A framework for assessing value chain agility

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Abstract

Purpose – To gain understanding of value chain (VC) agility in terms of value-adding processes, this paper seeks to present a VC agility framework and then to develop the involved constructs.

Design/methodology/approach – A framework of VC agility and its theoretical underpinnings is presented. Within the framework, drivers and determinants of VC agility are identified as characteristics enabling flexibility within key components of a firm's VC. Also, it is posited that information technology (IT) capability impacts the levels of achieved flexibility and agility, and that VC agility impacts business performance.

Findings – From scale development, key determinants of flexibility within VC activities are identified. Correlation analysis suggests that firms derive higher levels of agility through integrating information across the VC rather than within VC activities. Firms with flexibility in their VC functions enjoy higher levels of ensuing VC agility and on-time delivery, ROA, and market share.

Research limitations/implications – While the sample size is adequate for scale development, it is not adequate for structural equation modeling since the guideline is to have at least five survey responses for every item measure. Thus, insights were gleaned from initial analysis based on correlations.

Practical implications – Managerial insights concerning key value-adding activities that build flexibility and ultimately agility are identified.

Originality/value – To the best of one's knowledge, this work is the first to operationalize VC agility from the perspective that agility is derived from flexibility in the VC processes and is enabled by IT integration. From exploratory research, insights are gained on how VC agility links with business performance.

Keywords Value chain, Flexibility, Agile production, Product development

Paper type Research paper

Introduction

In today's market, firms face stiffer competition due to international trade agreements and increased customer accessibility via the internet (Li and O'Brien, 1999). Moreover, firms face other challenges such as rapid technological advancement, reduced product lifecycles, and increased global market fragmentation. Since an agile organization is better equipped to thrive in a competitive and turbulent environment, agility has become a necessary component in an organization's competitive strategy (Yusuf *et al.*, 1999) and a vital element for addressing market turbulence (van Hoek *et al.*, 2001).

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Given the importance of agility, several definitions have emerged since the Iacocca Institute first associated agility with organizational abilities in manufacturing (Iacocca Institute, 1991). Sharifi and Zhang (1999) define agility as:

> ... the ability to cope with unexpected challenges, to survive unprecedented threats of business environment, and to take advantage of changes as opportunities.

While Kidd (2000) provides one of the most comprehensive definitions of organizational agility:

> An agile enterprise is a fast moving, adaptable and robust business. It is capable of rapid adaptation in response to unexpected and unpredicted changes and events, market opportunities, and customer requirements. Such a business is founded on processes and structures that facilitate speed, adaptation and robustness and that deliver a coordinated enterprise that is capable of achieving competitive performance in a highly dynamic and unpredictable business environment that is unsuited to current enterprise practices.

These definitions depict organizational agility as dynamic, context-specific, change-embracing, and growth-oriented (Goldman *et al.*, 1994). It is dynamic because the manner in which an organization achieves agility today may not be effective tomorrow. It is context-specific because the market environment influences the level of needed agility. It is change-embracing because it provides the impetus to adapt. Last, agility is growth-oriented through the organization's ability to re-conceive its vision, regenerate its strategies, and reinvent its techniques (Hamel and Prahalad, 1994).

Agility is derived from the three building blocks of relevancy, accommodation, and flexibility (Global Logistics Research Team, 1995). Relevancy is "the ability to maintain focus on the changing needs of customers," accommodation is "the ability to respond to unique customer requests," and flexibility, which will be discussed later, is "the ability to adapt to unexpected circumstances." Clearly, agility is a broad concept that draws upon many characteristics in a firm. In a manufacturing context, one component of organizational agility is agility within the value chain (VC) which involves the activities, "to design, produce, market, deliver, and support its products" (Porter, 1985). An organization with an agile VC can adapt its abilities to develop, produce, and deliver innovative products. Although previous research has addressed the general issue of organizational agility (Fliedner and Vokurka, 1997; Mason-Jones and Towill, 1999; Nagel and Bhargava, 1994), there is little understanding of agility in terms of the organization's value-adding processes. This poses the logical question, "What are the determinants and key drivers of VC agility?"

The need for an operations-based framework of VC agility from a theory-building perspective motivates the development of our VC agility model. Our notion of VC agility considers the speed with which a VC can improve its ability to support its competitive priorities. Since flexibility is inherently focused on the ability of each VC process to effectively adapt, we theorize that flexibility impacts VC agility which represents a comprehensive ability of the entire VC to rapidly adapt. In our framework, the drivers and determinants of VC agility are identified by examining characteristics of flexibility within four key components of a firm's VC: product development, procurement, manufacturing, and logistics. We also propose that information technology (IT) capabilities impact flexibility within the four VC components as well as overall VC agility. Our analysis using this model provides initial insights into value-adding processes to employ to attain and increase VC agility.

The next section presents our framework with its propositions. The third section presents the scale development followed by a discussion of the managerial insights and benefits of using this framework in future research.

Value chain agility framework

Gunasekaran's (1998, 1999) frameworks of manufacturing agility posit that agility is attained through strategies, technologies, systems, and people. While these frameworks provide insights, we believe a different topology is needed to understand VC agility in terms of its underpinnings on flexibility. This philosophy is reflected in recent frameworks of manufacturing flexibility (Koste and Malhotra, 2000) and VC flexibility (Zhang *et al.*, 2002), wherein the authors overlay their perspectives while linking existing theories to explain the drivers and determinants of flexibility. While Zhang *et al.*'s (2002) recent framework of VC flexibility focuses on the relationship between competence and capability within each VC activity, it does not address synergy among the flexibilities nor the link between VC flexibility and VC agility.

We propose a framework involving the drivers and determinants of VC agility and its impact on firm performance. Although Zhang *et al.* (2002) do not describe agility, it appears they treat flexibility and agility interchangeably. In contrast, we distinguish between flexibility and agility, and view flexibility as an antecedent to agility.

Agility and flexibility

It is important to discuss how our notion of VC agility brings more clarity to the distinction between agility and flexibility. Flexibility is, "the ability to change or react with little penalty in time, effort, cost or performance" (Upton, 1994) whereas agility is:

> . . . the ability to thrive and prosper in a competitive environment of continuous improvement and unanticipated change, to respond quickly to rapidly changing markets driven by customer-based valuing of products and services (Nagel and Bhargava, 1994).

One difference is that flexibility focuses on the ability to change while agility focuses on rapid response through reduced reaction time (Gunasekaran, 1998), Another difference is that agility is commonly associated with overall organizational abilities. For example, Goldman *et al.* (1994) discuss agility as a comprehensive system that involves all processes within a firm plus the firm's suppliers and customers. Within a firm, agility depends on the firm's abilities to integrate and position the aforementioned building blocks which include flexibility (Global Logistics Research Team, 1995). Flexibility, on the other hand, is commonly associated with operational abilities like those found in manufacturing (Gupta and Somers, 1992; D'Souza and Williams, 2000; Vokurka and O'Leary-Kelly, 2000; Koste and Malhotra, 2000). Applying the viewpoint that capabilities are derived from competencies (Prahalad and Hamel, 1990; Roth and Jackson, 1995; Teece *et al.*, 1997), we characterize agility as a capability and flexibility as a competency. Competencies are, "more localized production expertise, . . . that can be linked to a specific point in the VC" while capabilities are, "broad-based, heterogeneous factors critical to business success" (Roth and Jackson, 1995) that are achieved through the firm's abilities to integrate, build, and reconfigure its competencies (Teece *et al.*, 1997). Thus, agility is an overall organizational capability derived from the competency of flexibility within the lower level operational processes.

Conceptual framework of value chain agility

Within our VC agility framework (Figure 1), flexibility within product development, procurement, manufacturing, and distribution impacts VC agility, and ultimately performance. Each flexibility is derived from the dimensions of range and adaptability.

This framework focuses on intra-firm abilities of the strategic business unit (SBU) within a firm. Intra-firm abilities represent organizational abilities to manage internal relationships as well as external relationships with suppliers and logistic providers. From this viewpoint, VC agility does not explicitly include the abilities of external firms; instead it focuses on how effectively the organization manages relationships with external firms. This corresponds to the resource-based view of the firm, which

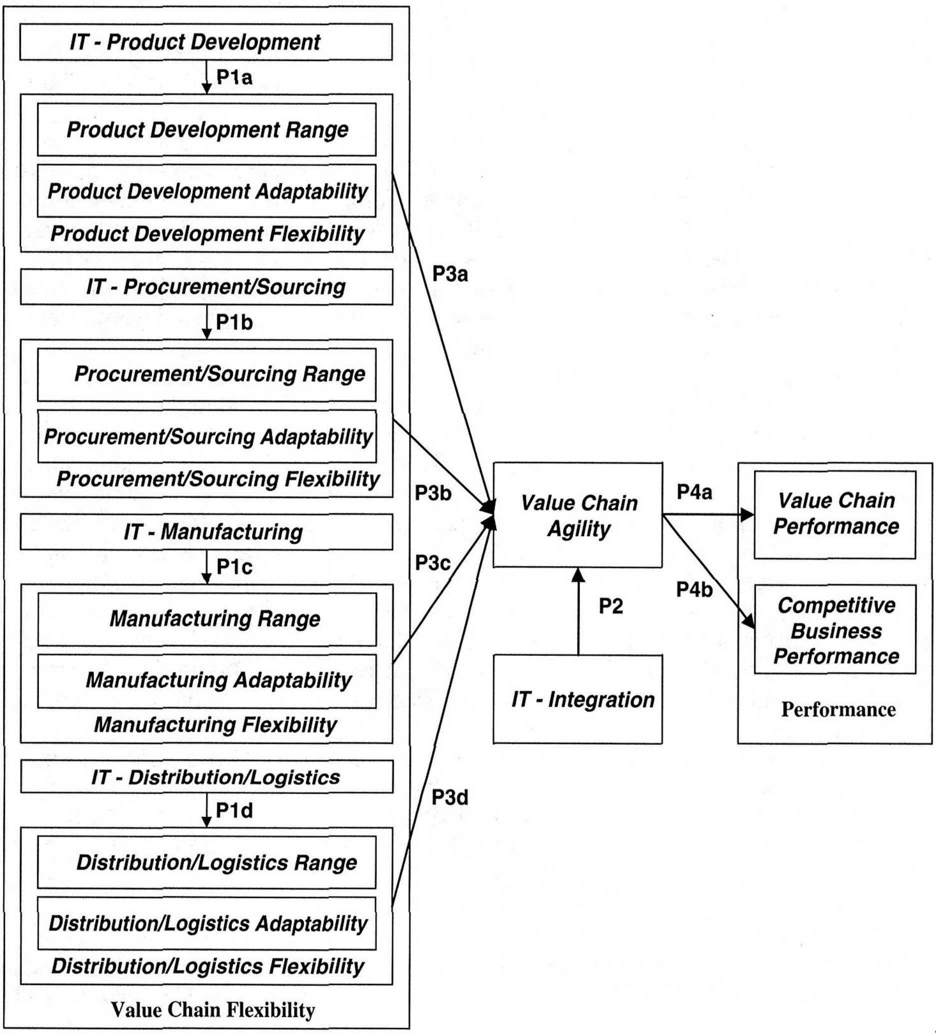

Figure 1.
VC agility framework

states that firms obtain a competitive advantage by focusing on strategies that better use their internal strengths and abilities (Barney, 1991).

Theoretical development

The VC agility framework presented is unified with existing theories on organization flexibility. The literature referenced is not exhaustive but does anchor our constructs and propositions. We begin by discussing the dimensions of flexibility then present each construct followed by our propositions.

Dimensions of flexibility

Most flexibility research focuses on manufacturing flexibility (Gerwin, 1987, 1993; Gupta and Goyal, 1989; DeToni and Tonchia, 1998; Vokurka and O'Leary-Kelly, 2000). While academics agree that flexibility is multi-dimensional, there are different views on its dimensions (Slack, 1983, 1987; Sethi and Sethi, 1990; Gupta and Somers, 1992; Upton, 1994; D'Souza and Williams, 2000). For example, Slack (1983) defines flexibility in terms of range, cost, and time while Upton (1994) defines flexibility in terms of range, mobility, and uniformity. Both have range representing the number of states a system can adopt, whereas Upton's (1994) concept of mobility represents the cost and/or time to move from one state to another. Upton (1994) adds the dimension of uniformity since his definition of flexibility includes the phrase, "ability to change or react with little penalty in... performance." Expanding on Upton's (1994) concept of "extent of differentiation," Koste and Malhotra (2000) divide range into the categories of range-number, representing the number of viable options, and range-heterogeneity, representing the difference between options.

While range-number and range-heterogeneity are approaches to measuring range, respondents might not reliably discern between the two. For example, Slack (1987) found that respondents had a difficult time identifying the number of available options, thus we treat range as a single dimension. Lastly, we use the term "adaptability" versus "mobility" to reflect the ability to change between a range of states while implicitly maintaining the desired level of performance. Thus, drawing upon Slack's (1983) approach, we measure flexibility using two dimensions, range and adaptability. We define range as the number of different states (levels, positions, or options) available to a firm without significant requirement of additional resources. This definition concurs with Slack (1983) and Upton (1994) with the added recognition that range can be altered by additional investment in resources. The gamut of options reflected by range within a firm may depict strategic or tactical choices within VC management.

Adaptability has been defined by Bordoloi *et al.* (1999) as, "the ability to change within a given state." For clarity, we define adaptability as the ability to change from one state to another state in a timely and cost effective manner. Since range and adaptability are co-determinants of flexibility, it follows that flexibility can be achieved through various combinations of both.

Value chain flexibilities

The first flexibility within the VC is product development. Rapid changes in technology, customer expectations, shrinking product lifecycles, and the push for increased product variety fuel the need for higher flexibility within product development. Product development flexibility provides the means to make design changes, improve products, and pursue a more effective development strategy (Thomke, 1997). The ability to reuse or adapt existing designs can significantly reduce development cycle time. This can increase the frequency of product introductions, which supports higher customer satisfaction and addresses issues caused by shrinking product lifecycles (Griffin, 1993).

Building on Thomke's (1997) definition of design flexibility, we define product development flexibility as the availability of a range of options and the ability to effectively exploit them to develop diverse products and/or product enhancements in response to customer or market requirements, or to exploit market opportunities. Modular and scaleable product design architecture, postponement of differentiation, platform-based designs, and product family-based designs can enhance product development flexibility (Griffin, 1993; Loch *et al.*, 1996; Thomke, 1997). For example, modular and platform-based designs reduce design complexity (Novak and Eppinger, 2001) thus allowing design changes to be localized to fewer modules (Thomke, 1997) and making shorter development times possible. Using platform-based designs to enable the introduction of as many as 20 different walkmans each year, Sony achieved a significant increase in market share (Sanderson and Uzumeri, 1995).

Procurement manages the purchasing and delivery of needed material while providing a crucial link between suppliers and internal activities such as logistics and product development. It follows that procurement is essential to integrating supplier and firm capabilities, and that the ability to integrate is impacted by abilities within the procurement group and existing supplier management policies (Tan *et al.*, 1996). Effective supplier relations also enable a firm to improve its responsiveness and customer satisfaction (Narasimhan and Das, 1999).

Using the literature, we define procurement/sourcing flexibility as the availability of a range of options and the ability of the purchasing function to effectively exploit them to respond to changing requirements for the supply of purchased components. To achieve procurement flexibility, the firm must understand its options for providing quality materials and services. However, having options is not enough, procurement must be able to exploit these options. Thus procurement flexibility is not only determined by flexibility in contracts with tier one suppliers but also by purchasing's ability to influence tier one supplier performance in areas of delivery frequency, delivery quantities, and lead time.

Manufacturing flexibility enables production to respond to variability in demand, product design changes, process technology, and disruption in material supply. We define manufacturing flexibility as the availability of a range of options and the ability of manufacturing to effectively exploit them to adapt its capabilities to produce quality products in response to changing product characteristics, material supply, and demand, or to employ technological process enhancements.

Manufacturing flexibility has been explained in terms of flexibility in the following forms: machine, labor, material handling, routing, operation, expansion, volume, mix, new product, market, and modification (Sethi and Sethi, 1990). Since this study is based at the SBU level, our constructs primarily represent flexibilities such as volume, modification, expansion, new product, and mix which are found at the plant level within the hierarchy of the flexibility dimensions (Koste and Malhotra, 2000). Volume flexibility enables an organization to manage a wider range of demand fluctuations while mix flexibility, which is related to volume flexibility, represents the number of products which can be produced (Gupta and Somers, 1992). In the hierarchy of manufacturing flexibilities, mix and volume flexibilities are partially derived from operation flexibility and labor flexibility (Koste and Malhotra, 2000) where operation flexibility is the number of different products that an operation can process (Sethi and Sethi, 1990).

Logistics is responsible for the delivery of products to customers, so it is vital to an organization's time-based competitive strategy (Fawcett and Clinton, 1996). To gain a competitive advantage through delivery, logistics must accommodate dynamic and diverse customer delivery requirements. Logistics serves customers throughout the VC, consequently changes in warehouse structure, distribution of products among warehouses, and transportation network may impact customer service (Kopczak, 1997). Drawing upon the definition of logistics from the council of logistics management, we define distribution/logistics flexibility as the availability of a range of options and the ability to effectively exploit them to adapt the process of controlling the flow and storage of materials, finished goods, services, and related information from origin to destination in response to changing marketplace conditions.

Logistics flexibility enables a firm to be more responsive to product delivery demands (Goldsborough, 1992). Logistics flexibility shares many similarities with different types of manufacturing flexibilities. At the aggregate level, logistics flexibility is analogous to material handling flexibility (Sethi and Sethi, 1990) which represents a material handling system's ability to move, position, and process different parts and assemblies through manufacturing. Logistics flexibility is partially achieved through multiple carrier relationships, which reduces the likelihood of late deliveries when the primary carrier cannot meet delivery requirements. Logistics flexibility range is determined by its options for storing and delivering products such as the number of delivery methods and delivery frequencies. The adaptability measures for logistics flexibility represent the ability to exercise the different logistics options within range. By supporting an assortment of delivery needs, logistics flexibility improves the organization's chances for a competitive edge (Sethi and Sethi, 1990).

Value chain agility

An agile organization must have structures and processes that enable rapid and fluid changes to provide customer-enriching business activities (Goldman *et al.*, 1994). Thus, we operationalize VC agility as the speed with which a VC can improve its competitive position with respect to cost, quality, flexibility, delivery speed, delivery reliability, and innovation. Since VC agility draws upon abilities within each of the VC operations, it is thereby influenced by flexibility within product development, procurement, manufacturing, and logistics, as well as the combinative effects that exist among these flexibilities. Capabilities are typically customer-facing (Stalk *et al.*, 1992; Zhang *et al.*, 2002), thus our measures of VC agility, shown in Table III, are linked to the ability to exploit VC flexibility to satisfy evolving customer expectations.

The first measure of VC agility is the speed at which a firm can reduce its product manufacturing lead time. Dell computers have demonstrated that shorter manufacturing lead times lead to higher customer service levels. So, agile firms are more likely to achieve shorter production cycle time between product conception and announcement (Goldman *et al.*, 1994). Our next measure is the speed to reduce product development cycle time. In turn, shorter product development cycle time supports more frequent product announcements, which enhances product variety. Since one objective of an agile organization is to enrich the customer (Goldman *et al.*, 1994), an agile firm must be able to quickly increase its level of customization and customer service while accommodating different delivery expectations. The speed with which a firm can improve its responsiveness to changing market needs is an aggregate measure of customer enrichment. Looking at these measures, VC agility is achieved through the synergies among the product development, procurement, manufacturing, and logistics processes.

Information technology capability

IT tools help an organization gather, store, access, and analyze information used to make strategic business decisions. IT can integrate and coordinate information within a functional area, across functional areas, and across organizational boundaries. Since IT can reduce the time needed to share information, it can reduce response time to unforeseen events, thereby impacting VC agility. The extent to which IT is used within the VC is a proxy for IT capability.

Several researchers have considered the nature and extent of IT use in an organization (Palvia, 1997; Powell and Dent-Micallef, 1997; Katayama and Bennett, 1999; Coranado *et al.*, 2002). Katayama and Bennett (1999) identify three activities within a manufacturing business unit that are related to agility – the use of CAD/CAE, the integration of information systems within manufacturing, and the integration of information systems across functional areas. A strong IT capability enhances an organization's ability to identify critical information and share it effectively. In this study, we broadly define IT capability as the extent to which IT systems and infrastructure are used in an organization's VC to adapt and support the changing requirements of the competitive marketplace. Since IT capability is broadly defined, our measures represent IT technologies within each of the VC functions and IT technologies that manage the entire VC and provide customer support.

Performance

Agility has been linked to competitive strategy (Goldman *et al.*, 1994), however, little is known about its impact on competitive performance. Thus, we include measures of VC performance and overall competitive business performance. Measures of an organization's VC performance must capture multiple attributes of the VC (Beamon, 1999; Gunasekaran *et al.*, 2001). Beamon (1999) classifies metrics of supply chain performance into resources, output, and flexibility categories where output performance reflects the firm's ability to provide high customer service levels. Customer service is impacted by output performance measures such as product availability and delivery performance. Also, measures such as on-time delivery, backorder level, percent of stockouts, and delivery lead time capture how effectively the VC delivers products. Other VC performance measures include manufacturing cycle time, capacity utilization, and time to market. Our VC performance construct reflects the effectiveness of the VC in development, production, and delivery.

Several measures of competitive business performance have been used in the literature to assess the impact of operational and strategic decisions on firm performance (Venkatraman, 1990; Husan and Nanda, 1995; Tan *et al.*, 1996; Gunasekaran *et al.*, 2001). Specifically, Venkatraman's (1990) profitability viewpoint advocates measures of competitive business performance such as ROA, operation income, cost per sales, and sales per number of employees. In addition, the literature advocates the use of profit margins, market share, and sales volume to reflect a firm's ability to compete for sales.

Development of propositions

As per Gunasekaran (1998), one category of technologies supporting agility is IT. Within our framework, IT impacts flexibility within the VC functions as well as VC agility. According to James (1999):

> IT not only enhances the ability of a multinational corporation to coordinate their intra-firm activities on a global scale, but it facilitates inter-firm network relationships of various kinds.

"Leveraging the impact of people and information" has also been identified as a dimension of agility (Goldman *et al.*, 1994). The effective use of IT to integrate information across functions enables an organization to leverage the synergies among these functions, therefore we view IT as an enabler (Gunasekaran, 1999) since IT provides a means to achieve agility and propose the following:

P1(a,b,c,d). IT capability within a VC function is a positive enabler of flexibility within the associated function.

P2. Integrative IT capability is a positive enabler of VC agility.

In environments where marketplace uncertainty is compounded by intense competition, the VC must possess flexibility within its value-adding processes of product development, procurement, manufacturing, and logistics; it must also be agile. From our prior discussion of VC agility, we state that agility is achieved through the synergies among these value-adding processes. For example, exhibiting product development flexibility through the use of modular or platform-based designs provides opportunities to tailor product variety and enables manufacturing to exhibit higher levels of manufacturing flexibility, thus yielding higher VC agility. Also, product development's use of postponement of differentiation provides options to delay product configuration decisions until later in the VC activities, possibly until the logistics function. Thus, product development flexibility is enabling the firm to provide more custom products by using logistics flexibility. Logistics flexibility can improve product delivery through processes that use inventory in alternate warehouses, distribution centers, and retail outlets. Lastly, manufacturing flexibility has also been linked to agility (Narasimhan and Das, 1999; Sharifi and Zhang, 1999; Yusuf *et al.*, 1999). To summarize, we view flexibility in the VC as an antecedent of VC agility and propose the following proposition:

P3(a,b,c,d). An organization's VC agility is positively impacted by flexibility within the four VC components of product development, procurement/sourcing, manufacturing and distribution/logistics.

Because flexibility positively impacts agility, which in turn positively impacts performance (Narasimhan and Das, 1999); agile VCs achieve higher performance than non-agile VCs. For example, an organization with higher levels of VC agility should have enhanced on-time delivery and time to market performance. It also gains a competitive advantage in fulfilling customer orders, thereby improving its competitive performance. Accordingly, financial and market performance improves as agility is achieved thus supporting our final propositions:

P4a. An organization's VC agility has a positive influence on its VC performance.

P4b. An organization's VC agility has a positive influence on its competitive business performance.

Scale development

Survey approach and sample statistics

This research relies on in-depth information about a firm's characteristics which is not publicly available via governmental agencies, thus we used a survey approach to gather data. Respondent's concerns of confidentiality often make it difficult to obtain quantitative data such as actual cost or time estimates, so we asked respondents to provide general descriptive information and answer questions using a five-point Likert scale (1 – low, 5 – high) based on abilities and performance of their SBU relative to their major competitors. While telephone and personal interviews can provide more complete and accurate information, they cost more (Forza, 2002) and require access to the respondents. Owing to the target sample size, the number of questions, and the cost involved in contacting respondents, we opted for mail surveys with prepaid postage return envelopes.

Survey development began with a review of the literature to identify appropriate item measures for each construct in our model. Using Dillman's (1978) approach for gathering survey data, we achieved a 20 percent (135 received/678 mailed) response rate. Respondents hold various upper and middle management positions in manufacturing firms in multiple industries (Table I). In this study, the unit of analysis is the SBU with those represented having an average employee base of 1,000-1,500 employees and average yearly sales from $250 to $500 million.

Using employee and sales information, *t*-tests were completed to assess non-response bias. Results yielded no significant difference, suggesting the absence of non-response bias. We also tested for significant differences between early respondents and late respondents, with late respondents being surrogates for non-respondents (Armstrong and Overton, 1977). Results indicate no difference between responses using five randomly selected survey items thereby supporting the absence of non-response bias. Thus, we conclude that non-response bias is not present and continued with our analysis.

SIC code	SIC description	Percentage of sample
23	Apparel and other finished products made from fabric	3.1
25	Furniture and fixtures	4.6
30	Rubber and miscellaneous plastic products	4.6
34	Fabricated metal products	7.6
35	Industrial and commercial machinery and computer equipment	25.2
36	Electronic and other electrical equipment and components	22.9
37	Transportation equipment	7.6
38	Measuring, analyzing, and controlling instruments	11.5
39	Miscellaneous manufacturing industries	13.0

Table I. Industry breakdown of sample by SIC code classification ($N = 135$)

Construct characteristics

Construct validity represents how well the item measures relate to each other with respect to a common concept, and is exhibited by the existence of significant factor loadings of measures on hypothesized constructs (Anderson and Gerbing, 1988). Each construct was individually assessed per Jöreskog and Sörbom's (1993) recommendation using confirmatory factor analysis. Item measures are shown in Tables II and III along with their standardized factor loadings and *t*-values. Only measures with significant factor loadings, *t*-values above 1.96 and factor loadings above 0.30, are retained with the exception being a manufacturing range measure, which was kept for content validity. Item measures without *t*-values were used to anchor the scale and discarded measures are indicated with an asterisk.

Reliability refers to the "consistency and stability of a measure" (O'Leary-Kelly and Vokurka, 1998) and is assessed using composite reliabilities instead of Cronbach α which assumes equal reliabilities among item measures leading to underestimation of construct reliability (Gerbing and Anderson, 1988). As indicated in Tables II and III, all composite reliabilities exceed Nunnally's (1967) recommended lower threshold of 0.60.

Goodness-of-fit criteria evaluate how well the data fits the proposed model (Schumacker and Lomax, 1996). In Table IV, we report the goodness-of-fit criteria of the measurement models for each construct. The root mean square error of approximation (RMSEA), χ^2-test, and the goodness-of-fit index (GFI) criteria measure how well the data fits the model. An insignificant χ^2-test indicates no difference between the observed and the estimated covariance matrices (Schumacker and Lomax, 1996). RMSEA values equal to 0.00 represent perfect fit while values less than 0.08 represent reasonable fit (Byrne, 1998). GFI values of 1 represent perfect fit while values greater than 0.90 represent acceptable fit (Schumacker and Lomax, 1996). The non-normed fit index (NNFI) and the comparative fit index (CFI) criteria compare the hypothesized model against the null model in which all correlations are set to zero. NNFI and CFI values greater than 0.90 indicate acceptable fit (Byrne, 1998), although values in the high 80s are indicative of reasonable fit. Overall, our constructs exhibit acceptable fit.

Managerial insights and conclusion

Managerial insights can be gained from the strength of the item measure loadings and the strength of correlations between the different constructs. Looking at product development flexibility in Table II, key determinants of range are the extent to which modular and platform-based designs are pursued whereas key determinants of adaptability are utilizing product differentiation and postponement strategies. Effective use of these strategies increases the available product selection options and enables the firm to support increased product variety. IT provides an important role in utilizing these strategies by assisting in the sharing of design information among the product design teams. Use of IT in product development correlates with product development range (Table IV); however, product development adaptability has an insignificant correlation with IT; thereby *P1a* is only marginally supported at best. Both product development range and adaptability have good correlations with VC agility thus supporting *P3a*.

In procurement flexibility, key determinants of range are the extent to which supplier capacity can be influenced and the extent of flexibility in supplier contracts while the key

Latent variable	Items	Completely standardized loadings	*t*-values
Procurement range (composite reliability = 0.644)			
	Extent to which supplier lead time can be expedited/changed	0.63	–
	Extent to which supplier short-term capacity can be influenced	0.83	3.69
	Number of suppliers actually selected per component on a global basis	0.36	3.36
	Extent of flexibility within supplier contracts	0.86	3.48
	[a]Range of supplier delivery frequencies, number of components purchased per supplier, range of possible order sizes from suppliers		
Procurement adaptability (composite reliability = 0.788)			
	Influence supplier's short-term capacity	0.44	–
	Change volume allocation among existing suppliers on a global basis	0.63	4.27
	Locate and procure services and products when required	0.53	3.92
	Change quantity of supplier's order	0.74	4.51
	Change delivery times of order placed with suppliers	0.75	4.52
	Influence supplier's ability to implement engineering change orders	0.60	4.16
	[a]Consolidate global demand for purchase orders, and change suppliers on a global scale when required		
Logistics range (composite reliability = 0.718)			
	Number of carriers used for each type of delivery mode, on average	0.34	–
	Number of items handled by each distribution facility, on average	0.72	3.46
	Number of worldwide storage/distribution facilities	0.34	2.64
	Number of items per order handled by each distribution facility, on average	0.79	3.50
	Number of customers supported by each distribution facility, on average	0.66	3.41
	[a]Number of customer delivery frequencies used and range of volume over which distribution can operate cost effectively		

(*continued*)

Table II. Range and flexibility constructs of the VC flexibility components

Latent variable	Items	Completely standardized loadings	*t*-values
Logistics adaptability (composite reliability = 0.764)			
	Fill customer orders from alternate global facilities	0.55	–
	Adjust worldwide storage capacity	0.74	5.31
	Adjust global delivery capacity	0.80	5.24
	Redistribute finished products among global storage facilities	0.57	5.7
	[a]Change delivery modes when necessary, adjust to different delivery requirements to meet customer delivery, and alter delivery schedules to meet changing customer requirements		
Manufacturing range (composite reliability = 0.617)			
	Range of products manufactured by your business unit	0.62	–
	Number of products that each manufacturing facility, on average, can produce	0.83	4.24
	Number of product changeovers per facility, on average, made each month	0.34	3.23
	Range of production capacity across which manufacturing can adjust	0.25	2.42
	Number of different tasks the typical worker can perform	0.37	3.48
	[a]Range of production volumes over which manufacturing can operate cost effectively and number of different manufacturing routings per product		
Manufacturing adaptability (composite reliability = 0.791)			
	Change production volume capacity when necessary	0.77	–
	Accommodate changes in production mix as required	0.77	7.81
	Implement engineering change orders in production	0.50	5.22
	Reduce manufacturing throughput times to satisfy customer delivery	0.67	6.97
	Adjust manufacturing process capabilities	0.43	4.5
	Rotate workers among different manufacturing tasks	0.56	5.87
	[a]Reallocate production product mix among global facilities		

(continued)

Table II.

Latent variable	Items	Completely standardized loadings	*t*-values
Product development range (composite reliability = 0.747)			
	Number of process technology options currently available in manufacturing to aid R&D	0.46	–
	Extent to which designs are modular	0.72	4.65
	Extent to which product platform development approach is pursued	0.84	5.03
	Extent to which product family-based development is pursued	0.63	4.37
	Number of product generations being simultaneously developed	0.35	3.2
	[a]Number of products, on average, in the development pipeline, extent to which product differentiation can be postponed in the bills of material structure, and extent to which product designs are scaleable		
Product development adaptability (composite reliability = 0.830)			
	Simultaneously design multiple products	0.44	–
	Design modular products	0.50	3.77
	Incorporate platform-based approach in R&D	0.63	4.20
	Reduce development cycle times when required	0.66	4.27
	Simultaneously perform product design activities	0.66	5.27
	Utilize product differentiation strategy during product development	0.78	4.49
	Utilize postponement strategy during product development	0.61	4.16
	[a]Incorporate scale-ability into product design		

Note: [a]Indicates items removed from scale

Table II.

determinants in adaptability are the abilities to change delivery quantities and implement design changes of purchased materials. Of interest is the lack of a significant correlation of either procurement range or adaptability with the use of IT to perform procurement activities, thus *P1b* is not supported. This could be the result of the IT applications represented in the IT construct. On the upside, both procurement flexibility dimensions strongly correlate with VC agility, thus supporting *P3b*. Of note are the positive correlations of procurement adaptability with on-time delivery and ROA. This concurs with results of prior studies (Tan *et al.*, 1996; Narasimhan *et al.*, 2001) that show

Latent variable	Items	Completely standardized loadings	t-values
VC agility (composite reliability = 0.791)			
	Reduce manufacturing lead time	0.66	–
	Reduce produce development cycle time	0.48	4.66
	Increase frequencies of new product introductions	0.36	3.59
	Increase level of customization	0.59	5.47
	Adjust worldwide delivery capacity/capability	0.44	4.24
	Improve level of customer service	0.58	5.31
	Improve delivery reliability	0.68	6.1
	Improve responsiveness to changing market needs	0.71	6.26
	[a]Reduce setup/changeover time, Increase production capacity, decrease ramp-up time for new products, and reduce delivery lead time		
IT in product development (composite reliatiliy = 0.692)			
	Use of internet technologies to access and manage product and process information during development	0.75	–
	Use of internet technologies to share CAD, CAE or other software design tools during development	0.69	5.12
	Use of project management software to manage product development	0.49	4.42
	Use of internet or B2B technologies to outsource product development activities	0.45	4.09
IT in purchasing (composite reliability = 0.783)			
	Use of internet exchanges, auctions, or B2B technologies used for material procurement	0.44	–
	Use of EDI, internet, or B2B technologies to manage purchasing transactions with suppliers	0.85	4.83
	Use of EDI or internet technologies to interface with worldwide suppliers	0.86	4.82
	Use of IT to coordinate and integrate activities in procurement and sourcing	0.56	4.19
IT in manufacturing (composite reliability = 0.765)			
	Use of ERP or manufacturing resource planning software for planning production activities	0.69	–

(continued)

Table III.
VC agility and IT constructs

Latent variable	Items	Completely standardized loadings	*t*-values
	Use of ERP or manufacturing execution software for managing production execution activities	0.77	10.8
	Use of IT to coordinate and integrate activities in manufacturing	0.82	5.36
	Use of internet or B2B technologies for outsourcing manufacturing activities	0.38	3.70
	Use of ERP for coordinating production activities in different countries	0.43	4.14
IT in logistics (composite reliability = 0.776)			
	Use of internet or B2B for locating and managing logistics related activities	0.56	–
	Use of information of internet technologies to track worldwide inventory and material movement of finished products	0.77	6.14
	Use of inventory management software to manage worldwide finished products inventory	0.77	6.15
	Use of IT to support exchange of information among global distribution centers	0.79	6.22
	Use of IT to manage transportation and distribution activities	0.67	5.65
IT for SBU integration (composite reliability = 0.848)			
	Use of ERP or supply chain planning software to manage/coordinate global supply chain activities	0.50	–
	Use of internet or B2B to coordinate with other businesses to manage the value supply chain	0.60	4.92
	Use of IT infrastructure to provide a competitive advantage	0.75	5.51
	Use of IT infrastructure to identify global market trends for finished products	0.71	5.35
	Use of IT infrastructure as a key enabler to integrate all activities of the supply chain	0.86	5.79
	Use of IT infrastructure as a key enabler of communication across all functions, departments, and divisions interfacing with it supply chain	0.72	5.4

Note: [a]Indicates items removed from scale

Table III.

Table IV.
Goodness-of-fit for measurement models

Construct	RMSEA[a]	Standardized RMR[b]	GFI[c]	NNFI[d]	CFI[e]
Product development range	0.059	0.034	0.983	0.964	0.986
Product development adaptability	0.048	0.040	0.967	0.975	0.986
Procurement range	0.000	0.002	1.000	1.019	1.000
Procurement adaptability	0.078	0.048	0.961	0.941	0.964
Manufacturing range	0.092	0.058	0.914	0.827	0.969
Manufacturing adaptability	0.079	0.047	0.960	0.930	0.958
Logistics range	0.046	0.052	0.981	0.975	0.988
Logistics adaptability	0.000	0.004	1.000	1.038	1.000
VC agility	0.025	0.039	0.965	0.992	0.995
IT – product development	0.041	0.028	0.991	0.979	0.993
IT – purchasing	0.290	0.028	0.992	0.996	0.999
IT – manufacturing	0.126	0.063	0.964	0.894	0.957
IT – logistics	0.051	0.029	0.980	0.99	0.980
IT – SBU integration	0.000	0.035	0.978	0.986	0.987

Notes: [a]Prefer <0.05; [b]prefer <0.05; [c]prefer >0.90; [d] prefer >0.90; [e]prefer >0.95

firms, which tap into suppliers' abilities achieve higher customer service levels. Firms seeking higher levels of flexibility should choose suppliers who can adapt with the firm, and not choose suppliers based on cost. While increased outsourcing does reduce complexity of a firm's internal supply chain (Vachon and Klassen, 2002), it is important to wisely select and manage supplier relationships in order to reap benefits of improved delivery performance (Table V).

For manufacturing to benefit from procurement flexibility, it must be able to adapt product mix, introduce new products, and incorporate design changes to meet customer demands. We believe capacity change is an important measure even though the ability to change capacity is not a statistically significant measure of manufacturing flexibility. One possible explanation for this result is that firms in our response pool may focus more on flexibility, as it pertains to product variety, not capacity. Based on insignificant correlations, there is no support for *P1c* which proposed that manufacturing is enabled by the use of IT. There is support for *P3c* based on the significant correlations of manufacturing range and adaptability with VC agility. Moreover, we found that manufacturing range has a negative relationship with time to market. One possible reason is that the range of manufacturing options can be broad that it may actually increase time to market. However, there is a positive correlation between manufacturing adaptability and ROA.

The number of items per distribution center and the number of items per customer order are prominent determinants of logistics range. Within logistics adaptability, key abilities are being able to change distribution capacity and redistribute finished products among global storage facilities. Here, we find support for *P1d* that using IT enables firms to achieve higher logistics flexibility according to the strong correlations of range and adaptability with IT in logistics. Also, the correlations provide support for *P3d* that logistics flexibility does positively influence VC agility. While logistics adaptability correlates with profit margin, it has a lackluster correlation with on-time delivery. One explanation of this counterintuitive result is that logistics adaptability measures capture the ability to move product among distribution centers which may

Construct	Number of Items	Mean	Standard Deviation	Procurement Range	Procurement Adaptability	Logistics Range	Logistics Adaptability	Manufacturing Range	Manufacturing Adaptability	Product Development Range	Product Development Adaptability	Value Chain Agility	IT - Product Development	IT - Procurement	IT - Manufacturing	IT - Logistics	IT - Corporate
Procurement Range	4	7.803	1.780														
Procurement Adaptability	6	11.744	2.000	.336 ***													
Logistics Range	5	9.020	2.389	.119	.054												
Logistics Adaptability	4	6.886	1.834	.181 **	.255 ***	.120											
Manufacturing Range	6	8.654	1.592	.075	.175 **	.228 ***	.124										
Manufacturing Adaptability	6	11.144	2.158	.197 **	.474 ***	-.017	.308 ***	.373 ***									
Product Development Range	5	9.424	2.123	.157 *	.071	.100	.229 ***	-.048	-.031								
Product Development Adaptability	7	12.380	2.153	.185 **	.167 *	.152 *	.044	.089	.214 **	.222 ***							
Value Chain Agility	8	11.195	2.378	.392 ***	.307 ***	.088	.299 ***	.209 **	.398 ***	.200 **	.269 ***						
IT - Product Development	4	7.123	2.008	.139	.083	.049	.132	-0.002	.126	.449 ***	-.043	.081					
IT - Procurement	4	7.213	2.517	.119	.127	.106	.180 **	.039	.151 *	.365 ***	.060	.122	.469 ***				
IT - Manufacturing	5	9.121	2.785	.184 **	.154 *	.100	.160 *	.058	.120	.242 ***	.236 ***	.044	.318 ***	.461 ***			
IT - Logistics	5	9.210	3.413	.197 **	.087	.173 **	.157 *	.069	.047	.243 ***	.124	.097	.052	.306 ***	.523 ***		
IT - Corporate	6	9.784	3.430	.247 ***	.129	.166 *	.236 ***	.073	.069	.309 ***	.061	.151 *	.274 ***	.509 ***	.624 ***	.716 ***	
On-time delivery	1	3.826	0.900	.089	.173 **	-.072	.161 *	.032	.184 **	.098	.107	.288 ***	.035	.191 **	.081	.093	.169
Delivery leadtime [a]	1	2.732	1.100	-.010	-.029	-.123	-.003	-.034	.084	-.077	-.012	-.071	.030	-.099	.022	-.128	-.027
Time to market (concept to launch) a	1	3.017	0.917	-.093	.042	-.006	-.035	-.199 **	.023	.021	-.015	-.195 **	-.059	.037	.102	.123	.075
ROA	1	3.192	0.966	.046	.243 ***	.073	.096	.026	.193 **	.190 **	.129	.195 **	.120	.094	.093	.250 ***	.174 **
Global market share	1	3.041	1.216	.034	.035	.110	.029	.039	.044	.208 **	.065	.131	.086	.191 **	.127	.315 ***	.278 ***
Profit margins (%)	1	3.220	0.998	-.160	.107	-.019	.188 **	.029	.082	.082	.034	.103	.030	.003	-.022	.114	.047

a: reverse coded item measures

*** significant at .01 level

** significant at .05 level

* significant at .10 level

Table V.
Correlation table

increase delivery time but be effective in moving product to regions with larger product demand.

Statistically significant correlations among the range and adaptability dimensions of flexibility within the VC functions indicate that synergy exists. Procurement flexibility enables a firm to utilize its manufacturing flexibility, take actions to procure components for new products, and incorporate design changes into purchased material. A possible reason that procurement relates negatively to logistics while relating positively to manufacturing and product development is that product development and manufacturing flexibility rely on a supplier's technology base and responsive delivery abilities, whereas logistics flexibility does not. The strong correlations among the range and adaptability constructs support our view that firms should equally focus on developing both range of options and adaptability. Overall there is support for *P3* given that VC agility is positively correlating with all flexibility constructs except for logistics range. Based on these results, achieving VC agility relies on the integrative nature of the VC functions.

Primary determinants of VC agility are the speed to improve delivery reliability and responsiveness to changing market needs. These relate to the speed of reducing manufacturing lead time, which is another key measure. While VC agility correlates positively with on-time delivery and ROA, it negatively correlates with time to market. Possibly, firms within our respondent pool place more emphasis on existing product delivery versus new product development. Overall, the correlations provide some support for *P4a* and *P4b*. Nevertheless, it is clear that future research is needed to truly understand VC agility's impact on VC performance and business performance.

Looking at IT, we see that the primary IT ability in product development is to employ internet technologies to access and manage product and process information. The ability to use internet technologies to share CAD, CAE and other software design tools runs a close second. Within purchasing, primary IT applications include the use of EDI, the internet, and B2B technologies for interfacing with suppliers. Within manufacturing, the use of IT and ERP to coordinate and manage production activities are important. Within logistics, inventory management and information exchange among distribution centers are key IT tasks. Lastly, the primary determinant of IT usage at the corporate level is using IT as an enabler for integrating activities within the organization's VC. While we posit that IT enables a firm to achieve flexibility, weak correlations exist. However, there are significant correlations between IT at the corporate level and VC agility thus supporting *P2* and indicating that firms derive higher levels of VC agility through integrating information across the VC activities rather than integrating information within these activities.

In closing, this paper has proposed a framework for understanding VC agility and developed a construct of VC agility. We have also further clarified the distinction between flexibility and agility. Our research indicates that VC agility is influenced by flexibility in the VC and that it impacts VC performance and business performance. We have also examined the role of IT in enabling agility in the VC. To the best of our knowledge, this study is the first to operationalize VC agility and theorize that VC agility is influenced by flexibility in the VC and enabled by IT integration.

While this analysis has provided initial insights, more research is needed to understand the strength of the relationships among the constructs within the VC agility model. For example, would this framework differ between firms producing standard products versus firms providing custom products and if so, how? These answers would guide firms with different customization strategies to tailor their approach to achieving VC agility. Another question that needs to be addressed is, "How does the level of competition impact the needed level of VC agility?" This study has presented measures of logistics flexibility, but more research is needed to further develop the construct of logistic flexibility for subsequent study of its role in a firm's competitive strategy. It is our hope that this paper provides exploratory insights concerning VC agility and aids in future research on agility.

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