Droge, C.; and Christensen, W. The mediating role of operations knowledge in the relationship of context with performance. *Journal of Operations Management, 19,* 4 (2001), 453–469.

31. Gosain, S.; Malhotra, A.; and El Sawy, O.A. Coordinating for flexibility in e-business supply chains. *Journal of Management Information Systems, 21,* 3 (Winter 2004–2005), 7–45.

32. Hitt, L.M. Information technology and firm boundaries: Evidence from panel data. *Information Systems Research, 10,* 2 (1999), 134–149.

33. Kopczak, L.R., and Johnson, M.E. The supply-chain management effect. *Sloan Management Review, 44,* 3 (2003), 27–34.

34. Koufteros, X.; Vonderembse, M.; and Doll, W. Concurrent engineering and its consequences. *Journal of Operations Management, 19,* 1 (2001), 97–115.

35. Krause, D.R. The antecedents of buying firms' efforts to improve suppliers. *Journal of Operations Management, 17,* 2 (1999), 205–224.

36. Lamming, R. *Beyond Partnership: Strategies for Innovation and Lean Supply.* London: Prentice Hall, 1993.

37. Lau, R.S.M. Critical factors for achieving manufacturing flexibility. *International Journal of Operations & Production Management, 19,* 3 (1999), 328–341.

38. Lee, H.L.; Padmanabhan, V.; and Whang, S. Information distortion in a supply chain: The bullwhip effect. *Management Science, 43,* 4 (1997), 546–558.

39. MacBeth, D., and Ferguson, N. *Partnership Sourcing: An Integrated Supply Chain Approach.* London: Pitman, 1994.

40. Magretta, J. The power of virtual integration: An interview with Dell Computer's Michael Dell. *Harvard Business Review, 76,* 2 (1998), 72–84.

41. Mahoney, J.T. The choice of organizational form: Vertical financial ownership versus other methods of vertical integration. *Strategic Management Journal, 13,* 8 (1992), 559–584.

42. Malone, J.T.; Yates, J.; and Benjamin I. Electronic markets and electronic hierarchies. *Communications of the ACM, 30,* 6 (1987), 484–497.

43. Mason-Jones, R., and Towill, D.R. Shrinking the supply chain uncertainty circle. *Control, 24,* 7 (September 1998), 17–22.

44. Mason-Jones, R., and Towill, D.R. Total cycle time compression and the agile supply chain. *International Journal of Production Economics, 62,* 1 (1999), 61–73.

45. Mendelson, H., and Pillai, R.R. Clockspeed and informational response: Evidence from the information technology industry. *Information Systems Research, 9,* 4 (1998), 415–433.

46. Mendelson, H., and Pillai, R.R. Industry clockspeed: Measurement and operational implications. *Journal of Manufacturing & Service Operation Management, 1,* 1 (1999), 1–20.

47. Morash, E.A., and Clinton, S.R. Supply chain integration: Customer value through collaborative closeness versus operational excellence. *Journal of Marketing Theory and Practice, 6,* 4 (1998), 104–120.

48. Narasimhan, R., and Das, A. The impact of purchasing integration and practices on manufacturing performance. *Journal of Operations Management, 19,* 5 (2001), 593–609.

49. Narasimhan, R., and Kim, S.W. Information system utilization strategy for supply chain integration. *Journal of Business Logistics, 22,* 2 (2001), 51–75.

50. Pagell, M., and Krause, D.R. A multiple-method study of environmental uncertainty and manufacturing flexibility. *Journal of Operations Management, 17,* 3 (1999), 307–325.

51. Pagell, M., and Krause, D.R. Re-exploring the relationship between flexibility and the external environment. *Journal of Operations Management, 21,* 6 (2004), 629–649.

52. Premkumar, G.; Ramamurthy, K.; and Saunders, C.S. Information processing view of organizations: An exploratory examination of fit in the context of interorganizational relationships. *Journal of Management Information Systems, 22,* 1 (Summer 2005), 257–294.

53. Raghunathan, S. Interorganizational collaborative forecasting and replenishment systems and supply chain implications. *Decision Sciences, 30,* 4 (1999), 1053–1071.

54. Ramamurthy, K.; Premkumar, G.; and Crum, M.R. Organizational and interorganizational determinants of EDI diffusion and organizational performance: A causal model. *Journal of Organizational Computing and Electronic Commerce, 9,* 4 (1999), 253–285.

55. Ramsay, J. The resource-based perspective, rents, and purchasing's contribution to sustainable competitive advantage. *Journal of Supply Chain Management, 37,* 3 (2001), 38–47.

56. Rutner, S.M.; Gibson, B.J.; and Gustin, C.M. Longitudinal study of supply chain information systems. *Production and Inventory Management Journal, 42,* 2 (2001), 49–56.

57. Sanchez, R. Strategic flexibility in product competition. *Strategic Management Journal, 16,* 5 (Special Issue 1995), 135–159.

58. Scannel, T.V.; Vickery, S.K.; and Droge, C.L. Upstream supply chain management and competitive performance in the automobile industry. *Journal of Business Logistics, 21,* 1 (2000), 23–48.

59. Schmenner, R.W., and Swink, M.L. On theory in operations management. *Journal of Operations Management, 17,* 1 (1998), 97–113.

60. Scott, J.E. Facilitating interorganizational learning with information technology. *Journal of Management Information Systems, 17,* 2 (Fall 2000), 81–113.

61. Shin, H.; Collier, D.A.; and Wilson, D.D. Supply management orientation and supplier/buyer performance. *Journal of Operations Management, 18,* 3 (2000), 317–333.

62. Son, J.Y.; Narasimhan, S.; and Riggins, F.J. Effects of relational factors and channel climate on EDI usage in the customer–supplier relationship. *Journal of Management Information Systems, 22,* 1 (Summer 2005), 321–353.

63. Srinivasan, K.; Kekre, S.; and Mukhopadhyay, T. Impact of electronic data interchange technology on JIT shipments. *Management Science, 40,* 10 (1994), 1291–1304.

64. Stanley, L.L., and Wisner, J.D. Service quality along the supply chain: Implications for purchasing. *Journal of Operations Management, 19,* 3 (2001), 287–306.

65. Stock, G.N.; Greis, N.P.; and Kasarda, J.D. Enterprise logistics and supply chain structure: The role of fit. *Journal of Operations Management, 18,* 5 (2000), 531–547.

66. Teece, D.J. Competition, cooperation, and innovation: Organizational arrangements for regimes of rapid technological progress. *Journal of Economic Behavior and Organization, 18,* 1 (1992), 1–25.

67. Upton, D.M. The management of manufacturing flexibility. *California Management Review, 36,* 2 (1994), 72–89.

68. U.S. Census Bureau. *Annual Survey of Manufacturers.* Washington, DC: U.S. Government Printing Office, 1985.

69. van Hoek, R.I. Logistics and virtual integration: Postponement, outsourcing and the flow of information. *International Journal of Physical Distribution & Logistics Management, 28,* 7 (1998), 508–523.

70. Venkatraman, N. The concept of fit in strategy research: Toward verbal and statistical significance. *Academy of Management Review, 14,* 3 (1989), 423–444.

71. Vickery, S.; Calantone, R.; and Droge, C. Supply chain flexibility: An empirical study. *Journal of Supply Chain Management, 35,* 3 (1999), 16–24.

72. Volberda, H.W. Building flexible organizations for fast-moving markets. *Long Range Planning, 30,* 2 (1997), 169–183.

73. Waller, M.; Johnson, M.E.; and Davis, T. Vendor-managed inventory in the retail supply chain. *Journal of Business Logistics, 20,* 1 (1999), 183–203.

74. Ward, P.T., and Duray, R. Manufacturing strategy in context: Environment, competitive strategy and manufacturing strategy. *Journal of Operations Management, 18,* 2 (2000), 123–138.

75. Wilding, R.D. The supply chain complexity triangle: Uncertainty generation in the supply chain. *International Journal of Physical Distribution & Logistics Management, 28,* 8 (1998), 599–616.

76. Williamson, O.E. *The Mechanisms of Governance.* New York: Oxford University Press, 1996.

77. Young-Ybarra, C., and Wiersema, M. Strategic flexibility in information technology alliances: The influence of transaction cost economics and social exchange theory. *Organization Science, 10,* 4 (1999), 439–459.

78. Zhang, Q.; Vonderembse, M.A.; and Lim, J.S. Manufacturing flexibility: Defining and analyzing relationships among competence, capability, and customer satisfaction. *Journal of Operations Management, 21,* 2 (2003), 173–191.