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On Theory in Supply Chain Uncertainty and its Implications for Supply Chain Integration

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Abstract

This paper develops a theoretical conceptualization of supply chain uncertainty, based on the foundation provided by contingency theory, classical organization theory and information processing theory. We develop a theoretical analogy between a supply chain and an organization, then highlight key differences, which leads us to hypothesize that there are three key types of supply chain uncertainty. Micro-level uncertainty is based on the variability of inputs to the technical core of a supply chain, corresponding to the traditional operationalization of uncertainty in the supply chain and operations management literature. Meso-level uncertainty is the lack of information needed by a supply chain member, corresponding to the information processing theory perspective. This is often due the conflicting pressures of differentiation and interdependence in a supply chain, where members may withhold information that they feel could compromise their interests. Macro-level uncertainty, based on the equivocality construct, is related to unclear and ambiguous situations faced by supply chain members in rapidly changing external environments. We propose that all three types of uncertainty coexist in a supply chain and may interact with each other. Based on contingency theory's focus on alignment of process and structure with the environment, we test the relationship between supply chain integration (process), centralization, formalization and flatness (organization structure) and the dimensions of uncertainty (environment). Hypotheses are tested using hierarchical regression on data collected from 339 globally distributed manufacturing plants. It reveals that, as hypothesized, micro-level and meso-level uncertainty are positively related to SCI and that macro-level uncertainty is inversely related to it. The organization structure variables of centralization and formalization had a moderating effect, strengthening or reducing the main effects of uncertainty. The results are discussed in terms of their consistency with the theoretical foundation, implications for decision makers facing supply chain uncertainty and future research opportunities.

Keywords: *uncertainty; supply chain integration; information processing theory; contingency theory; organization theory; factor analysis; hierarchical regression analysis*

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INTRODUCTION

Uncertainty is ubiquitous in supply chains. Some originates under a supply chain member's own roof, due to inter-functional inconsistencies in material quality levels or delivery dates, and external sources of uncertainty relate to variability in the quality and timing of incoming materials or in the quantities customers demand. A member of a supply chain also faces uncertainty when it lacks information that it needs from its customers and suppliers, because they withhold information they feel is not in their best interest to share. As it enters new markets, faces competitive turbulence or is surprised by a low probability-high impact event, such as a natural disaster, a supply chain member may also find that some uncertainty is so inordinate that its decision makers do not have an appropriate behavioral response residing in their repertoire and struggle with even conceptualizing what the right questions to ask are. In essence, uncertainty can manifest itself in different forms, including variability, lack of information and or ambiguity.

Although uncertainty has been widely studied in the organization theory literature, beginning with the seminal work of Thompson (1967), it has only recently become a subject of empirical inquiry in the context of supply chain management (e.g., Hult, et al., 2010; Bode, et al., 2011). Though the organizational theory literature acknowledges that it can assume different forms, uncertainty has been largely defined as variability, in the supply chain management literature (Fredendall & Melnyk, 1995; Germain, et al., 2008). Supply chain uncertainty can exist at multiple levels, including individual decision makers, functional departments, organizations and ultimately, supply chains (Carter, et al., 2015a). Furthermore, supply chain integration is sometimes prescribed as a response to uncertainty, without accounting for the differing demands engendered by different forms of uncertainty. Consequently, our understanding of uncertainty in the domain of supply chain management is still incomplete and some conflicting results remain unexplained. We attempt to shed light in two ways. First, we view supply chains through the lens of Thompson's (1967) conception of organizations, adding several key ways in which supply chains depart from it. Second, we synthesize the supply chain management and organization theory literatures to propose three different types of supply chain uncertainty, based on complexity and dynamism. Micro-level uncertainty deals with information that is predictable within a distribution, such as variability of customer demand. Meso-level uncertainty focuses on the need for information that is unavailable, while macro-level uncertainty exists in ambiguous, ill-structured contexts, where decision makers cannot even formulate appropriate questions to ask.

Building on contingency theory's contention that an organization's processes should align with its environment, we examine supply chain integration (SCI) as a response to uncertainty. SCI is characterized by both inter-organizational information flows and rich informal information sharing mechanisms that help supply chain members cope with uncertainty. We specifically examine the association of internal, customer and supplier integration with micro-level, meso-level and macro-level uncertainty. Because supply chain members simultaneously experience a combination of all three types of uncertainty, we also examine whether their interaction explains differing levels of SCI.

However, the effects of uncertainty do not exist in isolation. When a supply chain member faces uncertainty, its reliance on SCI may be lessened or amplified depending on its organization structure, consistent with contingency theory's focus on the fit between structure, processes and environment. Centralization, formalization and flatness may interact with types of uncertainty, such that they support or hinder SCI. We examine the alignment between types of uncertainty and organization structure with SCI, using survey data from 339 globally distributed manufacturing plants.

Our findings contribute to the uncertainty literature by extending it to a supply chain context as three distinct types, providing a foundation for alignment of processes with different types of uncertainty. It contributes to the SCI literature via linking it with the organization theory and organizational communications literature (Lengel & Daft, 1988). We begin by discussing the organizational theory literature as it relates to organizations and uncertainty. We discuss SCI as a response to some types of uncertainty, subject to organization structure. Hypotheses are tested using hierarchical regression, and the findings are interpreted in light of theoretical and managerial implications.

LITERATURE REVIEW

Supply Chain as an Organization

We build on classic organization theory concepts that are suited to describing supply chains, while highlighting unique features of supply chains that lead to challenges associated with supply chain uncertainty. A complex organization, which we henceforth refer to as an "organization," is a set of interdependent elements that comprise a whole, which each contributes something to and receives something from, in return. The whole is interdependent with its environment, both contributing to it and receiving from it. Its elements, such as functional departments, are dedicated to specialized tasks (Tushman & Nadler, 1978), determined through evolutionary processes. Homeostasis (Thompson, 1967) keeps the system viable, in the face of disturbances from its external environment; a dysfunctional element will either adjust to make a positive contribution or disengage from the organization. A supply chain can be viewed as an organization, as its members contribute goods and services to it and receive revenue, in return

(Carter et al., 2015a). A member of a supply chain is analogous to a functional department (Dunning, 1995; Hult, et al., 2004), in that it is focused on a single task within a specific supply chain. Supply chain members are regulated through an evolutionary process, governed by homeostasis; if there is a dysfunctional situation, the offending member either makes adjustments or terminates its membership.

In a key difference, however, supply chain members face substantial competing pressures exerted by their simultaneous interdependence and differentiation. They are in a reciprocal interdependence relationship (Thompson, 1967), where the outputs of one member are inputs for others, and they share resources. However, because each supply chain member is an independent firm that acts in its own interests (Ireland & Webb, 2007; Hult, et al, 2007), it is differentiated from other members, which are inherently dissimilar in structure, internal culture, resources and motivation for supply chain membership (Ireland & Webb, 2007). This mixed-motive nature of supply chain relationships (Hult, et al., 2010) provides unique challenges for dealing with supply chain uncertainty, where an event that amounts to an opportunity for one member may be a threat for another (Gioia & Thomas, 1996).

What makes this especially challenging is that supply chain membership is part-time (Hult, et al., 2004); members almost always simultaneously belong to more than one supply chain. While strong culture and common affiliation can create identity and loyalty among elements of an organization (Gioia & Thomas, 1996), supply chain members' primary loyalty resides with their own firm or adjacent supply chain members (Hult, et al., 2004). Whereas an organization's culture consists of rich sets of norms, values, rituals and beliefs, a supply chain's culture is more narrowly focused on serving its market (Hult, et al., 2007). Also, unlike an organization, a supply chain lacks a top management team, which can strongly influence the development of shared meaning in an organization (Gioia & Thomas, 1996).

Uncertainty in Supply Chains

Uncertainty is a central concept of contingency theory (Downey & Slocum, 1975), which specifies that an organization's performance is contingent on the fit between its structure, processes and environment (Lawrence & Lorsch, 1967). Its task environment contains elements that are relevant to goal attainment, including customers, suppliers, competitors and regulatory agencies. Its pluralism requires exchange with other elements, where each is involved in its own network of interdependence, with its own domain and environment.

Downey and Slocum (1975) describe four sources of uncertainty: physical manifestations, perceptions, behavioral response repertoire and social expectations. Thus, they describe uncertainty as a multilevel phenomenon (Carter, 2015a), existing at individual, group, functional and organizational levels. Physical manifestations include technical and organizational rationality. Technical rationality is the technical core of processes that are used to accomplish desired results, and organizational rationality includes the inputs taken for granted by the core technology and the disposition of its outputs (Thompson, 1967). Environmental fluctuations are exogenous factors (Hult, et al., 2010) that can penetrate the technical core (Thompson, 1967). If they are anticipated, they can be treated as constraints and adapted to. Unanticipated environmental fluctuations, however, interfere with the performance of the technical core. They are inherent in supply chains' reciprocal interdependence, whose flow of goods and information involves multiple lines of communication and tasks across firms (Miller, 1987). The number of members and their interconnectedness (Wu & Pagell, 2011) determine a supply chain's complexity. Because a supply chain member's need for scarce resources creates dependence on other members, whose goals are different than its own, interdependence is a potential source of uncertainty (Pfeffer & Salancik, 1978; Bode, et al., 2011), as a supply chain member poses a contingency for the others (Thompson, 1967). In making adjustments, other supply chain members can either show goodwill or select a more self-interested response that stems from their differentiation (Ireland & Webb, 2007). Thus, reciprocal interdependence contributes to physical manifestations of supply chain uncertainty.

The physical manifestations of uncertainty are modified by individual decision makers' perceptions (Downey, et al., 1975), as they organize and evaluate stimuli (Downey & Slocum, 1975), in order to give them informational value. Perception is a selective, interpretive process, due to the environment's lack of inherent meaning and humans' finite information processing capacity; "man cannot interact directly with his environment; instead, he must map it (Downey & Slocum, 1975, p. 571)." A complex, dynamic environment requires a high degree of abstraction, in order to produce manageable mappings. Thus, a decision maker's mapping is incomplete, with potential for distorted information that precludes testing of cognitive maps, which increases perceptions of uncertainty (Downey, et al., 1975). Individuals with a higher tolerance for ambiguity (Duncan, 1972) may perceive situations as less uncertain than those with lower tolerance (Downey & Slocum, 1975), based on their perception of the complexity and dynamism of the task environment and their personal ability to cope with ambiguity.

The third source of uncertainty pertains to individual decision makers' behavioral response repertoire, which is their capacity to display appropriate responses to a given set of environmental characteristics (Downey & Slocum, 1975). It is enlarged or diminished by the decision maker's prior experience (Bode, et al., 2011), as interactions provide opportunities to acquire skills, data and attitudes that increase the probability of an appropriate behavioral response to a specific environment. It evolves through learned preferences for parameters that elicit responses (Bode, et al., 2011), in light of knowledge and familiarity with the supply chain process (Hult, et al., 2004). Finally, social expectations contribute to supply chain uncertainty. This is related to the role of a supply chain member (Hult, et al., 2010; Downey & Slocum, 1975). For example, supply chain uncertainty may be perceived differently by a raw materials supplier vis-à-vis a logistics services provider in the same supply chain.

Thus, we view supply chain uncertainty as a multilevel phenomenon. Physical manifestations of uncertainty resulting from complexity and dynamism of the supply chain environment are modified by individual decision makers' perceptions and social expectations associated with supply chain roles. This is translated into a cognitive map, which is the basis for a behavioral response repertoire. In a supply chain, we propose that this results in three distinct types of uncertainty: micro-level uncertainty, meso-level uncertainty and macro-level uncertainty, whose characteristics are summarized in Tables 1 and 2.

--Insert Tables 1 & 2 Approximately Here--

Micro-Level Uncertainty. Micro-level supply chain uncertainty exists in repetitive processes in task environments characterized by lower complexity and dynamism. It is based on "uncertainty of material flows and information flows in the deviation from a scheduled or planned state, in terms of both times and quantity (Sivadasan, et al., 2002, p. 81)." The wider the dispersion of observations around the mean, the greater the variance (Miller, 1992; Van Langedehem & Vanmaele, 2002; Peck, 2006), which reduces a decision maker's certainty that the actual value will be close to the mean (Melnyk et al., 1992; Fredendall & Melnyk, 1995). Micro-level uncertainty has its roots in decision theory, with its "'focus' on the mathematical aspects of uncertainty, such as an individual's ability or inability to assign probabilities to events

(Duncan, 1972, p. 317)." This viewpoint is dominant in the finance and risk management literatures (Cheng et al., 2012). Micro-level uncertainty can be measured (Tan et al., 2014) based on "the uniformity and timeless consistency of nature" (Davidson, 1991, p. 135). It is primarily rooted in task characteristics that differ in execution predictability (Tushman & Nadler, 1978), due to inconsistency in the flow of goods into, through and out of a supply chain member (Germain, et al., 2008), where

> …uncertainty rules … sales deviate from forecast. Components are damaged in transit. Fabrication yields fail to meet a plan. Shipments are held up in suppliers. In truth, schedule execution is just a roll of the dice (Geary, et al., 2002, p. 52).

Micro-level uncertainty can have serious supply chain implications because of demand amplification and bracing behavior. Demand amplification occurs when small disturbances in demand increase as they transfer along a supply chain (Van Landeghem & Vanmaele, 2002). Depending on individual decision makers' perceptions of it, through their tolerance for uncertainty and prior experiences, bracing behavior (Tokar, et al., 2014) may be elicited from their behavioral response repertoires. Decision makers brace for a loss by anticipating that an event will have an adverse outcome (Sweeney & Shepperd, 2007), which they react to by overcompensating (Tokar, et al., 2014; Luce & Raiffa, 1957), as illustrated by the bullwhip effect (Lee et al., 1997). The bullwhip effect is especially potent due to its cumulative nature, as micro-level uncertainty is amplified by bracing as it moves through interdependent supply chain members.

***Meso-Level Uncertainty*.** Concerns have been raised about the narrowness of defining uncertainty solely as variability because

> volatility indices … implicitly assume uncertainty to be an environmental trait that can be 'objectively' measured. If uncertainty were defined as a perceptual quality, … the volatility of … activities would not adequately provide a … measure of uncertainty. High coefficients of variability do not necessarily indicate

> that the firm cannot predict its future performance (Downey & Slocum, 1975, p. 565).

The need for information increases as supply chain complexity increases (Leuschner, et al., 2013; Sivadasan, et al., 2002). Meso-level uncertainty arises from differentiated supply chain members, who may withhold information (Rabinovich, et al., 2007; Shrivastava & Mitroff, 1984), in their own self-interest. However, because of their interdependence, members require continuous information distribution (Hult, et. al, 2004). Thus, we define meso-level supply chain uncertainty as the difference between the amount of information needed by a supply chain member and the amount already possessed, based on information processing theory (Galbraith, 1973, 1977). Accurate and timely supply chain information can prevent lost sales, speed up payment cycles, prevent overproduction and reduce inventories (Stevenson & Spring, 2007). Thus, meso-level uncertainty is "a counterpart to information" (Downey & Slocum, 1975). Meso-level uncertainty is common in supply chains. For example, decision makers rarely have complete demand information when making inventory decisions (Tokar, et al., 2014), and assessing potential suppliers is routinely done with incomplete information (Wu & Barnes, 2012). Factors important to meso-level uncertainty include the ability to acquire appropriate information, transmit it in a timely fashion, convey it without distortion and handle appropriate quantities of information (Tushman & Nadler, 1978). Each of these is detailed in a supply chain context below.

The importance of acquiring appropriate information is self-evident; collection of appropriate information about customer demand, sales forecasts, order status, inventory levels, capacity availability, lead times and quality (Stevenson & Spring, 2007) is critical to the effective functioning of a supply chain. Croson and Donahue (2002) found that point-of-sales data benefitted upstream supply chain members, Rabinovich, et al. (2006) observed that demand information could substitute for inventory and Wu and Pagel (2011) describe the importance of complete information in evaluating the environmental impact of a supply chain.

Timely information dissemination affects a supply chain's ability to cope with uncertainty (Bode, et al., 2011); faster transmission is better for supply chain members in satisfying both their own differentiated goals and the supply chain's interdependent goals. For example, Bourland, et al. (1996) found that faster access to demand information improved suppliers' fill rates. However, there may also be benefits associated with deferring information acquisition (Fisher, 1997), in order to improve its accuracy (Boone, et al., 2007). For example, postponement defers final production until more accurate demand information is available (Fisher, et al., 1994; Van Hoek, 2001).

It is also important that information is transmitted without distortion, which is especially important with differentiated supply chain members. A substantial amount of information transfer is only partial, including historical information, forecasts, and vague impressions (de Treville, et al., 2004). The bullwhip effect (Lee et al., 1997), illustrates the distortion of demand signals caused by the use of inventory to compensate for meso-level uncertainty about peak demand. Their differentiated goals cause supply chain members to myopically order quantities that are locally optimal, without considering the effect on other supply chain members. If the needed demand information was available, meso-level uncertainty would be lower and members would feel less compelled to hoard.

Finally, it is important that information is delivered in the germane quantity. When the nature of a supply chain member's work is highly certain, its processing requirements are relatively small (Tushman & Nadler, 1975; Galbraith, 1977). It is important that needed information is delivered in a factual manner, without contamination by opinion, elaboration or debate (Tushman & Nadler, 1978). Thus, there is a curvilinear relationship between information quantity and outcomes (Hult, et al., 2004); after an inflection point, additional information can be overwhelming (Huber, 1991; Lengel & Daft, 1988).

Macro-Level Uncertainty. Macro-level supply chain uncertainty is associated with a complex, dynamic context featuring situations that are ambiguous and ill-structured, such as when there are sudden shifts in customer demand or when an organization encounters a natural disaster. Based on Weick's (1979) equivocality construct, macro-level uncertainty exists when it is difficult to even know the type of information that is needed, where data are unclear or suggest multiple interpretations of the environment (Daft & Weick, 1984). A highly equivocal environment is characterized by confusion, vague cues and lack of understanding (Daft & Lengel, 1986; Weick, 1979; Daft et al., 1987), which translates into poor perceptual mapping. Macro-level uncertainty is especially high when managers' frames of reference differ (Daft et al., 1987), such as between supply chain members.

Changes in economic conditions, market turbulence, competitive intensity and technological turbulence (Beckman, et al., 2004; Germain, et al; 2008) are some of the primary sources of macro-level uncertainty. They can be difficult to anticipate and understand, yet have a profound impact on supply chain operations. Low probability, high impact events (Hora & Klassen, 2013), such as natural disasters, wars, terrorist acts and accidents (Kauppi, 2012), also illustrate macro-level uncertainty. In both cases, their infrequent occurrence limits opportunities for experiential learning and map development. Decision makers facing a substantial volume of information apply simplifying heuristics, due to their bounded rationality (Simon, 1957; Thompson, 1967), replacing the maximum efficiency criterion with a satisficing criterion (Tiwana, et al., 2007). The search process is terminated once the "good enough" level is reached, based on heuristics that simplify cognitive decision making by focusing on a few salient cues to form heuristic-driven judgments (Tversky & Kahneman, 1974; Feldman & Lynch, 1988).

Supply Chain Integration

Supply chain integration (SCI) is defined as the scope and strength of linkages of supply chain processes across organizations (Leuschner, et al., 2013). It is facilitated by information, operational and relational integration. SCI can be an effective behavioral response to some types of uncertainty, by facilitating lateral relations that aid collaborating, coordinating and controlling materials and information (Koufteros et al., 2014; Wong et al., 2015) between members of a supply chain to develop the capability to respond to rapidly changing conditions (Wu and Barnes, 2012). It has three dimensions: internal integration, customer integration and supplier integration. Internal integration involves interaction and collaboration that link a plant's internal functions into a cohesive system (Flynn et al., 2010), sharing of information across functions (Morash, et al., 1997) to enhance collaboration and deepen understanding of customers (Wong, et al., 2011). Supplier and customer integration reflect similar relational behaviors, but between a plant and its suppliers or customers (Zhao et al., 2011).

SCI provides a foundation for the development of supply chain trust, memory, shared meaning and, ultimately, a supply chain culture. Trust, or the expectation that a supply chain partner will honor its commitments and has good intentions (Doney & Cannon, 1997), is developed through repeated exchanges with other supply chain members that align their differentiated interests (Ireland & Webb, 2007) through SCI's shared planning, joint responsibility for problem solving and flexibility in accommodating unexpected situations. Every action provides an opportunity for a member to demonstrate that it is acting reliably and in other members' best interests (Bode, et al., 2011). In the presence of stable and trusting supply chain relationships, supply chain memory provides a repository for shared supply chain experiences, including strong values, traditions and beliefs, as well as experience with its processes (Hult, et al., 2004, 2007). Supply chain memory focuses distribution of information to the members where it will lead to the best outcomes (Huber, 1991). SCI also leads to supply chain identity (Nahapiet & Ghoshal, 1998), based on individual members' perceptions of what is enduring and distinctive about it (Gioia & Thomas, 1996). SCI's face-to-face meetings (Ireland & Webb, 2007) help form supply chain identity through sharing knowledge and teams that span member boundaries. As supply chain identity and trust strengthen, members develop shared meaning (Ireland & Webb, 2007), which is critical in a supply chain, where frames of reference, such as leadership and organizational culture, are missing (Hult, et al., 2004). Supply chain memory provides a cognitive map that guides differentiated members toward common understanding (Huber, 1991). As a supply chain event or data is interpreted by differentiated supply chain members (Corner, et al., 1994; Huber, 1991), their repertoire of possible behaviors increases (Hult, et al., 2004). Thus, SCI's development of shared meaning channels the vision, strategies and operations of differentiated supply chain members in the same direction (Hult, et al., 2004) so that they function effectively as an interdependent system.

HYPOTHESES

According to contingency theory (Tushman & Nadler, 1978), an organization's processes should be aligned with its environment and structure, thus, we begin by testing the alignment between SCI (process) and supply chain uncertainty (environment) (Wong, et al., 2011). Key to our theoretical development is the notion that an organization's information processing ability should align with the level of uncertainty (Lengel & Daft, 1988; Daft et al., 1987), tested in H_1-

H_4. The need for SCI as a response to uncertainty, however, is also subject to a supply chain member's organization structure, which may mitigate or heighten these relationships (H_5-H_7).

Formal information systems, rules and standard processes are well aligned with micro-level uncertainty, because variability is reduced through precise, factual data (Tushman & Nadler, 1978). However, there is an inflection point, after which more information is not associated with better performance (Leuschner, et al., 2013). Because SCI's richer information processing capability may contain surplus meaning that could lead to data saturation (Daft & Lengel, 1988; Tushman & Nadler, 1978), greater micro-level uncertainty will be inversely associated with SCI.

H_{1a}: Micro-level uncertainty is inversely associated with customer integration
H_{1b}: Micro-level uncertainty is inversely associated with internal integration
H_{1c}: Micro-level uncertainty is inversely associated with supplier integration

Similarly, meso-level uncertainty requires apposite amount of information that can be swiftly and accurately obtained in a straightforward manner, without the engagement of rich media, critical elaboration or debates (Daft & Lengel, 1988) that have the potential for distortion and slow dissemination. If richer information about the objective, well-understood problems of meso-level uncertainty was available, it could contain unnecessary, surplus meaning (Lengel & Daft, 1988; Daft et al., 1987). However, there is also a need for deeper information than what is provided by formal information systems, requiring some interactions with other supply chain members, including special reports, planning activities and direct communication (Daft & Lengel, 1988). The lateral relations associated with SCI may be effective in addressing some of the questions associated with meso-level uncertainty, particularly when alternative sources for missing information are needed or missing information needs to be provided quickly. Thus, although we expect that meso-level uncertainty will be inversely associated with SCI, we expect that this relationship will be weaker than it is for micro-level uncertainty.

H$_{2a}$: Meso-level uncertainty is inversely associated with customer integration
H$_{2b}$: Meso-level uncertainty is inversely associated with internal integration
H$_{2c}$: Meso-level uncertainty is inversely associated with supplier integration.

In contrast, the need for SCI will be strong in supply chains characterized by macro-level uncertainty, where factual information is inadequate in coping with contingencies (Germain, et al., 2008) and a supply chain develops a behavioral repertoire by taking cues from its environment. Integrator roles and group meetings will be effective, due to the richness of their face-to-face interaction, which stimulates deliberation, debate, and interpretation (Daft & Lengel, 1986; Daft, et al., 1987). This provides instant feedback, allows real-time questions and corrections, uses multiple cues and natural language to convey a broad set of concepts, and infuses personal feelings into communication. Thus, SCI's richer media are superior for equivocal situations (Lengel & Daft, 1988; Daft, et al., 1987) by enabling "information to change understanding" (Daft & Lengel, 1986, p. 560) and affording "communication transactions that can overcome different frames of reference or clarify ambiguous issues to change understanding" (Daft & Lengel, 1986, p. 560). For instance, a plant experiencing rapidly changing customer needs and intense competition may turn to its suppliers and customers to help resolve challenges, with substantial deliberation regarding product development, quality, pricing, and service levels. There may be issues that can only be addressed by close involvement of process engineers, purchasing managers, customers and suppliers. Acquiring more transactional data or reducing its variability cannot resolve such issues; if standard reports and routine decision making are applied to macro-level uncertainty problems, crucial cues can be lost in the "data glut" (Daft et al., 1987). Thus,

H$_{3a}$: Macro-level uncertainty is positively associated with customer integration
H$_{3b}$: Macro-level uncertainty is positively associated with internal integration
H$_{3c}$: Macro-level uncertainty is positively associated with supplier integration

Interactions

Micro-, meso- and macro-level uncertainty do not exist in isolation. For example, Deming's (1986) work was based on the premise that variability (micro-level uncertainty) and knowledge (the counterpart of macro-level uncertainty) are inversely related, with the quest for knowledge driven by unexplained variability (Anderson, et al., 1994). Roth (1996) viewed variability and knowledge as conceptually synonymous: "One way to interpret supply chain process variability is as a proxy for depth and breadth of knowledge." Thus, micro-level uncertainty may be a driver for information that will also reduce macro-level uncertainty. In addition, supply chain memory provides an interface between meso-level and macro-level uncertainty. As SCI responds to macro-level uncertainty, it fosters supply chain memory, which makes more information available to reduce meso-level uncertainty. Thus, we propose that the types of uncertainty are experienced side-by-side, with a combined impact on SCI.

H$_{4}$**:** Interactions between the types of uncertainty will be associated with supply chain integration.

Organization Structure

Because structure is a central element of contingency theory (Lawrence & Lorsch, 1967), we add centralization, formalization and flatness, as moderators of the proposed relationship between SCI and uncertainty. Centralization is the extent to which decision-making authority resides in members at the apex of an organization's structure (Koufteros, et al., 2007). When a centralized supply chain member experiences micro-level uncertainty, its employees will seek variability reduction decisions from top management and will be less likely to draw upon SCI's lateral relations and inclusive decision making. Thus, we hypothesize that the inverse association between micro-level uncertainty and SCI will be heightened in the presence of centralization.

H$_{5a}$: The effect of micro-level uncertainty on SCI is subject to the level of centralization, such that the inverse association will be heightened.

Centralized decision making can hamper information acquisition and processing (Galbraith, 1977) for meso-level uncertainty. Employees in a centralized firm would attempt to obtain crucial missing information by working up the hierarchy, expecting top management to intervene with resources to obtain the requisite information. Although valuable information could reside with other sources, it would not be shared sans top management intervention. Thus, the inverse relationship between meso-level uncertainty and SCI will be intensified in a centralized structure.

H$_{5b}$: The effect of meso-level uncertainty on SCI is subject to the level of centralization, such that the inverse association will be heightened.

Macro-level uncertainty requires deliberation, interpretation and the creation of shared meaning. A centralized decision making structure could hamper the effects of SCI, as decision making would be undertaken by very few decision makers, without the benefit of the input and expertise of others. In a centralized structure, employees would rely on top management for guidance, instead of the wider network of sources afforded via SCI. In addition, lack of decision-making authority can discourage employees from proactively solving problems they are facing. Thus, the positive effects of macro-level uncertainty on SCI will be downgraded in a more centralized structure.

H$_{5c}$: The effect of macro-level uncertainty on SCI is subject to the level of centralization, such that the positive association will be tempered.

Formalization codifies an organization's strategy (Lin & Germain, 2003), providing a catalyst for cooperation and communication. It articulates the organization's strategic intent, while facilitating dissemination of plans and objectives, enhancing knowledge and information sharing across different levels (Grant, 1996). Formalization can diminish the impact of uncertainty among differentiated supply chain members (Koufteros & Vonderembse 1998), directing their focus and energy (Adler & Borys, 1996). Formalization strengthens a supply chain's behavioral response repertoire by implicitly stipulating the level, frequency, and quality of internal and external communication. For micro-level uncertainty, formalization prescribes tools and methods employees can exploit to assess variability, as well as prescribing responses, obviating the need for SCI.

> $\mathbf{H}_{6a}$: The effect of micro-level uncertainty on SCI is subject to the level of formalization, such that the inverse association will be heightened.

Similarly, formalization stipulates and legitimizes access to internal and external information and imposes planning across time horizons, which can address meso-level uncertainty, lessening the need for SCI when a supply chain member lacks information. It can serve as a sense-making process for members, harmonizing their strategies and processes with those of other members.

> $\mathbf{H}_{6b}$: The effect of meso-level uncertainty on SCI is subject to the level of formalization, such that the inverse association will be heightened.

On the other hand, when a supply chain member encounters macro-level uncertainty, formalization may not provide a resolution, since each situation is unique and unanticipated. Moorman et al. (1993) argue that formalization inhibits cooperation and trust, especially when its basis is the interpersonal relationship between exchange partners, such as suppliers or customers. Since formalization dictates compliance, it engenders rigidity (Dwyer, Schurr & Oh, 1987) which debilitates SCI's rich communication media and hampers experimentation to cope with equivocal situations. Thus, the need for SCI will be heightened when a supply chain member faces macro-level uncertainty, as SCI might offer a credible response.

> **H**$_{6c}$: The effect of macro-level uncertainty on SCI is subject to the level of formalization, such that the positive association will be heightened.

A flatter organization structure is less complex, with fewer layers through which information must travel (Koufteros et al., 2014), rendering communication faster and more accurate (Hull & Hage, 1982). Since a flatter organization structure implies a higher number of decision makers at each level (due to fewer hierarchical levels), it increases the number of potential contact points between a supply chain member and other members, enhancing its boundary spanning capability (Kostova & Roth, 2003). A flatter structure promotes common knowledge (Grant, 1996) since employees gain broader knowledge at each level. For meso-level uncertainty, a flatter structure facilitates obtaining the necessary data, lessening the need for SCI. However, if a supply chain member faces micro-level uncertainty, neither the number of layers in its hierarchy nor SCI can resolve the challenge, thus there is no expectation that the inverse effects of micro-level uncertainty on SCI would be affected by flatness. The positive effects of macro-level uncertainty on SCI would be tempered by flatness by allowing employees to directly interact with those who experience the problem.

> **H**$_{7a}$: The effect of micro-level uncertainty on SCI is not subject to the level of flatness, and as such that the inverse association will be maintained.
> **H**$_{7b}$: The effect of meso-level uncertainty on SCI is subject to the level of centralization, such that the inverse association will be heightened.
> **H**$_{7c}$: The effect of macro-level uncertainty on SCI is subject to the level of centralization, such that the positive association will be tempered.

METHODS

Data

This research uses data collected as part of the High Performance Manufacturing (HPM) project. Responses regarding a variety of manufacturing and other organizational variables were collected from 339 manufacturing plants (Table 3) in three industries, located in ten countries with a strong manufacturing base in both stable and rapidly changing industries. Participating plants were randomly selected from a master list of manufacturing plants in each country, comprised of plants from different parent corporations with at least 100 employees. A local member of the research team contacted each plant's manager to solicit participation. In exchange, the plants received a profile that compared their performance on a wide range of measures to high performing and traditional plants in their industry, both in their country and in the other countries surveyed.

--Insert Table 3 Approximately Here--

Participating plants were sent a battery of 23 questionnaires, targeted at the respondents who were the best informed about the topic of the specific questionnaire. The questionnaires, originally developed in English, were translated into the local language by a member of the research team. They were then back-translated into English by a different team member to assure the integrity of the translation. The final questionnaires were sent to a manager designated as the project's research coordinator at each plant who was responsible for distributing them and collecting the completed questionnaires, as well as serving as a liaison with the research team. The respondents returned their completed surveys to the coordinator in a sealed envelope. The survey items were divided across the questionnaires in order to obtain information from the respondents who were most knowledgeable. For example, the respondents for the indicators tapping internal integration included the plant manager, plant superintendent and a process engineer; similarly, responses for macro-level uncertainty were solicited from at least four respondents which include a process engineer, the plant manager, the plant superintendent, and supervisors. This design mitigates common method bias (Podsakoff & Organ, 1986; Podsakoff et al., 2003), because multiple informants scored each measurement item (see Table 4).

--Insert Table 4 Approximately Here--

Measures

Likert scale items were deployed to operationalize (Table 5) internal integration, customer integration and supplier integration and had been deployed in prior research (Turkulainen & Ketokivi, 2012; Koufteros, et al., 2014). We operationalized micro-level uncertainty using a newly-developed scale containing indicators reflecting demand stability, and macro-level uncertainty via a newly-developed scale containing indicators reflecting competitive pressures and dynamic customer needs. Meso-level uncertainty was operationalized via three separate variables, based on the source of the information that was needed. These included, “Our customers do not have access to our production plans” (customer), “Manufacturing management is not aware of our business strategy” (internal) and “We share our production plans with our suppliers” (suppliers, reverse coded). Measures for centralization, formalization, and flatness were taken from Koufteros et al. (2014). The multi-item latent variables developed specifically for this research (micro-level uncertainty and macro-level uncertainty) were first subjected to exploratory analytical techniques, including within-block factor analysis and Cronbach’s alpha, before applying confirmatory factor analysis on all latent variables. Two items were eliminated due to low loadings with the respective factor. There were two objective control variables. Plant size was operationalized as the log of the sum of the number of hourly and salaried personnel in each plant, since larger firms possess more resources that could be potentially committed to SCI. Industry was operationalized using two dummy variables, since uncertainty levels may differ across industries.

--Insert Table 5 Approximately Here--

Analysis of variance found that all cross-plant differences were significantly higher than the within-plant differences. Inter-rater reliability analysis indicated high consistency between respondents within each plant, allowing averaging of responses to create aggregate plant-level measures.

Measurement Analysis

Confirmatory factor analysis (CFA) was specified within Lisrel to assess the proposed measurement model. The data effectively fit the model: $\chi^2(624)=1151.48$, $\chi^2/df=1.84$, CFI=0.91, NNFI=0.90, RMR=0.057, RMSEA=0.049 and p-value for Test of Close Fit (RMSEA < 0.05) = 0.63. All item-factor loadings were statistically significant (Table 5). In examining discriminant validity, each variable's average variance extracted (AVE) was higher than the squared correlation between each pair of variables for all comparisons (the highest squared correlation was observed between internal integration and formalization=0.31, the AVEs were 0.51 and 0.58 respectively). All pair-wise χ^2 difference tests were significant, further supporting discriminant validity. Table 6 indicates that each of the composite reliability estimates was greater than 0.76, except for macro-level uncertainty, which included only three indicators. Thus, the measures are reliable and valid.

--Insert Table 6 Approximately Here--

Hypothesis Testing Analysis

To test the hypotheses, we built three hierarchical regression models, one for each dimension of SCI. In Step 1, we entered the control variables, followed by the main effects of micro-, meso- and macro-level uncertainty and the three organization structure variables in Step 2. Step 3 supplemented the main effects with the two-way interactions between the three uncertainty variables. The measure of meso-level uncertainty included in each model was based on the type of information that was most relevant to the dimension of SCI that served as the dependent variable. In Step 4, the interactions between uncertainty and structural variables were added.

The independent and moderator variables were centered at the item level by subtracting the mean from each variable, in order to mitigate multicollinearity that could emerge from interaction terms (Hayes, 2013). Multicollinerarity was evaluated for each model to assure that the findings could be meaningfully interpreted. The highest VIF values (i.e., 2.340, 1.953, 1.952), the lowest tolerance values (e.g., 0.427, 0.512, 0.512), and the highest condition numbers (i.e., 17.890, 16.853, 16.982) for the three models suggest that multicollinearity does not present a significant challenge. To evaluate whether the data set included influential observations, we examined the mean and maximum Cook's distance for each model (means of 0.003, 0.004, 0.004 respectively, and maximum values of 0.050, 0.358, 0.130 respectively), finding that both were significantly less than 1.00. The Mahanalobi's distances, with an average of 20.937, 20.937, 20.937, were not statistically significant ($p > 0.54$), suggesting that there were no influential observations. Multivariate normality was examined via a P-P plot. The three plots were essentially linear on the 45° line, suggesting multivariate normality. Scatterplots of predicted values and residuals suggested homoscedasticity.

RESULTS

Table 7 presents the results of the hierarchical regression analysis for internal integration. The F values for steps 2-4 were statistically significant, however, the ΔR^2 was not significant for steps 3 and 4. Step 2 indicates that micro-level uncertainty, meso-level uncertainty, formalization, and flatness were inversely related with internal integration, while macro-level uncertainty was positively associated with it, supporting H_{1a}, H_{2a}, and H_{3a}. Step 3 contains no significant interactions between the types of supply chain uncertainty. Step 4 reveals a significant negative interaction between micro-level uncertainty and formalization, supporting H_{7a}. The plot of the interaction in panel A of Figure 1 shows that the relationship between micro-level uncertainty and integration is negative for supply chain members with high formalization. On the other hand, for members with low levels of formalization, the relationship between micro-uncertainty and internal integration is less negative.

--Insert Tables 7-9 and Figure 1 Approximately Here--

Table 8 contains the results of the hierarchical regression analysis with customer integration as the dependent variable. The F values for all steps were statistically significant, however, the ΔR^2 was only significant for step 2. Micro-level and meso-level uncertainty and centralization were negatively related to customer integration, while macro-level uncertainty, formalization, and flatness were positively related to it, supporting H_{1b}, H_{2b} and H_{3b}. Step 3 reveals no significant interactions between the types of uncertainty. Step 4 demonstrates inverse relationships between micro-level uncertainty X centralization and micro-level uncertainty X formalization with customer integration, and a positive relationship between meso-level uncertainty X formalization with customer integration.

We had hypothesized that the inverse relationship between micro-level uncertainty and SCI would be amplified by centralization. This was supported by Panel B (Figure 1), which illustrates that highly centralized supply chain members exhibit an inverse relationship between micro-level uncertainty and customer integration. A similar pattern is displayed in Panel C (Figure 1). Lastly, panel D (Figure 1) displays the interaction between meso-level uncertainty and formalization. H_{7b} predicted that a highly formalized structure would furnish needed information via mechanisms such as contracting, obviating the need for SCI. However, the results suggest the contrary; a highly formalized supply chain member experiencing meso-level uncertainty will likely seek higher levels of customer integration.

Table 9 contains the results of the regression analysis for supplier integration, which reveals that Steps 2-4 were statistically significant, as well as the ΔR^2 for steps 2 and 4. Both micro- and meso-level uncertainty were negatively related to supplier integration, while macro-level uncertainty and formalization were positively related to it. Thus, H_{1c}, H_{2c} and H_{3c} were supported. Step 3 indicates that one of the interactions (micro-level X macro-level) between uncertainty variables is statistically significant. In step 4, two of the interactions were statistically significant: micro-level uncertainty X macro-level uncertainty and micro-level uncertainty X centralization were both inversely related to supplier integration.

Panel E (Figure 1) contains the interaction plots for the dual effect of micro-level and macro-level uncertainty. Although micro-level uncertainty was consistently inversely associated with SCI and macro-level uncertainty was consistently positively related, the plot suggests that the inverse association between micro-level uncertainty and supplier integration is amplified in the presence of high macro-level uncertainty. We expected instead that, since macro-level uncertainty demands high levels of integration, the relationship between micro-level uncertainty and supplier integration would be tempered. Although the slope for the low macro-level uncertainty environment is positive, it is nevertheless trivial.

Panel F (Figure 1) presents the interaction plot between micro-level uncertainty and centralization. We had anticipated that the inverse association between micro-level uncertainty and integration would be heightened in a centralized structure (H_{5a}), which was supported by the results. When a centralized supply chain member experiences micro-level uncertainty, there is lower inclination to integrate with suppliers. Overall, our results provide strong support for H_1, H_2 and H_3, and partial support for H_4-H_7.

DISCUSSION, LIMITATIONS AND FUTURE RESEARCH

This research focused on the concept of supply chain uncertainty, building on the organizational theory literature that examines uncertainty and adapting it to the realm of supply chains. Supply chain uncertainty originates in the task environment and can be manifested as variability of key inputs (micro-level uncertainty), absence of needed information (meso-level uncertainty) or equivocality (macro-level uncertainty). Based on contingency theory and organizational theory, we hypothesized a relationship between process (SCI), structure (centralization, formalization and flatness) and environment (micro-, meso- and macro-level uncertainty).

Theoretical Contributions

Though uncertainty can assume different forms, it has been largely conceptualized as a singular concept, often variability, in the extant supply chain literature (Melnyk & Fredendall, 1995; Germain, et al., 2008). Viewing supply chains as complex organizations, we synthesize the diverse perspectives into three types of uncertainty, allowing further understanding of how organizations can employ SCI to better align their processes with different types of uncertainty. This also suggests differential effects on organizational action. Our theoretical development and empirical analysis provide a starting point for future research on supply chain uncertainty, in light of its three types.

The supply chain management literature generally suggests that greater information sharing reduces supply chain uncertainty (Lee et al., 1997). It advocates that a supply chain member facing a high level of uncertainty should employ SCI to coordinate information and materials flows across interconnected businesses (Williams et al., 2013). We found, instead, that there was an *inverse* relationship between both micro-level uncertainty and meso-level uncertainty and all three dimensions of SCI. While this finding is inconsistent with the general consensus in the literature, it supports Daft and Lengel's (1986) contention that the richness of the communication medium should align with the type of uncertainty. Both micro- and meso-level uncertainty can be reduced through the acquisition, dissemination, and assessment of timely and accurate information. Factual information is best conveyed using non-rich media, such as databases, spreadsheets, reports, contracts and policies, thus the inverse relationship between these two types of uncertainty and SCI is not surprising. We proposed a positive relationship between macro-level uncertainty and SCI, which was supported. Important elements of macro-level uncertainty's ambiguous task environment may not even be known, thus, cannot be addressed through better databases or more quickly disseminated standard reports. The richer media that characterize SCI can narrow macro-level uncertainty's domain and generate innovative solutions to emerging issues.

There were no interactions between the types of uncertainty, except for a significant inverse relationship between micro-level X macro-level uncertainty and supplier integration. At lower levels of micro-level uncertainty, macro-level uncertainty is positively related to supplier integration, consistent with the main effect described above. However, at higher levels of micro-level uncertainty, macro-level uncertainty is inversely related to supplier integration, suggesting that micro-level uncertainty is more salient above a certain threshold. None of the other interactions between types of uncertainty was significantly related to SCI. Although counter to expectations, this is an interesting finding. Combined with their strong main effects, this suggests the three types of supply chain uncertainty function independently, due to their different nature.

Contingency theory suggests that processes should be aligned with an organization's structure, which we investigated through the moderating effect of centralization, formalization and flatness. Centralization was inversely related to customer integration, but not to internal or supplier integration. In a centralized organization, individuals look to top management for guidance and provision of information, so there is less reliance on customer integration as a source of information. Formalization was positively related to all three dimensions of SCI, thus, a strategy that is well communicated and understood is consistent with SCI. Similarly, flatness was positively related to internal and customer integration, but not to supplier integration, suggesting that a less hierarchical organization structure is consistent with SCI. Put together, these main effects signify an alignment of SCI with a decentralized, flatter organization in which there is shared understanding of strategic intent, goals and objectives. This is supported by the literature on organic forms of organizations, which create an environment that supports the rich media of SCI.

The interactions between structure and environment (uncertainty) yielded interesting findings. First, there were more significant structure X uncertainty relationships with customer integration than there were with internal or supplier integration. Second, almost all of the significant interactions were between micro-level uncertainty and a structural characteristic. Only one included meso-level uncertainty and none were between macro-level uncertainty and a structural characteristic. This provides further support for the notion that the types of uncertainty are independent and operate in different ways. Third, none of the significant interactions included flatness, although it had a significant main effect for customer and internal integration.

The micro-level uncertainty X formalization relationship with internal and customer integration indicated that formalization enhanced the negative relationship between micro-level uncertainty and SCI, as hypothesized. This implies that, as a supply chain member faces higher micro-level uncertainty, the potential for SCI to serve as a rich information medium is lessened through formalization. Having a good understanding of strategic intent, goals and objectives may help decision makers make sense of information provided by richer media. On the other hand, low formalization enables more informal interaction and fosters trust between departments and with customers, in order to cope with micro-level uncertainty. Interestingly, there was a positive relationship between meso-level uncertainty X formalization and customer integration. Rather than a highly formalized structure furnishing needed information and, in effect, substituting for customer integration, requisite information is conveyed via higher levels of customer integration. This suggests that having better knowledge of strategic intent, goals and objectives heightens awareness of information that is missing, driving a stronger focus on customer integration as a means of obtaining the needed information.

The other significant interactions were between micro-level uncertainty X centralization with both customer integration and supplier integration. Both were negative, as expected, indicating that centralization heightened the inverse association between micro-level uncertainty and SCI. In a more centralized structure, employees turn to top management to orchestrate resources to address variability, rather than addressing it through customer or supplier integration. For example, micro-level uncertainty can be reduced by isolating the causes of variability and studying its level in order to enact effective responses; these efforts require authorization by top management. When top management is proactively involved, in a centralized structure, the need for SCI when the organization encounters micro-level uncertainty is further weakened.

Based on the literature, we had suggested that, although both micro-level and meso-level uncertainty would be inversely related to SCI, the weaker relationship would be for meso-level uncertainty. This was not the case. We had expected that somewhat richer communication media would be aligned with meso-level uncertainty. This finding warrants further investigation. One possible explanation may be that media richness's contribution to identifying the difference between needed information and existing information is greater than its data saturation effect.

Managerial Implications

Our theoretical exposition of the concept of supply chain uncertainty and subsequent empirical findings offer several implications for practice. First, we suggest that uncertainty cannot be treated as a singular variable in decision-making. Supply chain members should consider different types of supply chain uncertainty, as there is no single resolution that can equally serve all types of uncertainty. Second, the results demonstrate that different types of uncertainty require different levels of SCI. Without this understanding, conscientious managers may invest in SCI that is not aligned with the type of uncertainty their firm faces, given the widely touted positive contributions of SCI in press articles and some academic research. Our findings suggest that SCI may only be apposite to macro-level uncertainty.

Third, the largely non-significant interactions between uncertainty types imply that they are functioning relatively independently. This is informative, as supply chain members can dedicate their efforts to resolving one type of uncertainty at a time, without worrying about spillover to other types of uncertainty. Finally, our findings offer empirical evidence regarding the impact of organization structure. Whether supply chain uncertainty drives supply chain members to implement SCI is contingent on how they are structured. Since organization structure is subject to top management discretion, it can be altered to solicit higher or lower levels of SCI. Our findings point to factors that supply chain members should consider when allocating resources. For instance, in situations where the organization structure weakens the need for SCI to mitigate uncertainty, a supply chain member should not rely on SCI, but rather deploy resources and tools that are better aligned with the specific type of uncertainty.

Future Research and Limitations

There are many interesting opportunities for future research related to this study. This research rests on the tenets of classic organizational theory and information processing theory. Resource dependence theory (RDT) (Pfeffer & Salancik, 1967) provides another important perspective on supply chain uncertainty. In their research on supply chain disruptions, Bode, et al. (2011) describe how RDT relates to a supply chain member's control, power and vulnerability, relative to its external resource providers (customers and suppliers) as it responds to uncertainty. According to RDT, a supply chain member's need for scarce resources creates dependence on its exchange partners, which they strive to minimize (Bode, et al., 2011). Uncertainty, therefore, is associated with lack of control and power over the environment, which reflects in some respects our concept of macro-level uncertainty. RDT's conception of uncertainty may be instrumental in positioning information as a means to reduce dependence.

Further, we develop theory on supply chain uncertainty by building on the foundation of existing organization theory perspectives. Although this body of literature provides a useful and insightful foundation, the challenge for future researchers is to develop more granular theory on supply chain uncertainty that is unique to the context of supply chains (Carter, et al., 2015b).

Future research should also investigate how the types of uncertainty can co-exist and impact a specific supply chain member. For example, there may be distinct clusters or profiles of uncertainty types that may vary by industry, national culture, and other factors. Such research could investigate whether there are different uncertainty reduction and accommodation strategies associated with the various uncertainty clusters. Thus, although our research revealed almost no interactions between types of uncertainty, this is a fruitful area for future research.

We positioned uncertainty as having a direct relationship with SCI and found that this was supported. However, others argue that it serves as a moderator between SCI and performance. Wong et al. (2011) cite delivery and production flexibility as especially sensitive to uncertainty generated by the external environment, while product quality and production cost are more related to internal sources of uncertainty. Other research questions for future research relate to the chicken-and-egg nature of uncertainty vis-a-vis strategy; does a firm's strategy determine the amount of uncertainty that it faces, or does the amount of uncertainty that it faces determine a firm's strategy?

Our focus was at the level of organizations within supply chains. However, supply chain decisions are ultimately made by individual managers operating with workgroups within a functional area of an organization. Thus, there is a hierarchical nesting of decision making within supply chains (Carter, et al., 2015a). This suggests the need for multilevel analysis in supply chain management research. Examination of uncertainty from a multilevel perspective may lead to a richer conceptualization of the supply chain uncertainty construct.

As with all research, generalizability is limited by methodology. This research used data from an existing data set, thus, the measurement indicators were not purpose-built. There are opportunities to improve the measurement indicators so that they align more closely with the theoretical foundation. Also, because this data is cross-sectional, it is only possible to specify associations between variables, rather than cause and effect relationships. For example, although we posit that macro-level uncertainty is aligned with SCI as a way of dealing with vague, poorly defined questions, it might also be argued that SCI causes such questions, due to the rich media it engenders. Longitudinal data could help to address this problem. Although we build on the foundation of media richness, the measures of SCI do not explicitly measure their media richness. Finally, there may be multiple levels of uncertainty (Carter et al., 2015b), such as task, strategic and environmental uncertainty, embedded within the broader constructs of micro-level, meso-level and macro-level uncertainty. Future research should differentiate between the types of uncertainty that a supply chain member faces, as well as potential interactions between them.

References

Adler, P.S., & Borys, B. (1996). Two types of bureaucracy: enabling and coercive. *Administrative Science Quarterly*, 41(1), 61-89.

Anderson, J.C., Rungtusanatham, M., & Schroeder, R.G. (1994). A theory of quality management underlying the Deming management method. *Academy of Management Review*, 19(3), 472-509.

Bagozzi, R.P., & Phillips, L.W. (1982). Representing and testing organizational theories: a holistic construal. *Administrative Science Quarterly*, 27(3), 459-489.

Beckman, C.M., Haunschild, P.R., & Damon, J. (2004). Friends or strangers? Firm-specific uncertainty, market uncertainty and network partner selection. *Organization Science*, 15(3), 259-275.

Bendoly, E., & Swink, M. (2007). Moderating effects of information access on project management behavior, performance and perceptions. *Journal of Operations Management*, 25, 604-622.

Birou, L., Germain, R.N., & Christensen, W.J. (2011). Applied logistics knowledge impact on financial performance. *International Journal of Operations and Production Management*, 31(8), 816-834.

Bode, C., Wagner, S.M., Peterson, K.J., & Ellram, L.M. (2011). Understanding responses to supply chain disruptions: Insights from information processing and resource dependence perspectives. *Academy of Management Journal*, 54(4), 833-856.

Bourland, K.E., Powell, S.G., & Pyke, D.F. (1996). Exploiting timely demand information to reduce inventories. *European Journal of Operational Research*, 92(2), 239-253.

Carter, C.R., Meschnig, G., & Kaufmann, L. (2015a). Moving to the next level: why our discipline needs more multilevel theorization. *Journal of Supply Chain Management*, 51(4), 94-102.

Carter, C.R., Rogers, D.S., & Choi. T.Y. (2015b). Toward the theory of the supply chain. *Journal of Supply Chain Management*, 51(2), 89-97.

Cheng, T.C.E., Yip, F.K., & Yeung, A.C.L. (2012). Supply chain risk management via guanxi in the Chinese business context: The buyer's perspective. *International Journal of Production Economics*, 139(1), 3-13.

Corner, P.D., Kinicki, A.J., & Keats, B.W. (1994). Integrating organizational and individual information processing perspectives on choice. *Organizational Science*, 5(3), 294-308.

Croson, R., & Donahue, k. (2002). Experimental economics and supply chain management. *Interfaces*, 32(5), 74-82.

Daft, R.L., & Lengel, R.H. (1986). Organizational information requirements, media richness and structural design. *Management Science*, 32(5), 554-571.

Daft, R.L., Lengel, R.H., & Trevino, L.K. (1987). Message equivocality, media selection and manager performance: implications for information systems. *Management Information Systems Quarterly*, 11(3), 355-366.

Daft, R.L., & Weick, K.E. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review*, 9(2), 284-295.

Davidson, P. (1991). Is probability theory relevant for uncertainty? A post Keynesian perspective. *Journal of Economic Perspectives*, 5(1), 129-143.

Deming, W.E. (1986). Out of the Crisis. Cambridge, MA: MIT Press.

deTreville, S., Shapiro, R.D., & Hameri, J.P. (2004). From supply chain to demand chain: The role of long-term reduction in improving demand chain performance. *Journal of Operations Management*, 21, 613-627.
Doney, P.M., & Cannon, J.P. (1997). An examination of the nature of trust in buyer-supplier relationships. *Journal of Marketing*, 61(2), 35-51.
Downey, H.K., Hellriegel, D., & Slocum, J.W. (1975). Environmental uncertainty: The construct and its application. *Administrative Science Quarterly*, 20(4), 613-629.
Downey, H.K., & Slocum, J.W. (1975). Uncertainty: Measures, research and sources of variation. *Administrative Science Quarterly*, 18, 562-577.
Duncan, R.B. (1972). Characteristics of organizational environmentsl and perceived environmental uncertainties. *Administrative Science Quarterly*, 17(3), 313-327.
Dunning, J.H. (1995). Reappraising the eclectic paradigm in an age of alliance capitalism. *Journal of International Business Studies*, 26, 461-492.
Dwyer, FR, Schurr, PH, Oh, S. (1987). Developing Buyer-Seller Relationships. *Journal of Marketing*, 51, 11-27
Feldman, J.M., & Lynch, J.G. (1988). Self-generated validity and other effects of measurement on belief, attitude, intention and behavior. *Journal of Applied Psychology*, 13(3), 421-435.
Fisher, M.L. (1997). What is the right supply chain for your product? *Harvard Business Review*, March-April, 105-117.
Fisher, M.L., Hammond, J., Obermeyer, W., & Raman, A. (1994). Making Supply Meet Demand in an Uncertain World, *Harvard Business Review*, May–June, 83-92.
Flynn B.B., Huo B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of Operations Management*, 28(1), 58-71.
Fredendall, L.D., & Melnyk, S.A. (1995). Assessing the impact of reducing demand variance through improved planning on the performance of a dual resource constrained job shop. *International Journal of Production Research*, 33(6), 1521-1534.
Fry LW, Slocum JW, Jr. (1984). Technology, structure, and workgroup effectiveness: A test of a contingency model. *Academy of Management Journal*, 27(2), 221-246.
Galbraith, J. (1973). *Designing Complex Organizations*. Addison-Wesley, Reading, MA.
Galbraith, J. (1977). *Organizational Design*. Addison-Wesley, Reading, MA.
Geary, S., Childerhouse, P., & Towill, D. (2002). Uncertainty and the seamless supply chain. *Supply Chain Management Review*, July/August, 52-61.
Germain, R., Claycomb, C., & Droge, C. (2008). Supply chain variability, organization structure and performance: The moderating effect of demand unpredictability. *Journal of Operations Management*, 26, 557-570.
Gioia, D.A., & Thomas, J.B. (1996). Identity, images and issue reinterpretation: Sensemaking during strategic change in academia. *Administrative Science Quarterly*, 41(3), 370-402.
Grant, R.M. (1996) Prospering in dynamically-competitive environments: organizational capability as knowledge integration. *Organization Science*, 7(4), 375-387.
Hayes, A. F. (2013). *An Introduction to Mediation, Moderation, and Conditional Process Analysis*. New York: The Guilford Press.
Huber, G.P. (1991). Organizational learning: The contributing processes and literature. *Organizational Science*, 2(1), 88-115.
Hull F, Hage J. (1982). Organizing for innovation: Beyond Burns and Stalker's organic type. *Sociology*, 16, 564-577.

Hult, G.T.M., Craighead, C.W., & Ketchen, D.J. (2010). Risk, uncertainty and supply chain decisions: A real options perspective. *Decision Sciences*, 41(3), 435-458.
Hult, G.T., Ketchen, D.J., & Slater, S.F. (2004). Information processing, knowledge development and strategic supply chain performance. *Academy of Management Journal*, 47(2), 241-253.
Hult, G.T.M., Ketchen, D.J., & Arrfelt, M. (2007). Strategic supply chain management: Improve performance through a culture of competitiveness. *Strategic Management Journal*, 28(10), 1035-1052.
Ireland, R.D., & Webb, J.C. (2007). A multi-theoretic perspective on trust and power in strategic supply chains. *Journal of Operations Management*, 25, 482-497.
Kauppi, K. (2012). Extending the use of institutional theory in operations and supply chain management research: Review and suggestions. *International Journal of Operations and Production Management*, 33(10), 1318-1345.
Koufteros, X.A., & Vonderembse, M.A. (1998). The impact of organization structure on the level of JIT attainment: towards theory development. *International Journal of Production Research*, 36(10), 2863-2878.
Koufteros, X.A., Nahm, A., Cheng, T.C.E., & Lai, K-H. (2007). An empirical assessment of a nomological network of organizational design constructs: From culture to structure to pull production to performance. *International Journal of Production Economics*, 106(2), 468-491.
Koufteros, X., Peng, D.X., Lu, G., & Peters, R. (2014). The impact of organizational structural design on internal and external integration: An empirical assessment and a cross-regional examination. *Journal of Organization Design*, 3(2), 1-17.
Kostova, T, Roth, K. (2003). Social capital in multinational corporations and a micro-macro model of its formation. *Academy of Management Review*, 28, 297-317.
Lawrence, P.R., & Lorsch, J.W. (1967). Differentiation and integration in complex organizations. *Administrative Science Quarterly*, 12(1), 1-47.
Lee, H., Padmanabhan, V., & Whang, S. (1997). Information distortion in a supply chain: the bullwhip effect. *Management Science*, 43(4), 546-558.
Lengel, R.H., & Daft, R.L. (1988). The selection of communication media as an executive skill. *Academy of Management Executive*, 2(3), 225-232.
Leuschner, R., Rogers, D.S., & Charvet, F.F. (2013). A meta-analysis of supply chain integration and firm performance. *Journal of Supply Chain Management,* 49(2), 34-57.
Lin, X., & Germain, R. (2003). Organization structure, context, customer orientation, and performance: Lessons from Chinese state-owned enterprises. *Strategic Management Journal*, 24, 1131-1151.
Luce, R.D., & Raiffa, H. (1957). *Games and Decisions*. New York: Wiley.
Melnyk, S.A., Denzler, D.R., & Fredendall, L.D. (1992). Variance control vs. dispatching efficiency. *Production and Inventory Management Journal*, 33(3), 6-13.
Miller, D. (1987). The structural and environmental correlates of business strategy. Strategic *Management Journal*, 8(1), 55-76.
Miller, K.D. (1992). A framework for integrated risk management in international business. *Journal of International Business Studies*, 23, 311-331.
Moorman, C., Desphande, R., & Zaltman, G. (1993). Factors affecting trust in market relationships. *Journal of Marketing*, 57: 81-102.

Morash, E.A., Droge, C. & Vickery, S. (1997). Boundary-spanning interfaces between logistics, production, marketing and new product development. *International Journal of Physical Distribution and Logistics Management*, 27 (5/6), 350-369.

Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital and the organizational advantage. *Academy of Management Review*, 23(2), 242-266.

Peck, H. (2006). Reconciling supply chain vulnerability, risk and supply chain management. *International Journal of Logistics: Research and Applications*, 9 (2), 127-142.

Pfeffer, J. & Salancik, G.R. (1978). *The External Control of Organizations*. New York: Harper & Row.

Podsakoff, P.M., & Organ, D.W. (1986). Self-Reports in organizational research: problems and prospects. *Journal of Management*, 12(4), 531-544.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y., & Podsakoff, N.P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88(5), 879-903.

Rabinovich, E., Knemeyer, A.M., & Mayer, C.M. (2007). Why do Internet commerce firms incorporate logistics service providers in their distribution channels? The role of transaction costs and network strength. *Journal of Operations Management*, 25(3), 661-681.

Roth, A.V. (1996). Achieving strategic agility through economies of knowledge. *Strategy and Leadership*, 24(2), 30-37.

Simon, H. (1979). Rational decision making in business organizations. *American Economic Review*, 69(4), 483-513.

Sivadasan, S., Efstathiou, J., Frizelle, G., Shirazi, R., & Calivescu, A. (2002). An information-theoretic methodology for measuring the operational complexity of supplier-customer systems. *International Journal of Operations and Production Management*, 22(1), 80-102.

Stevenson, M., & Spring, M. (2007). Flexibility from a supply chain perspective: Definition and review. *International Journal of Operations and Production Management*, 27(7), 685-713.

Sweeney, K. & Shepperd, L.A. (2007). Do people brace sensibly? Risk judgments and risk prevalence. *Personnel and Social Psychology Bulletin*, 33, 1064-1075.

Tan, K.H., Tse, Y.K. & Chen, J. (2014). Quality risk in global supply networks. In Flynn, B.B. & Zhao, X. eds., *Global Supply Chain Quality Management: Product Recalls and Their Impact*. Taylor & Francis.

Thompson, J.D., 1967. *Organizations in Action: Social Science Bases of Administrative Theory*. New Brunswick, NJ: Transaction Publishers.

Tiwani, A., Wang, J., Keil, M., & Ahluwalia, P. (2007). The bounded rationality bias in managerial valuation of real options: Theory and evidence from information technology projects. *Decision Sciences*, 38(1), 157-181.

Tokar, T., Aloysius, J., Williams, B., & Waller, M. (2014). Bracing for demand shocks: An experimental investigation. *International Journal of Operations and Production Management*, 34(2), 205-216.

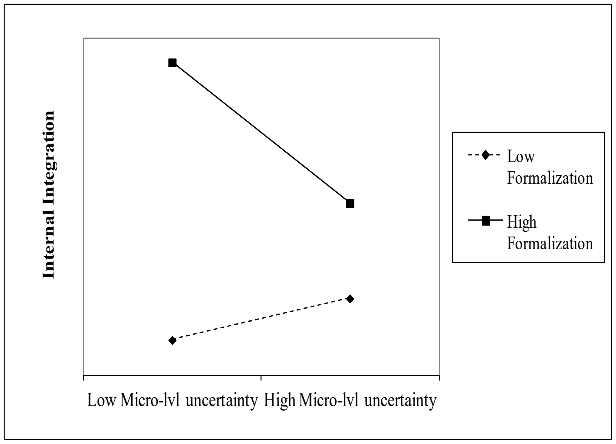
Turkulainen V, & Ketokivi M. (2012). Cross-functional integration and performance: What are the real benefits? *International Journal of Operations and Production Management*, 32(4), 447-467.

Tushman, M.L, & Nadler, D.A. (1978). Information processing as an integrative concept in organizational design. *Academy of Management Review*, 3(3), 613-624.

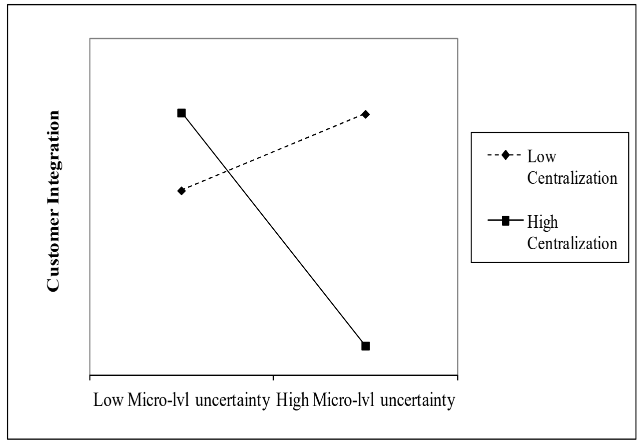
Tversky, A. & Kahneman, D. (1974). Rational choice and the framing of decisions. *Journal of Business*, 59(4), 251-278.

Van Londeghem, & Vanmaele, H. (2002). Robust planning: A new paradigm for demand chain planning. *Journal of Operations Management*, 20, 769-783.
Williams, B.D., Roh, J., Tokar, T., & Swink, M. 2013. Leveraging supply chain visibility for responsiveness: The moderating role of internal integration. *Journal of Operations Management*, 31(7-8), 543-554.
Wallin, C., Rungtusanatham, M. J., & Rabinovich, E. (2006). What is the “right” inventory management approach for a purchased item? *International Journal of Operations and Production Management*, 26, 50–68.
Weick, K.E. (1979). *The Social Psychology of Organizing*. Addison-Wesley, Reading, MA.
Wu, C., & Barnes, D. (2012). A dynamic feedback model for partner selection in agile supply chains. *International Journal of Operations and Production Management*, 32(1), 79-103.
Wu, Z., & Pagell, M. (2011). Balancing priorities: Decision-making in sustainable supply chain management. *Journal of Operations Management*, 29 (6), 577-590.
Wong, C.Y., Bom-itt, S., & Wong, C.W.Y. (2011). The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance. *Journal of Operations Management*, 29, 604-615.
Wong, C.W.Y, Lai, K.H. & Benroidey, E.W.N. (2015). The performance of contingencies of supply chain integration: The roles of product and market complexity. *International Journal of Production Economics*, 165, 1-11.
Zhao, X., Huo, B., Selen, W., & Yeung, J.H. (2011). The impact of internal integration and relationship commitment on external integration. *Journal of Operations Management*, 29(2).

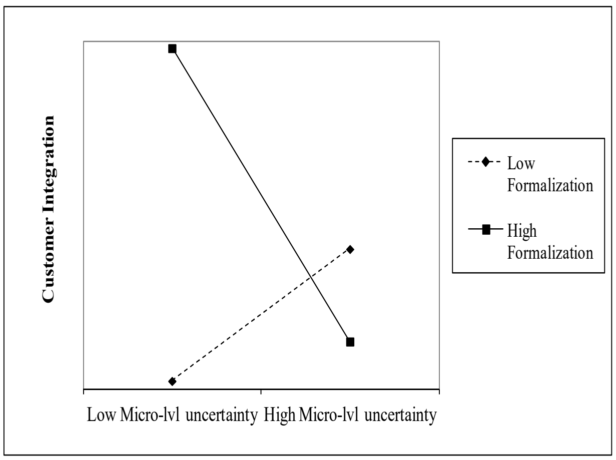
FIGURE 1
Plot of the Significant Interactions



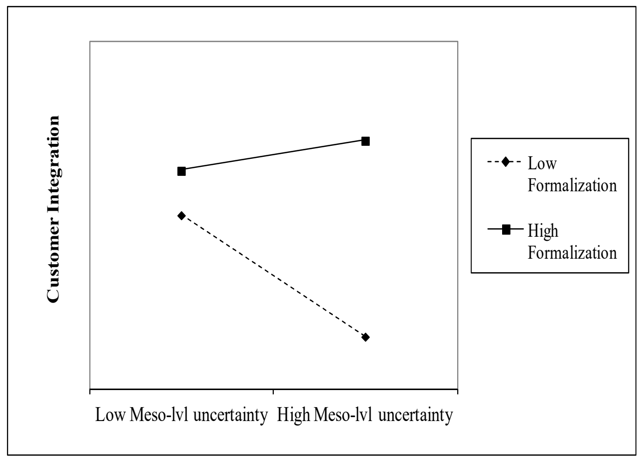
Panel A



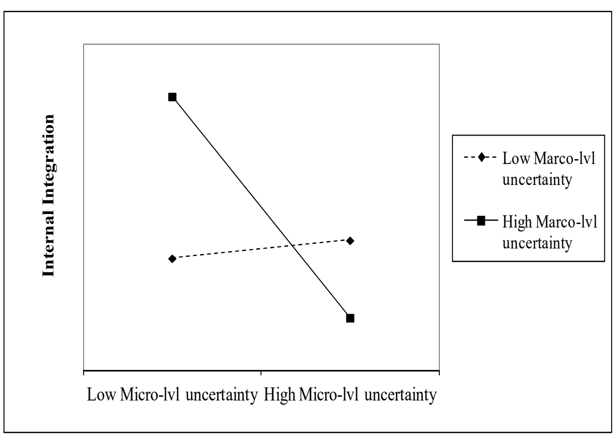
Panel B



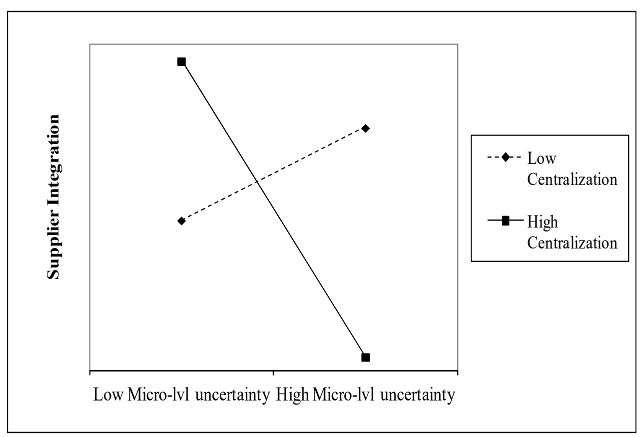
Panel C



Panel D



Panel E



Panel F

TABLE 1
Overview of Literature Related to Supply Chain Uncertainty

Type	Definition	Origins	Implications
Micro-Level Uncertainty	**Variability Around a Mean** Duncan, 1972; Melnyk, et al., 1992; Miller, 1992; Peck, 2006; Van Landgehem & Vanmaele, 2002 **Risk Management** Markowitz, 1952; Miller & Reuer, 1996 Rao & Goldsby, 2009	**Task Characteristics** Tushman & Nadler, 1978; Geary, et al., 2002	**Demand Amplification** Van Langedehem & Vanmaele, 2002; Germain, et al., 2008 **Bracing** Tokay, et al., 2014; Sweeney & Shepperd, 2007 **Bullwhip Effect** Lee et al., 1997; Chen, et al., 2000
Meso-Level Uncertainty	**Lack of Information** Downey & Slocum, 1975; Hult, et al., 2004; DeMeyer, et al., 2002; Sivadasen, et al., 2002 **Information Processing Theory** Galbraith, 1973, 1975, 1977	**Information Withholding** Shrivastava & Mitroff, 1984; Van de Ven & Koenig, 2011 **Information Unavailability** Tushman & Nadler, 1978; Tokar, et al., 2014; Wu & Barnes, 2012	**Acquisition** Stevenson & Spring, 2007; Birou, et al., 2011; Hult, et al., 2004 **Timeliness** Bode et al., 2011; Fisher, 1997; Boone et al., 2007; Hult, et al., 2010 **Distortion** deTreville et al., 2004 Sterman, 1989; Lee, et al., 1997 **Quantity** Tushman & Nadler, 1975; Huber, 1991; Lengel & Daft, 1988
Macro-Level Uncertainty	**Equivocality** Weick, 1979; Daft & Weick, 1984; Daft, et al., 1987 **Media Richness** Daft & Lengel, 1986; Lengel & Daft, 1988	**Low Probability, High Impact Events** Hora & Klassen, 2013; Kauppi, 2012; Thompson, 1967 **Market Turbulence** Beckman, et al., 2004	**Bounded Rationality** Simon, 1957; Thompson, 1967 **Decision Making Heuristics** Tiwana, et al., 2007; Tversky & Kahneman, 1974

TABLE 2
Types of Uncertainty

	Micro-Level Uncertainty	Meso-Level Uncertainty	Macro-Level Uncertainty
Stability of information	Predictable, within a distribution	Unavailable	Rapidly changing, confusing, vague cues
Prior experience	Substantial	Some	Little or none
Source of information	Internal information system	Interconnected information system	Unknown
Managerial questions	Explicit	What if?	Unknown
Uncertainty reduction	Rules, procedures, data	Planning, sensitivity analysis, special reports	Clarify, reach agreement, face-to-face contact
Stability of demand	Stable, predictable	Not shared between supply chain members	Rapidly changing
Supply chain strategy	Efficient supply chain	Responsive supply chain	Integrated supply chain
Problems	Objective, well understood	Explicit	Unclear, poorly defined, not well understood
Organizational structure	Reciprocal interdependence	Reciprocal interdependence	Synthetic organization Reciprocal interdependence

TABLE 3
Descriptive Statistics

Panel 3a: Distribution of Plants by Industry and Country

Industry	Country										
	Finland	Sweden	Germany	Italy	Austria	Japan	South Korea	United States	Brazil	Spain	China
Electronics	14	7	9	10	10	10	10	9	5	9	21
Machinery	6	10	13	10	7	12	10	11	8	9	16
Transportation Components	10	7	19	7	4	13	11	9	9	10	14
Total	30	24	41	27	21	35	31	29	22	28	51

Panel 3b: Industry Characteristics

Characteristic	Overall	Electronics	Transportation Components	Machinery
Average life cycle of products (years)	8.46	7.41	7.32	10.86
Median annual sales volume ($000)	108,250	82,900	133,188	112,936
Number of hourly personnel	479	317	714	396
Number of salaried personnel	724	567	901	705

TABLE 4
Respondents by Scale

	1*	2	3	4	5	6	7	8
Internal Integration			●	●	●			
Supplier Integration	●	●				●		
Customer Integration	●		●			●	●	
Micro-Level Uncertainty	●		●			●		
Meso-Level Uncertainty		●	●	●	●			
Macro-Level Uncertainty			●	●	●		●	
Centralization	●						●	●
Formalization			●	●	●			
Vertical Differentiation – Flatness					●		●	●

*1:Direct Laborers, 2:Inventory Manager, 3: Process Engineer, 4: Plant Manager, 5: Plant Superintendent, 6: Quality Manager, 7: Supervisors, 8: HR

TABLE 5
Measurement Analysis

Items		Std. Coefficient	t-Value
Internal Integration (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	The functions in our plant are well integrated.	.80	---[1]
2	Problems between functions are solved easily, in this plant.	.77	15.60
3	Functional coordination works well in our plant.	.82	16.95
4	The functions in our plant cooperate to solve conflicts between them, when they arise.	.76	15.36
5	Our plant's functions coordinate their activities.	.72	14.27
6	Our plant's functions work interactively with each other.	.79	16.39
7	Our managers communicate effectively with managers in other functions.	.70	13.80
8	Our planning system generates operations plans that do not result in functional conflicts.	.56	10.82
Supplier Integration (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	We actively engage suppliers in our quality improvement efforts.	.80	---[1]
2	We maintain cooperative relationships with our suppliers.	.72	13.72
3	We help our suppliers to improve their quality.	.79	15.14
4	Our key suppliers provide input into our product development projects.	.67	12.46
5	We maintain close communications with suppliers about quality considerations and design changes.	.78	15.07
6	Our suppliers are actively involved in our new product development process.	.60	10.92
7	We work as a partner with our suppliers, rather than having an adversarial relationship.	.39	7.17
Customer Integration (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	We frequently are in close contact with our customers.	.77	---[1]
2	Our customers give us feedback on our quality and delivery performance.	.66	11.53
3	Our customers are actively involved in our product design process.	.63	11.02
4	We strive to be highly responsive to our customers' needs.	.66	11.30
5	Our customers involve us in their quality improvement efforts.	.64	10.79
6	We work as a partner with our customers.	.50	9.04
Micro-Level Uncertainty (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	The demand for our plant's products is unstable and unpredictable.	.43	---[1]
2	Manufacturing demands are stable in our firm (reverse-coded).	.84	7.53
3	Our total demand, across all products, is relatively stable (reverse-coded).	.84	7.56
4	We need better accuracy in our demand forecasts.	--[2]	--[2]
Macro-Level Uncertainty (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	Our competitive pressures are extremely high.	.71	---[1]
2	Competitive moves in our market are slow and deliberate, with long time gaps between different companies' reactions (reverse-coded).	.42	4.97
3	The needs and wants of our customers are changing very fast.	.33	4.27
4	Our customers' needs and wants are difficult to ascertain.	--[2]	--[2]
Centralization (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	Even small matters have to be referred to someone higher up for a final answer.	.83	---[1]
2	Any decision I make has to have my boss's approval.	.85	17.19
3	There can be little action taken here until a supervisor approves a decision.	.78	15.71
Formalization (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	Our plant has a formal strategic planning process, which results in a written mission, long-range goals and strategies for implementation.	.87	---[1]
2	This plant has a strategic plan, which is put in writing.	.85	18.17
3	Plant management routinely reviews and updates a long-range strategic plan.	.70	14.33
4	The plant has an informal strategy, which is not very well defined (reverse-coded).	.63	12.42
Flatness (Likert scale, 7=strongly agree, 1=strongly disagree)			
1	Our organization structure is relatively flat.	.57	---[1]
2	There are few levels in our organizational hierarchy.	.53	12.06
3	Our organization is very hierarchical (reverse-coded).	.88	8.93
4	Our organizational chart has many levels (reverse-coded).	.65	11.72

[1] Anchor Indicators, [2] Items dropped from new multi-item scales at the EFA stage
Measurement Model Fit Indices: $\chi^2(624)=1151.48$, $\chi^2/df=1.84$, CFI=0.91, NNFI=0.90, RMR=0.057, RMSEA=0.049 & P-Value for Test of Close Fit (RMSEA < 0.05) = 0.63

TABLE 6
Correlation Coefficients

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Internal Integration	5.25	.62	.91[a]													
2. Supplier Integration	5.20	.53	.42**	.86												
3. Customer Integration	5.39	.53	.38**	.49**	.81											
4. Macro-Level Uncertainty	5.20	.69	.27**	.21**	.17**	.49										
5. Micro-Level Uncertainty	3.95	.93	-.13*	-.22**	-.16**	.17**	.76									
6. Meso-Level Customer Uncertainty	4.18	1.15	-.07	-.18**	-.23**	-.07	.22**	-								
7. Meso-Level Internal Uncertainty	2.40	1.04	-.37**	-.17**	-.31**	-.09	-.13*	.00	-							
8. Meso-Level Supplier Uncertainty	3.11	1.10	-.19**	-.42**	-.15**	-.20**	.25**	.36**	-.01	-						
9. Centralization	3.51	.90	-.16**	-.11*	-.25**	-.04	-.24**	-.06	.34**	-.04	.86					
10. Formalization	5.25	.87	.56**	.37**	.37**	.21**	-.13*	-.11*	-.42**	-.22**	-.20**	.84				
11. Vertical Differentiation-Flatness	4.49	.90	.20**	.09	.24**	-.04	.04	.08	-.20**	.07	-.49**	.15**	.76			
12. Industry 1[b]	N/A	N/A	.10	.08	.06	.10	.22**	.04	-.00	-.00	-.06	.03	.02	-		
13. Industry 2[b]	N/A	N/A	-.02	.03	.14**	-.03	-.28**	-.10	-.04	-.09	.02	.14*	.03	-.50**	-	
14. Plant Size	1203	2.30	.04	.11	-.02	.04	-.28**	-.25**	.14*	-.20**	.17**	.18**	-.22**	.04	-.02	-

****p<.001, **p<.01, *p<.05*

[a] *Composite reliabilities appear on the diagonal only for multi-item variables*

[b] *Categorical variable*

TABLE 7
Regression Results for Internal Integration

	Step 1	Step 2	Step 3	Step 4
Industry1	.120	.045	.045	.051
Industry2	.053	-.098	-.099	-.104*
Size	.052	.020	.018	.011
Micro-Level Uncertainty		-.163***	-.160**	-.165**
Meso-Level Uncertainty		-.184***	-.171***	-.170**
Macro-Level Uncertainty		.184***	.190***	.164***
Centralization		.024	.009	-.005
Formalization		.415***	.416***	.450***
Vertical Differentiation-Flatness		.133**	.133**	.125
Micro-Level x Meso-Level Uncertainty			-.004	-.051
Micro-Level x Macro-Level Uncertainty			-.027	-.029
Meso-Level x Macro-Level Uncertainty			-.058	-.034
Micro-Level Uncertainty x Centralization				-.001
Macro-Level Uncertainty x Centralization				-.054
Meso-Level Uncertainty x Centralization				.028
Micro-Level Uncertainty x Formalization				-.123*
Macro-Level Uncertainty x Formalization				.022
Meso-Level Uncertainty x Formalization				.019
Micro-Level Uncertainty x Vert. Diff. - Flatness				-.010
Macro-Level Uncertainty x Vert. Diff. – Flatness				.022
Meso- Level Uncertainty x Vert. Diff. - Flatness				.038
R^2	*.014*	*.392*	*.396*	*.414*
F	*1.54*	*23.00****	*17.36****	*10.42****
Adjusted R^2	*.005*	*.375*	*.373*	*.374*
$F \Delta R^2$	--	*33.27****	*.65*	*1.08*

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

TABLE 8
Regression Results for Customer Integration

	Step 1	Step 2	Step 3	Step 4
Industry1	.176**	.124*	.123*	.109
Industry2	.245***	.129*	.124*	.106
Size	-.036	-.065	-.069	-.074
Micro-Level Uncertainty		-.145***	-.152**	-.167**
Meso-Level Uncertainty		-.206***	-.209***	-.230***
Macro-Level Uncertainty		.132***	.133**	.112**
Centralization		-.154**	-.164**	-.169**
Formalization		.209***	.198***	.200***
Vertical Differentiation-Flatness		.139*	.141*	.145*
Micro-Level x Meso-Level Uncertainty			-.039	-.038
Micro-Level x Macro-Level Uncertainty			-.056	-.063
Meso-Level x Macro-Level Uncertainty			.021	.009
Micro-Level Uncertainty x Centralization				-.122*
Macro-Level Uncertainty x Centralization				-.028
Meso-Level Uncertainty x Centralization				-.023
Micro-Level Uncertainty x Formalization				-.127*
Macro-Level Uncertainty x Formalization				.020
Meso-Level Uncertainty x Formalization				.110*
Micro-Level Uncertainty x Vert. Diff. - Flatness				-.063
Macro-Level Uncertainty x Vert. Diff. – Flatness				.069
Meso- Level Uncertainty x Vert. Diff. - Flatness				.031
R^2	*.049*	*.268*	*.273*	*.309*
F	*5.61****	*13.09****	*9.96****	*6.57****
Adjusted R^2	*.040*	*.248*	*.246*	*.262*
$F\ \Delta\ R^2$	--	*16.06****	*.68*	*1.76*

** p<0.05, ** p<0.01, *** p<0.001*

TABLE 9
Regression Results for Supplier Integration

	Step 1	Step 2	Step 3	Step 4
Industry1	.129*	.075	.076	.065
Industry2	.097	-.041	-.046	-.040
Size	.056	-.032	-.029	-.034
Micro-Level Uncertainty		-.180***	-.180***	-.224***
Meso-Level Uncertainty		-.316***	-.320***	-.318***
Macro-Level Uncertainty		.122*	.124*	.125*
Centralization		-.079	-.086	-.079
Formalization		.227***	.210***	.196***
Vertical Differentiation-Flatness		.040	.045	.073
Micro-Level x Meso-Level Uncertainty			.010	-.020
Micro-Level x Macro-Level Uncertainty			-.085	-.127*
Meso-Level x Macro-Level Uncertainty			.043	.028
Micro-Level Uncertainty x Centralization				-.158*
Macro-Level Uncertainty x Centralization				-.095
Meso-Level Uncertainty x Centralization				-.089
Micro-Level Uncertainty x Formalization				-.011
Macro-Level Uncertainty x Formalization				.002
Meso-Level Uncertainty x Formalization				.092
Micro-Level Uncertainty x Vert. Diff. - Flatness				-.064
Macro-Level Uncertainty x Vert. Diff. – Flatness				-.052
Meso- Level Uncertainty x Vert. Diff. - Flatness				-.070
R^2	*.017*	*.290*	*.298*	*.341*
F	*1.91*	*14.62****	*11.27****	*7.65****
Adjusted R^2	*.008*	*.276*	*.271*	*.297*
F Δ R^2	--	*20.63****	*1.16*	*2.28***

** p<0.05, ** p<0.01, *** p<0.001*