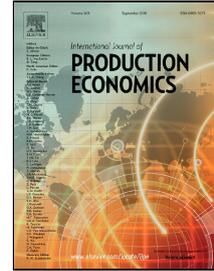# Accepted Manuscript

Impact of Supply Chain Risk on Agility Performance: Mediating Role of Supply Chain Integration

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**ABSTRACT**

Supply chain literature highlights the importance of agility performance for firms facing supply chain risk. However, the literature explaining the ways in which companies facing supply chain risk organize the key elements of their supply chain to enhance agility performance provides space for more research. We use dynamic capabilities view to explain why supply chain risk may motivate companies integrate their supply chain to enhance agility performance. Structural equation modelling is used to test the hypotheses using data of 770 manufacturing companies obtained from the sixth version of International Manufacturing Strategy Survey. Empirical examination provides evidence that (a) a firm's supply chain risk has positive association with supplier and customer integration, (b) supplier, internal, and customer integration have positive impact on agility performance, though the impact of internal integration is weak, (c) supplier and customer integration mediate the relationship between a firm's supply chain risk and agility performance, and (d) supplier and customer integration mediate the relationship between internal integration and agility performance. The findings of this paper suggest that companies cope with supply chain risk by using integrative practices with suppliers and customers that enhance agility performance. Internal integration is the foundation for building up supplier and customer integration for agility performance. Future research may examine these relationships over time and in different industries and contexts.

**KEYWORDS**

**INTRODUCTION**

Increasing globalization, rapid technological development, and evolving competitive advantages hamper the organization's ability to anticipate and manage behavior of its supply chain partners (Tang and Musa, 2011, Tang, 2006). The lack of organizational ability to anticipate and favorably influence the behavior of various entities within the organization's supply chain has resulted in supply chain risk (Brindley, 2004, Tummala and Schoenherr, 2011). Consequently, the last couple of decades have seen examples of companies suffering from uncertainty in the environment resulting in performance damages. Incidents like a fire at the Philips semiconductor plant in 2000 disrupted the production process leading to a $400 million loss to Ericsson (Chopra and Sodhi, 2004). Similarly, in 2011, Toyota's production dropped by 40,000 vehicles costing a loss of $72 million per day due to earthquake, tsunami and nuclear disaster in Japan (Pettit *et al.*, 2013). Therefore, in order to avoid such huge losses, considerable attention has been given to supply chain risk by both practitioners and academia (Colicchia and Strozzi, 2012).

The research on supply chain risk has delved into two broad issues that are relevant here: sources and antecedents of supply chain risk, and management and consequences of supply chain risk (Appendix A provides a list of representative studies.). It is argued that supply chain risk may originate from several sources (Norrman and Jansson, 2004) such as a firm's supply and customer base, regulatory regime (Tummala and Schoenherr, 2011), forecasting capability, transportation means (Gaudenzi and Borghesi, 2006), labor issues (Jiang *et al.*, 2009), and firm size (Thun *et al.*, 2011). These factors enhance a firm's network complexity that combined with efficiency objectives increase the firm's supply chain risks (Thun and Hoenig, 2011). Extending the discussion on sources and antecedents of supply chain risk several authors have proposed and empirically examined frameworks for management and consequences of supply chain risk. The qualitative or literature review based research in this direction presents various supply chain risk management frameworks (Ritchie and Brindley, 2007, Blos *et al.*, 2009, Tummala and Schoenherr, 2011). These frameworks seek to present organizational strategies and programs to manage risk for maintaining competitive performance (Diabat *et al.*, 2012).

The empirical research based on large scale data, though fairly limited in this stream (Ho *et al.*, 2015), has proposed managing supply chain risk through various approaches such as developing warning and recovery capability (Riley *et al.*, 2016), efficient consumer response capability (Kotzab, 1999), continuous improvement (Kern *et al.*, 2012), demand deviation and inventory management (Hung and Ryu, 2008, Zepeda *et al.*, 2016), intra- and inter-organizational contingency planning (Richey *et al.*, 2009), supply chain security (Speier *et al.*, 2011), and supply chain and market orientation (Gligor *et al.*, 2016). A key insight in these studies investigating management of supply chain risk is that the companies facing supply chain risk need to outperform others on agility performance, thus presenting agility performance as a solution to supply chain risk (Christopher and Peck, 2004, Gligor *et al.*, 2016, Lee, 2004, Wieland and Marcus Wallenburg, 2012, Braunscheidel and Suresh, 2009, Abrahamsson *et al.*, 2015). Scholars argue that agility performance ensuing from a company's ability to avoid or minimize disruption in the delivery of right products to their customers regardless of the unwanted changes in their supply chain (Sangari and Razmi, 2015, Das, 2001) is "the key to survival in these changed conditions" i.e. increasing complexity, volatility and uncertainty (Christopher 2000, p. 37). Hence some initial attempts have been made to empirically examine organizational response to supply chain risk for achieving agility performance (Gligor *et al.*, 2016, Wieland and Marcus Wallenburg, 2012). For example, Gligor *et al.* (2016) examined the argument that a firm's environmental uncertainty may require a firm to enhance supply chain and market orientation for improving supply chain agility. However, there is a need for empirical research (see Appendix A) seeking to explain the ways in which companies facing supply chain risk may organize their supply chain to enhance the agility performance (Ho *et al.*, 2015, Sodhi *et al.*, 2012, Stonebraker and Liao, 2004, Wong and Boon-itt, 2008, Zhao *et al.*, 2013).This paper seeks to make a contribution in this direction.

We use Resource Based View (RBV), with particular emphasis on Dynamic Capabilities View (DCV), to propose relationships between a firm's supply chain risk, supply chain integration, and agility performance (Wernerfelt, 1984, Teece, 2007). DCV has been used in earlier studies seeking to understand the relationship between uncertainties in supply chain and organizational actions and outcomes (Kauppi *et al.*, 2016, Li *et al.*, 2008, Brusset and Teller, 2017, Abrahamsson *et al.*, 2015). The DCV logic draws that

an organization operating in a dynamic environment and facing uncertainties in the supply chain needs to develop capabilities to manage the uncertainties and the ensuing supply chain risk (Teece, 2007). These capabilities enhance communication, coordination, and joint action with critical actors in the supply chain to sense and seize opportunities as well as reconfigure to adapt to the ecosystem (Eisenhardt and Martin, 2000). These capabilities help the organization to plan and execute the organizational function and achieve desired outcomes in a robust manner (Williams *et al.*, 2013).

Inspired from DCV, we posit that companies facing supply chain risk seek to enhance supply chain integration, which entails integration among key elements inside (i.e. internal functional units) and outside the firm (i.e. key suppliers and customers). To this extent, our argument seems to mismatch with the earlier work linking supply chain risk and supply chain integration by Zhao *et al.* (2013). Zhao *et al.* (2013) argue that supply delivery and demand variability risks generate inaccurate and unreliable information, which can render supply chain integration ineffective, inefficient, and thus unattractive. Our argument, consistent with the literature, is that supply chain integration may actually provide "end-to-end" visibility and can address the problem of inaccurate and unreliable information and be a firm's supply chain risk management capability (Christopher and Lee, 2004, Wong and Boon-itt, 2008, Riley *et al.*, 2016, Skjoett-Larsen *et al.*, 2006, Derrouiche *et al.*, 2008). A real life example supporting our argument is a Spanish brand Zara that can complete a design to delivery cycle in just few weeks because of the firm's closely connected and highly synchronized supply chain. Companies like Zara, having increasingly global and risk prone supply chains, can maintain such a high degree of agility and confidence because of transparency of information, joint action, configurability, and adaptation (Christopher and Lee, 2004). Thus, drawing from DCV and the supply chain literature it makes sense to argue for a positive relationship from firm's supply chain risk to supply chain integration.

Next, seeking insights from DCV we argue that supplier, internal, and customer integration capabilities have a positive impact on agility performance. In addition, we hypothesize for the presence of mediation effects of the three dimensions of supply chain integration between a firm's supply chain risk and agility performance. These mediation hypotheses seek to explain that supply chain integration may

provide response mechanisms to companies facing supply chain risk to outperform others on agility performance. To our knowledge, our study is one of the first to empirically examine this linkage from firm's supply chain risk to supply chain integration to agility performance. Finally, we argue for the mediation effect of supplier and customer integration between internal integration and agility performance. The earlier studies, reporting inconsistent evidence for the mediation effect of supplier and customer integration between internal integration and organizational performance, provide motivation for this investigation (Cheng *et al.*, 2016, Koufteros *et al.*, 2005). We test the hypotheses using the data obtained from the sixth version of International Manufacturing Strategy Survey (IMSS VI).

Overall, we seek to present a novel and detailed explanation and empirical examination of why presence of supply chain risk may motivate firms to develop supply chain integration mechanisms as means to enhance agility performance. The remaining paper is organized as follows. In the following section, a research framework is developed along with the hypotheses. Thereafter, a detailed research methodology section consisting of scale development, data collection, hypotheses testing, and results is presented. Finally, we report and discuss our findings and conclude with theoretical and managerial implications, and directions for future research.

**RESEARCH FRAMEWORK**

**Supply Chain Risk**

The extant research defines a firm's supply chain risk in multiple ways (Ho *et al.*, 2015, Ellis *et al.*, 2010, Jüttner *et al.*, 2003, Zsidisin, 2003, Zhao *et al.*, 2013). Nevertheless, a common theme in these definitions is that probable events leading to disruptions of a firm's key supply sources (Zsidisin, 2003, Ellis *et al.*, 2010, Zhao *et al.*, 2013), internal operations (Tummala and Schoenherr, 2011, Christopher and Peck, 2004), and delivery means (Ravindran *et al.*, 2010, Zhao *et al.*, 2013) set a firm's supply chain at risk. Similarly, various approaches have been proposed to operationalize firm's supply chain risk. While few authors have argued in favor of using the impact of a possible disruption as a measure of a firm's supply chain risk (Wagner and Bode, 2008), others have argued in favor of using the probability (Zsidisin, 2003) or a combination of probability and impact of a possible disruption to measure a firm's supply chain risk

(Aminbakhsh *et al.*, 2013, Ho *et al.*, 2015). A key motivation behind defining and operationalizing firm's supply chain risk from different standpoints mentioned above is the suitability to a certain research domain and set of research objectives.

Adapting from the earlier definitions, here a firm's supply chain risk is defined as a combination of likelihood and impact associated with the disruption of a firm's supply, internal-manufacturing, and delivery operations, i.e., the entire set of a firm's supply chain activities (Jüttner *et al.*, 2003, Zsidisin, 2003, Ho *et al.*, 2015, Zhao *et al.*, 2013). Importantly, our definition aggregates the risk from the three sources together to define a firm's supply chain risk because disruption at any of these areas can affect the firm's whole supply chain functioning (Bogataj and Bogataj, 2007, Jüttner *et al.*, 2003). For example, supply delivery or demand variability related disruptions do not only impact supply and demand functions respectively but each of these disruptions affect all three dimensions of a firm's supply chain functions i.e. supply side, internal functions, and delivery side (Zhao *et al.*, 2013). Thus, in this research a firm's supply chain risk is an aggregated factor based on the three supply chain risk dimensions (supply, internal, and delivery operations). In addition, we use the product of likelihood and impact of disruption, as opposed to using either likelihood or impact, to assess supply chain risk (Tummala and Schoenherr, 2011, Ho *et al.*, 2015, Aminbakhsh *et al.*, 2013). A combination of likelihood and impact of disruption represents the effective risk in each area (Norrman and Jansson, 2004, Group, 1992).

**Supply Chain Integration**

The strategic collaboration with key supply chain partners and an effective and efficient management of intra- and inter-organizational activities related to the flow of products, services, information, finance and joint decision-making are identified as supply chain integration (Zhao *et al.*, 2008, Childerhouse and Towill, 2011, Schoenherr and Swink, 2012). The literature presents three main dimensions of supply chain integration: supplier integration, internal integration, and customer integration (Frohlich and Westbrook, 2001, Zhao *et al.*, 2011). Internal integration refers to the extent to which an organization has structured the procedures, practices, and behaviors of its internal functional units to achieve mutual collaboration and synchronization for fulfilling customer requirements (Chen and Paulraj,

2004). The communication by information sharing and cooperation by joint decision-making among the functional units or departments are the two key features of internal integration (Ellinger *et al.*, 2000). The functional units share information about sales forecasts, production schedules, and existing inventories over organizational management information systems (Narasimhan and Kim, 2001). Similarly, these units work together rather than in silos for product and process improvement (Koufteros *et al.*, 2001). Some authors argue that internal integration provides the foundation to achieve higher-level practices of supply chain integration, that is termed, external integration (Cheng *et al.*, 2016, Zhao *et al.*, 2011).

External integration, which can be further divided into supplier integration and customer integration (Koufteros *et al.*, 2005, Droge *et al.*, 2004), refers to the extent to which a firm partners with its key customers and suppliers to build their inter-organizational strategies, processes, policies, and actions into collaborative and synchronized processes for mutual value (Chen and Paulraj, 2004, Zhao *et al.*, 2011, Frohlich and Westbrook, 2001). Supplier integration includes the flow of information and product, control and planning, mutually active and engaged partnerships, and trust and commitment between buyer and supplier (Vijayasarathy, 2010). The buyer considers key suppliers as strategic collaborators and develops their technological and managerial capabilities (Jajja *et al.*, 2016). These complementary capabilities are leveraged in product development, production and delivery. Both parties develop effective and efficient mechanisms to share information about product design and development, marketing plans, production schedules, inventory levels, and delivery systems (Lau *et al.*, 2010, Devaraj *et al.*, 2007). In global supply sources, buyers even send their technical teams and develop international platforms, such as buying houses, to work jointly and provide assistance to their off-shore suppliers (Christopher, 2000).

Customer integration entails involvement with key customers to understand their requirements and align organizational functions to create value for customers (Koufteros *et al.*, 2005). Involvement of the customers may cover activities ranging from idea generation to management of production and delivery of products. Companies develop and adopt various approaches to understand and engage with their customers in product and process development (Lau *et al.*, 2010). Engagement and collaboration with key customers in product design and joint decision-making can help companies understand customer problems and reduce

uncertainties about customer expectations (Koufteros *et al.*, 2005). Similarly, organizations develop systems to share information and synchronize planning to jointly manage operational and production challenges (Devaraj *et al.*, 2007). It enables companies to develop a collaborative relationship with key customers and leverage each other's capabilities to enhance mutual value.

**Agility Performance**

Supply chain literature has conceptualized agility at multiple levels, ranging from being a paradigm to strategy to capability to performance dimension (Narasimhan *et al.*, 2006, Tallon and Pinsonneault, 2011, Sarkis *et al.*, 2007, Yusuf *et al.*, 2014, Sangari and Razmi, 2015). As a paradigm, agile manufacturing is defined as a system of practices, also containing philosophical, value, and cultural elements, using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace (Narasimhan *et al.*, 2006, Ben Naylor *et al.*, 1999). At strategic level, agile strategy refers to the organizational direction and commitment towards quick and effective response to changing customer needs (Jayaram *et al.*, 2010, Qi *et al.*, 2009, Lee, 2002, White *et al.*, 2005). At capability level, agility refers to a firm's ability to perform operational activities together with channel partners in order to adapt or respond to marketplace changes in a rapid manner (Kauppi *et al.*, 2016, Blome *et al.*, 2013a, Law and Gunasekaran, 2012, Swafford *et al.*, 2008, Swafford *et al.*, 2006a, Swafford *et al.*, 2006b). At performance level, agility performance outcomes and metrics generally relate to enhanced product customization, shortened new product development and lead time, reduced system changeover time and cost, and efficient scaling up and down of operations (Sarkis *et al.*, 2007, Das, 2001, Narasimhan *et al.*, 2006, Paulraj and Chen, 2007b). Narasimhan *et al.* (2006) mention that sometimes researchers mix these levels in defining and operationalizing the aspect of agility under investigation. Thus it is important to clearly define how agility is conceptualized in a research.

In this research, we have focused on agility performance so as to see how supply chain risk and integrative practices affect agility outcomes and metrics. Yauch (2011) argues that since there are myriad of ways to develop agility and subtle differences in organizational agility cannot be empirically observed, agility should be judged by performance metrics. The emphasis on agility performance in this research is

also well placed because the organizational need to perform on agility metrics is considered directly proportionate to the turbulence in the organization's internal and external business environment (Sharifi and Zhang, 2001, Sangari and Razmi, 2015, Gligor *et al.*, 2016). Several authors argue that as environmental uncertainty increases organizations endeavor to outperform their competitors on agility performance metrics (Christopher and Lee, 2004, Braunscheidel and Suresh, 2009, Hoyt *et al.*, 2007, Yusuf *et al.*, 2014). This is because agility performance incorporates those supply chain performance outcomes that indicate achieving success and competitiveness in the dynamic and turbulent business environment (Sangari and Razmi, 2015).

Previous studies have used various combinations of performance indicators to define agility performance (Narasimhan *et al.*, 2006). For example, Paulraj and Chen (2007b) use flexibility, time, delivery, and responsiveness as the four critical factors of agility performance in the context of logistics management. Similarly, others have associated cycle time, delivery speed and reliability, customization, new product introduction, and flexibility with agility performance (Das, 2001, Prince and Kay, 2003, Brown and Bessant, 2003, Narasimhan *et al.*, 2006). The diverse dimensions of agility performance can be merged into three common areas in manufacturing organizations (See Table 1): delivery performance in terms of delivery speed and reliability, flexibility performance in terms of volume and mix flexibility, and design performance in terms of new product introduction and product customization. Thus, based on the prior literature, agility performance in this research refers to a combination of metrics measuring organizational responsiveness to market needs in areas of design, delivery, and flexibility (Sangari and Razmi, 2015, Yauch, 2011, Narayanan *et al.*, 2015). These performance dimensions play a critical role in how an organization changes its operational state under uncertain and changing demands (Narasimhan *et al.*, 2006, Yauch, 2011).

Table 1. Agility performance metrics

| Author(s) | Delivery | | Flexibility | | Design | |
|---|---|---|---|---|---|---|
| | Speed | Reliability | Volume | Mix | New product | Customization |

| | | | | | | |
|---|---|---|---|---|---|---|
| Narayanan *et al.* (2015) | | | | ✓ | ✓ | ✓ |
| Sangari and Razmi (2015) | ✓ | ✓ | | | ✓ | ✓ |
| Vinodh *et al.* (2012) | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Yauch (2011) | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Li *et al.* (2008) | ✓ | | ✓ | ✓ | | ✓ |
| Sarkis *et al.* (2007) | ✓ | ✓ | ✓ | ✓ | | |
| Paulraj and Chen (2007b) | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Narasimhan *et al.* (2006) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Das (2001) | ✓ | ✓ | | | ✓ | ✓ |
| Power *et al.* (2001) | | ✓ | | ✓ | ✓ | |

## HYPOTHESES

### Dynamic Capabilities View

The roots of DCV in part originate from the theoretical extensions of RBV (Teece *et al.*, 1997). RBV argues that firms consist of a bundle of resources that are distributed heterogeneously among the firms and the distributional differences persist over time (Wernerfelt, 1984). Further, RBV argues that an organization's resources that are rare, valuable, inimitable, and non-substitutable may provide sustained competitive advantage and thus superior competitive performance (Eisenhardt and Martin, 2000). RBV has been criticized on the grounds that it assumes that a firm's environment is static and relatively unchanged (D'Aveni, 1994). It is argued that the assumptions of RBV do not hold in dynamic markets that are attributed as having unclear market boundaries, non-linear and unpredictable changes, lack of clarity regarding successful business models, and ambiguous and shifting market players (Eisenhardt and Martin, 2000). Thus, in dynamic markets, over time, the resource advantage may become less important or diminish (Teece, 2007).

Extending RBV, DCV stresses the importance of the dynamic capability building processes in gaining competitive advantage (Eisenhardt and Martin, 2000, Teece *et al.*, 1997). A Dynamic Capability (DC) can be defined as the firm's ability to integrate, build, and reconfigure internal and external resources

to address rapidly changing environment (Teece *et al.*, 1997). According to Teece and Pisano (1994) DCs of a firm may reside in three domains – processes, positions, and paths. Processes refer to the managerial and organizational ways of doing things in a firm. Processes may also be referred to as a firm's 'routines' or patterns of current practice and learning. Positions refer to a firm's current endowment of technology and intellectual property, as well as the firm's customer base and upstream relations with suppliers. Paths refer to the strategic alternatives available to a firm and the attractiveness of opportunities that lie ahead. DCV argues that when the ecosystem in which the firm is embedded is unstable it needs to continuously reinvent itself (Teece, 2007). Thus, the firm develops dynamic capabilities that lend it the mechanism to direct the firm's internal and external resources consistent with marketplace needs and imperatives (Eisenhardt and Martin, 2000, Teece *et al.*, 1997, Helfat *et al.*, 2009).

**Supply Chain Risk and Supply Chain Integration**

The DCV literature consistently employs terms such as "coordinate," "combine," "configure," and "integrate" to describe the process of dynamic capability development (Eisenhardt and Martin, 2000, Barreto, 2010) – all referring to the core elements of supply chain integration. Thus, scholars have argued that supply chain integration, which is a set of managerial and organizational routines, is a DC as each dimension of supply chain integration (i.e. supplier, internal, and customer) enables integrating, sensing, learning, and coordinating (Baofeng, 2012, Vickery *et al.*, 2013). These core concepts emphasize working effectively across organizational boundaries – both intrafirm and interfirm – thus providing a network of partners having close relationships and linkages. The close relationships and linkages lead to the creation of a shared understanding and collective sense-making, enhancing the identification and interpretation of opportunities in the environment in an efficient and effective way. This same network feeds a continual stream of new knowledge that can be used to revamp existing capabilities (resources and processes) and develop new ones to respond to the opportunities. Finally, such network also stimulates the firm's partners to identify synergies among their varied tasks, activities, and resources, leading to better orchestration and deployment of the firm's competitive capabilities. In doing so, supply chain integration lends the mechanisms that work as a DC (Allred *et al.*, 2011, Vickery *et al.*, 2013).

DCV infers that in rapid and unpredictable markets firms seek to develop dynamic capabilities by which managers 'integrate, build, and reconfigure internal and external competencies' (Teece et al., 1997: 516) to maintain sustained competitive advantage (Eisenhardt and Martin, 2000). Thus scholars have argued that the presence of uncertainty leads to development of DCs such as supply chain orientation and integration, though large-scale empirical examination of this argument is limited (Wong and Boon-itt, 2008, Stonebraker and Liao, 2004, Sheffi, 2001, Gligor *et al.*, 2016). These capabilities are required to adapt to changing needs and opportunities in the organization's network. In supply chain risk management literature, however, some scholars have presented a reverse argument that integrative practices are means to reduce supply chain risk thus presenting the direction of relationship from integration to risk (Faisal *et al.*, 2007, Faisal *et al.*, 2006, Abrahamsson *et al.*, 2015). They argue that information sharing, collaborative relationship, trust, alignment of incentives, and common knowledge of risk among supply chain partners reduce disruption risk - impact or uncertainty or both (Norrman and Jansson, 2004, Faisal *et al.*, 2006). Both arguments, however, presume and appreciate that potential risk is the original factor driving organizational strategies and actions for management of risk (Ritchie and Brindley, 2007, Norrman and Jansson, 2004, Gligor *et al.*, 2016) because in the absence of risk potential, management of risk is not imperative. Thus, our theorization begins from supply chain risk. We use DCV (Eisenhardt and Martin, 2000, Teece *et al.*, 1997) to argue that firms facing supply chain risk, which is an inevitable reality ensuing from environmental dynamism and uncertainty (Trkman and McCormack, 2009, Jüttner, 2005), develop supply chain integration practices - a set of DCs (Allred *et al.*, 2011, Vickery *et al.*, 2013, Baofeng, 2012, Teece *et al.*, 1997). Below, we develop the association between supply chain risk and the three dimensions of supply chain integration. Figure 1 illustrates the theoretical model of this study.
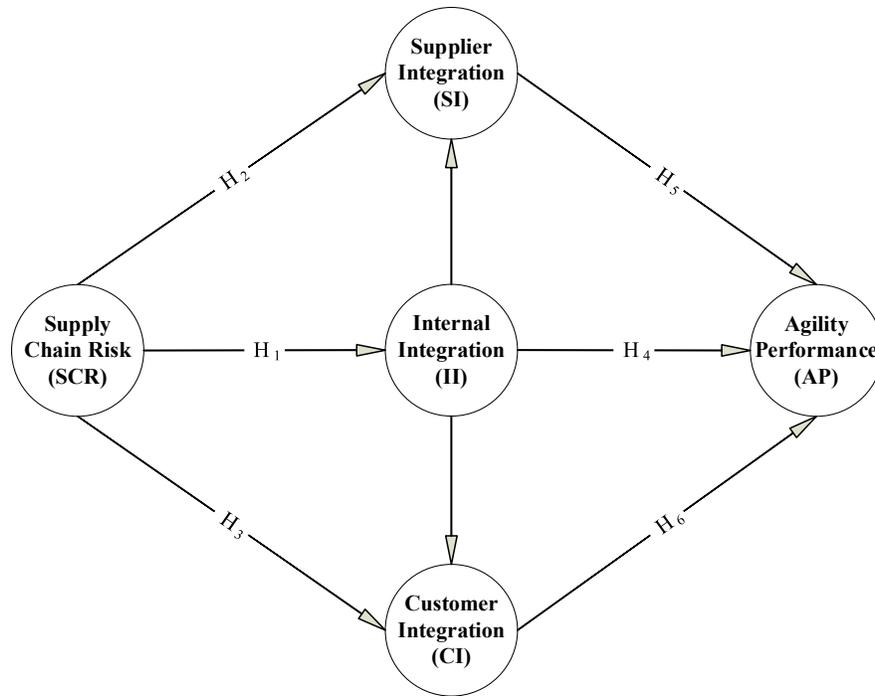
| H₇: SCR → II → SI | H₁₀: II → CI → AP |
|---|---|
| H₈: SCR → II → CI | H₁₁: SCR → II → AP |
| H₉: II → SI → AP | H₁₂: SCR → SI → AP |
| H₁₃: SCR → CI → AP | |

Direction of arrows indicates direction of positive relationship.

Figure 1. Hypothesized model

In a dynamic environment, organizations continuously and intensively scan the environment in their supply chain and share information among key functional units of the organization (Teece *et al.*, 1997, Eisenhardt and Martin, 2000). Scholars argue that as the degree of environmental uncertainty increases the need for environmental scanning, particularly through human interaction which is considered richer and quicker, increases (Ebrahimi, 2000, Elenkov, 1997, May *et al.*, 2000). These scanning and interacting routines build unique relationships and specialized knowledge within a firm (Teece *et al.*, 1997, Eisenhardt and Martin, 2000). The scanning behavior is essential because changes in the environment require quick changes and readjustments in operational strategies, plans, and actions (Tang, 2006). The sharing of knowledge regarding demand-side changes that come from marketing and sales unit, and supply-side

changes that come from purchasing unit play a critical role in the organizational analysis and sense making (Lee *et al.*, 2007). This happens by direct engagement with internal customers to understand requirements, codifying these requirements into a coherent statement of need and effectively communicating them to the supply market (Handfield *et al.*, 2015). The provision of this analysis to key stakeholders in the organization is a basic input in operational and tactical level decision-making process. The robustness of emerging strategies and actions increases with availability of relevant information and inclusion of relevant stakeholders in the decision-making process. Thus, it can be argued that risk in the supply chain may lead to more information sharing and joint decision making among key stakeholders in the organization. Hence we hypothesize:

*$H_1$: Firm's supply chain risk makes the firm increase internal integration*

Drawing from DCV, scholars have argued that supplier integration can be considered a dynamic capability that is needed to maintain adaptation to environmental changes (Vanpoucke *et al.*, 2014, Stonebraker and Liao, 2004, Fawcett *et al.*, 2011). DCV suggests that under dynamic environments, buyers enhance their communication and collaboration processes with existing and potential partners such as suppliers (Eisenhardt and Martin, 2000, Teece, 2007). Thus it can be argued that supply chain risk motivates firms to work closely with key suppliers to make sense of supply market and maintain adaptability in supply functions (Christopher and Peck, 2004, Stonebraker and Liao, 2004). Communication and collaboration processes with the key suppliers provide an essential route to scanning the supply market, learning from suppliers, and influencing the suppliers' decision-making and behavior (Lau *et al.*, 2010, Elenkov, 1997, Fliess and Becker, 2006). These processes lend the mechanisms to understand, develop, and benefit from the suppliers' capabilities. For example, collaborative buyers would engage key suppliers in product/process development and for mutual capability alignment (Fliess and Becker, 2006). The supplier, as a result, sees value in this nature of the relationship that in turn lends power to influence to the buyer (Paulraj *et al.*, 2006). The active, engaging, long-term, and mutually beneficial relationship motivates the

supplier to extend the cooperation even in unusual or disruptive circumstances (Paulraj and Chen, 2007a). This type of understanding and relationship enables the buyer to explore and reconfigure the resources and capabilities of its key suppliers to manage supply chain risks (Lau *et al.*, 2010). Thus, in a risky supply chain environment, it makes sense for buyers to develop multiple ways to enrich the interaction with the key suppliers. This leads us to the hypothesis:

*$H_2$: Firm's supply chain risk makes the firm increase supplier integration*

Finally, DCV suggests that companies operating in dynamic environment seek to develop the capabilities needed for sensing and responding to changes in the demand market (Teece *et al.*, 1997, Eisenhardt and Martin, 2000). Using the DCV logic, Gligor *et al.* (2016) argue that in environments characterized by high uncertainty firms seek to develop processes, that work as DCs, to generate, disseminate (to relevant functionaries), and respond to market intelligence. On similar lines, Stonebraker and Liao (2004) argue that environmental turbulence, which ensues from interdependence, frequent changes in competitive landscape, and increased globalization, is a key factor enhancing a firm's production-distribution integration. Companies seek to integrate with key customers because deep understanding of key customers' demands and delivery mechanisms enables the companies to anticipate customers' behavior and the potential challenges in the delivery processes in unusual situations (Lau *et al.*, 2010). Similarly, joint product and process development with key customers helps untangle and incorporate customer's voice thereby making the organizational outcomes more aligned with the demand market (Koufteros *et al.*, 2005, Koufteros *et al.*, 2007). This mutual understanding and coordination enables the firm to appropriately reconfigure its internal and external resources and adapt to rapid environmental changes (Wu, 2010). Finally, uncertainty in the future demand urges companies to seek long-term contracts and continuity of business from their key customers (Koufteros *et al.*, 2007). Thus, it makes sense to argue that supply chain risk pushes companies to develop processes and platforms for information sharing and

joint value creation with key customers (Paulraj and Chen, 2007b, Danese *et al.*, 2013). Hence, the following hypothesis is formulated:

*H₃: Firm's supply chain risk makes the firm increase customer integration*

**Supply Chain Integration and Agility Performance**

DCV, extending the argument of RBV, draws that variance in firm performance can be explained by heterogeneity in dynamic capabilities rooted in high performance routines that seek to exploit firm's internal and external resources (Teece and Pisano, 1994). Effective dynamic capabilities contribute to a firm's competitive advantage by enabling a series of temporary advantages, which allow a firm to stay ahead of competitors and maintain a competitive advantage (Teece, 2007, Eisenhardt and Martin, 2000). In this context, the creation of new processes and the development of new organizational forms and business models lead to superior performance (Teece, 2007). As such, the possession of dynamic capabilities, enabling for example the speedy reconfiguration of a firm's supply chain, promises to hold great potential, especially in today's dynamic and fast-changing environment (Ambrosini and Bowman, 2009). Thus, it can be argued that supply chain integration, a dynamic capability, may lead to enhanced firm performance (Allred *et al.*, 2011, Vickery *et al.*, 2013, Baofeng, 2012, Teece *et al.*, 1997).

As a dynamic capability, supply chain integration enhances the understanding of supply chain partners regarding each other's businesses and supports the partners to form new routines (Vickery *et al.*, 2013). In addition, supply chain integration can help companies develop learning capabilities to cope with competitive environments. Through effective supply chain integration, companies are more likely to acquire and absorb external knowledge quickly and effectively (Handfield *et al.*, 2015). Supply chain integration can help update old information in rapidly changing environments, and help reconfigure and transform structures and processes to conduct business flexibly (Jayaram *et al.*, 2010). It is argued that internal, supplier, and customer integration lends the ability to quickly share information and make decisions with key stakeholders of the organization (Lee *et al.*, 2007). Prior research has examined the

relationship between dimensions of supply chain integration and various performance measures though the results have been inconsistent (Lau *et al.*, 2010, Koufteros *et al.*, 2005, Devaraj *et al.*, 2007, Closs *et al.*, 2005, Zhao *et al.*, 2015). In addition, despite the emphasis on supply chain collaborations as a means to achieve agility performance, scholars note that how these outcomes are gained via supply chain relationships remains less explored (Narayanan *et al.*, 2015, Paulraj and Chen, 2007b). Thus, an empirical examination of the association of the three elements of supply chain integration (internal, supplier, and customer) with agility performance is required. Below, we develop these relationships (Figure 1).

Internal integration enhances the communication between functional units of the organization to increase in-house efficiency and effectiveness of manufacturing activities (Lee *et al.*, 2007, Williams *et al.*, 2013). The enhanced integrative actions may yield shortened product development time and more variety of products (Koufteros *et al.*, 2001). Early and effective involvement of informed internal stakeholders in manufacturing planning and execution can provide an opportunity to learn about interdependencies and uncertainties, and help prepare more robust and responsive strategies (Koufteros *et al.*, 2005). Sharing of information and early involvement in the decision-making process creates shared ownership and understanding towards manufacturing operations (Flynn *et al.*, 2010). This nature of relationship among organizational functional-units breaks silos associated with traditional departmentalization and speeds up the conflict resolution and response (Gimenez and Ventura, 2005, Brusset, 2016). The coordinated efforts and focus on achieving collective objectives enhances the utilization of organizational resources and accelerates organizational response to customer requirements (Danese *et al.*, 2013, Droge *et al.*, 2004). Thus we present the following hypothesis:

*H₄: Internal Integration has a positive impact on agility performance*

Scholars argue that sourcing capabilities provide important ways to gain superior agility performance (Quinn and Hilmer, 1994, Paulraj and Chen, 2007b). Elements of supplier integration such as information sharing, cooperative and collaborative decision-making, and informal and relationship

orientation enhance buying firm's agility performance (Narayanan *et al.*, 2015). Particularly, such buyer-supplier relationships facilitates enhanced utilization of suppliers' investments, innovations, and specialized human resources (Quinn and Hilmer, 1994, Jajja *et al.*, 2017). Increased communication and coordination in a buyer-supplier dyad is characterized by a superior understanding of mutual needs (Frohlich and Westbrook, 2001, Derrouiche *et al.*, 2008). This mutual understanding facilitates a more focused effort in responding to the market needs (Lee and Whang, 1997, Schoenherr and Swink, 2012). Also, increased integration with supplier is characterized by joint decision-making that lends more confidence to the supplier's top management (Chen and Paulraj, 2004, Zhao *et al.*, 2011). This joint planning and subsequent mutual ownership facilitates better resource allocation to meet the supply chain goals (Yan and Dooley, 2013, Skjoett-Larsen *et al.*, 2006). In addition, increased integration suggests an intensive information exchange with the supplier which is a necessity for successful new product development and product modification (Yan and Dooley, 2013). These findings support that enhanced supplier integration provides mechanisms to a firm to outperform on agility performance metrics. Thus we hypothesize:

> *H5: Supplier integration has a positive impact on agility performance*

Involvement of key customers with the product development team in the early stages of product development of the focal organization can provide quick insights about the product's effectiveness and manufacturability (Droge *et al.*, 2004). Similarly, at an advanced stage of the product development, this collaborative approach can speed up product and process development (Droge *et al.*, 2004). The involvement of customers may bring complementary knowledge and infrastructure that can increase product value as well as the number of products (Lau *et al.*, 2010). The operational integration with key customers can improve preparation and response time for specific customization requests from customers (Chen *et al.*, 2013). Similarly, information sharing and coordinated operations with customers are key inputs in the development of quick and reliable production and delivery systems (Close *et al.*, 2005, Schoenherr and Swink, 2012). The sharing of demand information by the customer reduces the uncertainty in the forecast, which in turn makes production scheduling simpler and enhances supplier and internal

delivery reliability. The constant interaction with key customers may provide a sense of the actual demand and reduces the lag in the flow of information to internal stakeholders and key suppliers (Lee and Whang, 1997). This sharing of information reduces ordering costs and demand hikes and the resulting over- and under-stocks, thereby enhancing the operating efficiency throughout the supply chain (Lee, 2004, Frohlich and Westbrook, 2001). These practices of real-time data sharing, collaborative planning, and jointly managed inventories enable companies to become more responsive to market requirements for variation in volume and mix (Danese, 2011, Schoenherr and Swink, 2012). Based on these arguments we hypothesize:

*$H_6$: Customer integration has a positive impact on agility performance*

**Mediation Effects**

The literature argues that internal integration is likely followed by external integration (Zhao *et al.*, 2011, Cheng *et al.*, 2016). This does not mean to suggest that internal integration is the necessary condition for external integration (Droge *et al.*, 2004, Danese *et al.*, 2013) but it provides the support for effective supplier and customer integration (Koufteros *et al.*, 2005). This is because the information sharing and coordination between functional units of an organization enhances the organizational ability to effectively engage with external stakeholders including suppliers and customers (Lee *et al.*, 2007). The positive effect of internal integration on supplier integration and customer integration has also been reported in earlier research (Koufteros *et al.*, 2005, Cheng *et al.*, 2016). Combining $H_1$, $H_2$, and $H_3$ with earlier findings of the positive relationship of internal integration with supplier integration and customer integration we hypothesize:

*$H_7$: Internal integration partially mediates the relationship between firm's supply chain risk and supplier integration*

*$H_8$: Internal integration partially mediates the relationship between firm's supply chain risk and customer integration*

Internal integration provides the needed support for supplier and customer integration (Cheng *et al.*, 2016, Koufteros *et al.*, 2005, Childerhouse and Towill, 2011), which in turn positively impact agility performance. Thus, it makes sense to argue that internal integration may affect agility performance through supplier and customer integration. However, the evidence of the mediation effect of supplier and customer integration between internal integration and performance measures is inconsistent. For example, the findings of Koufteros *et al.* (2005) suggest that supplier integration does not mediate the relationship between internal integration and product innovation and quality. On the contrary, Cheng *et al.* (2016) report that external integration consisting of supplier integration and customer integration mediates the relationship between internal integration and operational performance of networked plants. These inconsistent findings suggest the need for further empirical examination of this relationship. Combining earlier findings of the positive relationship of internal integration with supplier and customer integration with $H_4$, $H_5$, and $H_6$, we hypothesize:

*$H_9$: Supplier integration partially mediates the relationship between internal integration and agility performance*

*$H_{10}$: Customer integration partially mediates the relationship between internal integration and agility performance*

DCV and supply chain literature draw that in dynamic environment, an organization's agility performance is a critical element affecting the organization's long-term competitiveness (Lee, 2004, Li *et al.*, 2008, Teece *et al.*, 1997). Thus, firms operating under supply chain risk seek to be agile because firms consider agility as a risk management approach (Gligor *et al.*, 2016, Christopher and Peck, 2004). Supply chain risk motivates firms to develop their organizational structure to enhance integration among internal functional units and with external supply chain partners (key suppliers and customers) which in turn improves agility performance (Paulraj and Chen, 2007a, Hoyt *et al.*, 2007, Li *et al.*, 2008, Christopher,

2000). This relationship draws a similarity to the supply chain strategy-structure-performance paradigm which argues that a firm's supply chain strategy, formed in consideration of external environmental factors, drives the development of organizational structure and processes which in turn affect performance (Defee and Stank, 2005). In hypotheses $H_1$ through $H_6$, we have sought to explain the role of integration, i.e., supplier, internal, and customer integration, as a consequence of supply chain risk and an antecedent to agility performance. Thus, here we suggest a mediating role of supplier, internal, and customer integration in the relationship between supply chain risk and agility performance. This mediation relationship has not been examined in the earlier research. We hypothesize:

> $H_{11}$: *Internal integration mediates the relationship between firm's supply chain risk and agility performance*
>
> $H_{12}$: *Supplier integration mediates the relationship between firm's supply chain risk and agility performance*
>
> $H_{13}$: *Customer integration mediates the relationship between firm's supply chain risk and agility performance*

**METHOD**

**Sampling and Data Collection**

The data from IMSS VI was used to test the hypotheses. The IMSS is a global network of institutions that collaborate with each other and manufacturing companies to develop a common survey instrument and protocol for collecting data for research from manufacturing companies. The IMSS VI was carried out during June 2013 to June 2014. The IMSS VI survey was designed to collect data from the population of assembly manufacturing plants (ISIC 25-30 classifications) with more than 50 employees. As a result, 7167 companies from different countries were selected.

The questionnaire was originally developed in English and later translated by researchers into other languages (e.g. French, Spanish, and Chinese), using double- and reverse-translation procedures, in a

coordinated manner for countries with language constraints (Vanpoucke *et al.*, 2014). The questionnaire was extensively pre-tested with company managers before the official launch. The target respondents were selected considering the knowledge and awareness required to respond to the strategic and operational information sought in the IMSS VI questionnaire. The local research teams sent a questionnaire by ordinary mail, fax or email. If necessary, they also sent reminders periodically to increase response rates (Zhao *et al.*, 2008). In all countries, the survey respondents were usually operations, production, supply chain, or plant manager/director.

In total, 2586 questionnaires were distributed across different countries. The final IMSS VI sample consisted of 931 companies from 22 countries situated in Europe, Asia, and the Americas giving 36% (931/2586) effective response rate. The local research teams tested the non-respondent and late-respondent biases by comparing the publicly available secondary information in terms of size, industry, sales, or proprietorship of the target companies with the received responses. In cases where such information was not available, survey responses were used to test the differences between early and late responses. However, significant evidence of late-response bias and non-response bias was not found in the data (Armstrong and Overton, 1977).

IMSS VI survey followed the techniques described by Podsakoff *et al.* (2003) to minimize common method bias (CMB) proactively. First, items of constructs prone to CMB, such as predictor and criterion variables, were separated from each other in the questionnaire. Second, the survey employed different scale anchors/formats to measure independent and dependent variables. Third, the data collection process maintained the anonymity of the respondent and the firm to reduce the social desirability need of the respondent. Finally, the survey employed objective concepts and provided an explanation of items where needed to reduce ambiguity.

The authors screened the data to remove the cases with missing values of variables of interest in this research. This screening resulted in shortlisting of data to 770 complete data points (see Table 2) that were used for measurement and hypothesized model testing.

Table 2. Sample demographics

| Firm size *(number of employees)* | Number | % of Usable Sample |
|---|---|---|
| Small *(less than 250)* | 360 | 46.75 |
| Medium *(251 to 500)* | 131 | 17.01 |
| Large *(more than 500)* | 277 | 35.98 |
| Missing | 2 | 0.26 |
| **Industry** | | |
| ISIC 25 Manufacture of fabricated metal products, except machinery and equipment | 236 | 30.65 |
| ISIC 26 Manufacture of computer, electronic and optical products | 105 | 13.64 |
| ISIC 27 Manufacture of electrical equipment | 124 | 16.1 |
| ISIC 28 Manufacture of machinery and equipment not elsewhere classified | 189 | 24.55 |
| ISIC 29 Manufacture of motor vehicles, trailers, and semi-trailers | 79 | 10.26 |
| ISIC 30 Manufacture of other transport equipment | 37 | 4.8 |
| **Region[a] and Country** *(country sample size)* | | |
| Europe and North America | 438 | 56.88 |
| *Belgium (21), Canada (19), Denmark (30), Finland (31), Germany (12), Hungary (43), Italy (36), Netherlands (41), Norway (24), Portugal (27), Romania (36), Slovenia (17), Spain (20), Sweden (25), Switzerland (19), United States of America (37)* | | |
| Asia and South America | 332 | 43.12 |
| *Brazil (26), China (110), India (85), Japan (73), Malaysia (12), Taiwan (26)* | | |

Total usable sample size = 770

ISIC: International Standard Industrial Classification

**Measurement Scale**

We operationalized all constructs in this study as first-order reflective constructs, except agility performance, consisting of multiple items (Jarvis *et al.*, 2003) from IMSS VI survey which includes a limited number of practices and routines related to these constructs (Vanpoucke *et al.*, 2014). Firm's supply chain risk was operationalized to capture risk in three areas: supply side, internal manufacturing operations, and delivery side (Chen *et al.*, 2013, Ravindran *et al.*, 2010, Ellis *et al.*, 2010). The IMSS VI survey used a single item, given in Appendix B, to separately measure the impact and probability of disruption in each of these three areas on Likert-Scale (Low = 1 to High = 5) (Ellis *et al.*, 2010). In this paper, the risk of each of the three areas was measured as a product of the respective impact and probability, thus generating three

product terms. Each product term, in turn, represented an item of the three-items based supply chain risk scale used in this paper (Hallikas *et al.*, 2002). The use of such a product term is recommended to measure risk because it combines the magnitude of impact and probability that together represent the effective risk in each area (Norrman and Jansson, 2004, Group, 1992).

Internal integration was operationalized in terms of current level of cross-functional information sharing and joint decision-making about manufacturing operations between manufacturing and purchase/sales departments using Likert scale (None = 1 to High = 5) (Germain and Iyer, 2006, Gimenez and Ventura, 2005, Zhao *et al.*, 2011). Combined information from purchasing, manufacturing, and sales teams provides an end-to-end sense of an organization's operating state and the basis for decision-making (Lee *et al.*, 2007, Ellinger *et al.*, 2000). Earlier, these items of the IMSS VI have been used to measure internal integration in the work of Cheng *et al.* (2016).

Supplier integration and customer integration were operationalized in terms of current level of implementation of information sharing (Devaraj *et al.*, 2007, Close *et al.*, 2005, Lau *et al.*, 2010, Braunscheidel and Suresh, 2009, Vijayasarathy, 2010), collaborative approaches (Devaraj *et al.*, 2007, Close *et al.*, 2005, Braunscheidel and Suresh, 2009, Vijayasarathy, 2010), joint decision-making (Lau *et al.*, 2010, Braunscheidel and Suresh, 2009), and systems coupling (Devaraj *et al.*, 2007, Braunscheidel and Suresh, 2009, Vijayasarathy, 2010) with key suppliers and customers respectively, using the Likert-Scale (None = 1 to High = 5). Supplier integration and customer integration have been operationalized using these items of the IMSS VI in the existing research (Cheng *et al.*, 2016).

Agility performance was operationalized as a second-order construct consisting of three first order constructs: design, delivery and flexibility performance. Earlier studies report these dimensions as key determinants of agility performance (Vinodh *et al.*, 2012, Narasimhan *et al.*, 2006, Narayanan *et al.*, 2015, Paulraj and Chen, 2007b, Sarkis *et al.*, 2007). The questionnaire items measured current performance relative to the main competitors using Likert scale (Much lower = 1 to Much higher = 5).

Finally, firm size, region, and industry were used as control variables to ensure the contextual validity of the results because company size and regional and industrial dynamics may affect the firm's

behavior and performance (Devaraj *et al.*, 2007, Cheng *et al.*, 2016, Wiengarten *et al.*, 2014). Firm size was operationalized as a logarithm of the total number of employees of a business unit. Firm region was operationalized as a dichotomous variable identifying a firm with one of the two regions: Europe and North America versus Asia and South America (Table 2). Countries in each of these two regions are relatively similar within the region and dissimilar to the other region in terms of developmental level and industrial dynamics. Finally, we used ISIC classifications to operationalize industry type as a dichotomous variable (Kauppi *et al.*, 2016, Wiengarten *et al.*, 2014) identifying a firm with one of the two comparative categories: high-tech (ISIC 26 and 27) versus low-tech or traditional industries (ISIC 25, 28, 29, and 30). Although companies in the sample are from closely related manufacturing industries, i.e. ISIC 25-30, companies manufacturing computer, electronic, optical products, and electrical equipment (i.e. high-tech) operate under relatively different technological and market dynamics as compared to companies manufacturing fabricated, machinery, and transportation products (i.e. low-tech or traditional manufacturing) (Law and Gunasekaran, 2012).

**Measurement Model**

Covariance based structural equation modeling (SEM) approach was used for empirical examination (Shah and Goldstein, 2006). The two-step approach of Anderson and Gerbing (1988) was used to test the measurement model for testing construct validities and reliabilities prior to testing the structural model. Thus, all constructs were made subject to confirmatory factor analysis (CFA) using the AMOS modeling software (Version 22), which provided overall reasonable model fit ($\chi^2_{176\ df.} = 668.779$, RMSEA $= 0.060$, GFI $= 0.921$, AGFI $= 0.897$, CFI $= 0.942$, TLI $= 0.931$, IFI $= 0.942$, NFI $= 0.923$). The higher value of $\chi^2$/d.f. is because of the skewness and kurtosis in the data that tend to inflate absolute fit indices. Overall the values of fit indices are acceptable (Hu and Bentler, 1999, Shah and Goldstein, 2006). Appendix B shows the values of Cronbach's alpha, Joreskog $\rho$, comparative fit index (CFI), average variance extracted (AVE), and factor loadings with respective standard errors.

Factor loadings of all items are significant (at p-value $< 0.001$) above the satisfactory limit of 0.60 (Hair *et al.*, 2013). All values of Cronbach's alpha and Joreskog $\rho$ are greater than 0.70 except design

performance (Cronbach's alpha = 0.626, Joreskog $\rho$ = 0.627), thus satisfying the construct reliability and internal consistency (Nunnally and Bernstein, 1994). All values of CFI are greater than or close to 0.90, thus satisfying the condition of unidimensionality. Similarly, all values of AVE are greater than 0.50 satisfying the condition of convergent validity except design performance (AVE = 0.456). Overall, values of reliability and convergent validity indicators of design performance are weak but within the acceptable range (Fornell and Larcker, 1981, Hair *et al.*, 2010), thus design performance was retained to maintain content validity of agility performance. Unidimensionality and convergent validity indicate that all items in the construct measure the same construct (Bagozzi and Yi, 1991). Squared inter-construct correlation values between all pairs of constructs are less than the AVE values of the individual constructs in each pair, thus providing evidence for satisfactory discriminant validities of the constructs (Table 3) (Segars and Grover, 1993).

Additionally, to test for discriminant validity, the correlation between each pair of constructs in the CFA model was set equal to 1 to find the chi-square value of the constrained model. The constrained model's chi-square value was then compared with the chi-square value of the unconstrained model. A significant difference (p-value < 0.05) in the values of chi-square for all pairs of constructs provides evidence of discriminant validity (Segars and Grover, 1993). Finally, the confirmatory single-factor test suggested by Podsakoff et al. (2003) was used to examine CMB. A significant increase (p-value < 0.05) in the value of chi-square ($\chi^2_{176\,d.f}$ = 668.779 to $\chi^2_{189\,d.f}$ = 4295.791.405) when comparing a single-factor model to one in which items are loaded onto their respective constructs, provides evidence that common method bias is not a significant problem in this research (Podsakoff *et al.*, 2003).

Table 3. Correlations among constructs

| Construct | SCR | SI | II | CI |
|---|---|---|---|---|
| SI | 0.113 | | | |
| II | -0.009 | 0.657 | | |
| CI | 0.104 | 0.750 | 0.544 | |
| AP | 0.053 | 0.388 | 0.388 | 0.341 |

SCR: Supply chain risk, II: Internal integration, SI: Supplier integration, CI: Customer integration

Agility performance construct was operationalized as a second-order construct consisting of flexibility, design, and delivery performance, so additional measurement analysis was carried out to test the validity of this choice (Jarvis *et al.*, 2003). Firstly, the second-order factor loadings provided in Appendix B are significant at p 0.001, indicating the appropriateness of adopting second-order factors. Secondly, the value of T-coefficient is 1.000, which is well above generally acceptable lower cut-off value of 0.80, thus providing satisfactory evidence for the presence of second-order construct. Thirdly, value of $\chi^2$ of first-order single factor model (363.313 at d.f. = 9) is significantly (p-level = 0.01) greater than the value of $\chi^2$ of three first-order correlated factors model (28.313 at d.f. = 6). The findings of this measurement analysis support the second-order operationalization of agility performance (Marsh and Hocevar, 1985, Cheng *et al.*, 2016).

Finally, since the respondents were from multiple regions we tested measurement invariance of the constructs by splitting the data into two geographically determined groups: Europe and North America; Asia and South America (Table 2). The measurement invariance was tested using the CFA approach (Steenkamp and Baumgartner, 1998, Jajja et al., 2017). The unconstrained CFA model was first run with two groups in the AMOS model corresponding to the two subsamples. Values of the fit indices ($\chi^2_{336 \text{ d.f.}}$ = 920.370, RMSEA = 0.048, GFI = 0.898, AGFI = 0.859, CFI = 0.933, TLI = 0.916, IFI = 0.934, NFI = 0.899) indicated satisfactory fit. All factor loadings were above 0.60 and significant (p < 0.01) with the exception of two items of design performance (factor loadings: 0.541 and 0.595) and one item of supplier integration (factor loading: 0.594) in the Europe and North America group but still significant (p < 0.01). It can thus be concluded that all constructs exhibit satisfactory configural invariance across the groups. In addition, the $\chi^2$ test was used to assess the statistical significance of $\Delta\chi^2$ between the constrained and unconstrained multi-group CFA models. For the constrained CFA model, regression weights for all items were fixed between the two groups. This yielded $\chi^2_{351 \text{ d.f.}}$ = 954.895, thus $\Delta\chi^2$ was significant ($\Delta\chi^2_{15 \Delta \text{d.f.}}$ = 34.525, p = 0.003) though the values of other model fit indices (RMSEA = 0.047, GFI = 0.893, AGFI = 0.860, CFI = 0.931, TLI = 0.917, IFI = 0.931, NFI = 0.896) remained satisfactory. Further analysis indicated that the significant increase in the value of $\chi^2$ was due primarily to the earlier mentioned item in supplier

integration whose factor loading was 0.594 for the Europe and North America subsample but 0.746 for the Asia and South America subsample. To test for partial metric invariance, the regression weight for this item was allowed to vary. The value of $\chi^2$ for the constrained model improved to $\chi^2_{349\ d.f.} = 939.046$, thus $\Delta\chi^2_{13\ \Delta d.f.} = 18.676$ which is insignificant (p = 0.133). As such, there is evidence to suggest partial metric invariance (with only 1 of 21 items invariance constraints relaxed), and thus support for measurement invariance across the subsamples (Jajja et al., 2017, Cheng et al., 2016).

**Hypothesized Model Testing**

The structural model was tested using the AMOS modeling software (Version 22). SEM is a recommended approach when the research involves complex models seeking to test theory using existing theoretical foundation (Shah and Goldstein, 2006). The goodness-of-fit indices of our model are better than generally accepted threshold values ($\chi^2_{235\ d.f.} = 1024.381$, RMSEA = 0.066, GFI = 0.901, AGFI = 0.874, CFI = 0.909, TLI = 0.894, IFI = 0.910, NFI = 0.886) (Hu and Bentler, 1999).

The results in Figure 2 show the path coefficients of the structural model. The path from supply chain risk to internal integration is insignificant ($\beta = -0.007$, p-value > 0.10), thus rejecting $H_1$. The direct paths from supply chain risk to supplier integration ($\beta = 0.125$, p-value < 0.01) and customer integration ($\beta = 0.116$, p-value < 0.01) are positive and significant, thus supporting $H_2$ and $H_3$ respectively. Similarly, the results indicate positive and significant paths from supplier integration ($\beta = 0.220$, p-value < 0.01) and customer integration ($\beta = 0.129$, p-value < 0.05) to agility performance, thus supporting $H_5$ and $H_6$ respectively. The effect of internal integration on agility performance is weakly significant ($\beta = 0.133$, p-value < 0.10) (Cheng *et al.*, 2016). Finally, paths from internal integration to supplier integration ($\beta = 0.695$, p-value < 0.01) and customer integration ($\beta = 0.588$, p-value < 0.01) are positive and significant. The control variables firm size, region, and industry type have insignificant relationships with the dependent variable.

In addition, we tested the appropriateness of second-order operationalization of agility performance at structural model level as proposed by Bollen (1989) and Cheng *et al.* (2016). We compared the model illustrated in Figure 2 against the model in which the second-order construct (i.e. agility performance) was replaced by three first-order constructs (i.e. flexibility performance, design performance, and delivery

performance). In addition, new paths were added from internal integration, supplier integration, and customer integration to each of the first level performance constructs. The remaining paths were similar to those in Figure 2. Overall the revised model's goodness-of-fit indices ($\chi^2_{226 \text{ d.f.}}$ = 1321.271, RMSEA = 0.079, GFI = 0.875, AGFI = 0.834, CFI = 0.874, TLI = 0.847, IFI = 0.875, NFI = 0.853) were inferior to the fit indices of the original model thus providing additional structural model level support for second-order operationalization of agility performance (Cheng *et al.*, 2016).
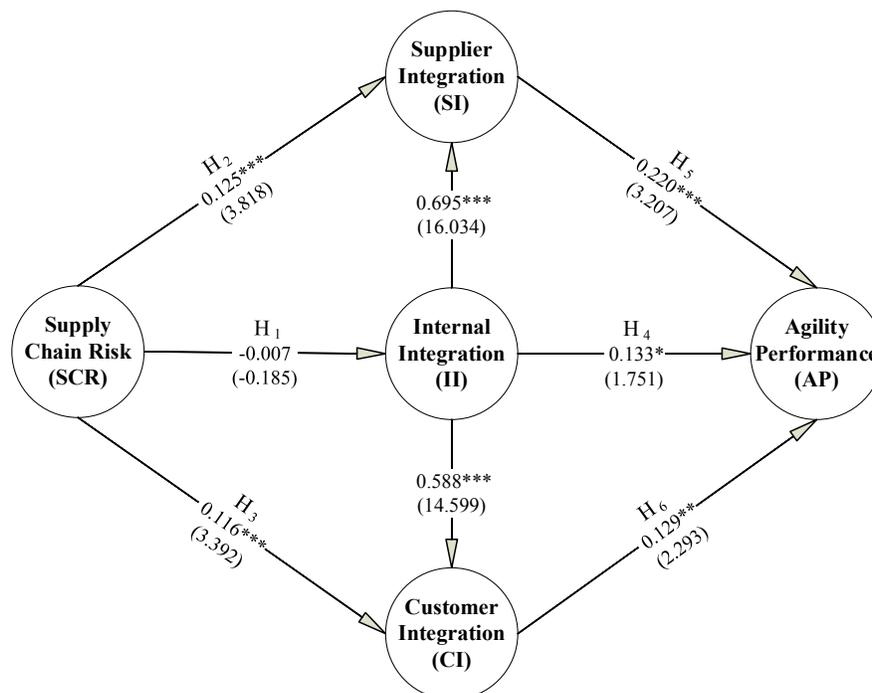


* = significance < 0.10. ** = significance < 0.05. *** = significance < 0.01

Values in parenthesis are t-values.

Direction of arrows indicates direction of positive relationship.

Figure 2. Results with path coefficients for direct hypotheses testing

We tested for the mediation effects using the bootstrapping approach of Preacher and Hayes (2008). Following the recommendation of Malhotra *et al.* (2014), we preferred this approach over those of Baron and Kenny (1986) and Sobel (1982) because the former provides statistically a more powerful and robust test of mediation (Hayes, 2009). The bootstrapping approach has a higher statistical power, can accommodate multiple mediation hypotheses in a model, is more robust to the assumptions of normality,

and maintains acceptable level of Type 1 error when applied using large sample size (Rungtusanatham *et al.*, 2014). Thus, we used bias-corrected bootstrapping approach that generated 5000 resamples to empirically estimate the indirect effects and their significance. According to the decision tree proposed by Zhao *et al.* (2010), estimates of direct and indirect effects between independent and dependent variables provided the needed information to understand the presence of a mediation factor. The results of the mediation analysis using estimates of direct and indirect paths for $H_7$ and $H_8$ are presented in Table 4. The results of the bootstrapping analysis show that both indirect effects (i.e. from supply chain risk to supplier integration and supply chain risk to customer integration) are not significant (p-value > 0.05), thus rejecting $H_7$ and $H_8$.

Table 4. Bootstrapping results for mediation relationship tests (H7-H8)

| Hypothesis | IV | MV | DV | Effect of IV on MV (a) | Effect of MV on DV (b) | Direct effect (c') | Indirect effect of IV on DV | SE of indirect effects | 95% CI for mean indirect effect |
|---|---|---|---|---|---|---|---|---|---|
| $H_7$ | SCR | II | SI | -0.007 | 0.695*** | 0.125*** | -0.005 | 0.031 | -0.067 - 0.053 |
| $H_8$ | SCR | II | CI | -0.007 | 0.588*** | 0.116*** | -0.004 | 0.026 | -0.057 - 0.045 |

IV: Independent variable, MV: Mediating variable, SCR: Supply chain risk, II: Internal integration, SI: Supplier integration, CI: Customer integration, SE: Standard error, CI: Confidence interval
Note: Standardized effects, *** = p-value < 0.01

The indirect effects hypothesized in $H_9$ through $H_{13}$ cannot be tested in the full structural model because (a) the indirect effect of internal integration on agility performance is through two parallel mediators (supplier integration i.e. $H_9$ and customer integration i.e. $H_{10}$), and (b) the indirect effect of supply chain risk on agility performance is through three parallel mediators (internal integration i.e. $H_{11}$, supplier integration i.e. $H_{12}$, and customer integration $H_{13}$). When there are more than one parallel mediators in the relationship between two variables it is recommended to individually examine each indirect path (Macho and Ledermann, 2011). Generally, there are two approaches used to test these specific indirect paths: matrix methods and phantom variable based approach (Bollen, 1989, Cheung, 2007). In this paper, we used

phantom model approach because it is more suitable for complex structural models testing over graphical

user interface SEM software (Macho and Ledermann, 2011). Results of the bootstrapping analysis based

on 5000 resamples presented in the Table 5 summarize estimated effects and respective 95 percent for each

hypothesized relationship.

Table 5. Bootstrapping results for mediation relationship tests ($H_9 – H_{13}$)

| Hypothesis | IV | MV | DV | Direct effect | Indirect effect of IV on DV | SE of indirect effects | 95% CInt for mean indirect effect |
|---|---|---|---|---|---|---|---|
| $H_9$ | II | SI | AP | 0.153** | 0.196*** | 0.048 | 0.104 – 0.291 |
| $H_{10}$ | II | CI | AP | 0.217*** | 0.126*** | 0.032 | 0.064 – 0.191 |
| $H_{11}$ | SCR | II | AP | 0.054 | -0.002 | 0.015 | -0.031 – 0.027 |
| $H_{12}$ | SCR | SI | AP | 0.008 | 0.045*** | 0.018 | 0.012 – 0.084 |
| $H_{13}$ | SCR | CI | AP | 0.018 | 0.036** | 0.016 | 0.008 – 0.070 |

IV: Independent variable, MV: Mediating variable, SCR: Supply chain risk, II: Internal integration, SI: Supplier integration, CI: Customer integration, AP: Agility performance, SE: Standard error, CInt: Confidence interval
Note: Standardized effects, *** = p-value < 0.01, ** = p-value < 0.05

The results show that the indirect effects of internal integration on agility performance through supplier

integration and customer integration are significant (both at p-value < 0.01). The direct effect of internal

integration on agility performance is significant in case of both mediators, thus suggesting partial mediation

effects of supplier and customer integration in the relationship between internal integration and agility

performance (Zhao *et al.*, 2010) thus supporting hypotheses $H_9$ and $H_{10}$. In addition, the results show that

the indirect effect of supply chain risk on agility performance through internal integration is not significant

thus rejecting $H_{11}$. Finally, the results show that the indirect effects of supply chain risk on agility

performance through supplier integration (p-value < 0.01) and customer integration (p-value < 0.01) are

significant. Even though statistically significant, it is apparent that the influence of indirect effect of supply

chain risk on agility performance through supplier integration or customer integration lacks strength. The

direct effect of supply chain risk on agility performance is not significant in case of both mediators (supplier

integration and customer integration), thus suggesting indirect-only mediation effects of supplier and

customer integration in the relationship between supply chain risk and agility performance (Zhao *et al.*,

2010), thus supporting hypotheses $H_{12}$ and $H_{13}$.

**DISCUSSION**

Most of our direct and mediation hypotheses are supported. Interestingly, the hypotheses that lacked support or received weak support involved internal integration as a dependent ($H_1$), independent ($H_4$), or mediating ($H_7$, $H_8$, $H_{11}$) variable. All the results are summarized in Table 6.

Table 6. Hypotheses test results

| Hypothesis | Supported (Yes/WS/No) |
|---|---|
| $H_1$: Supply chain risk → internal integration | No |
| $H_2$: Supply chain risk → supplier integration | Yes |
| $H_3$: Supply chain risk → customer integration | Yes |
| $H_4$: Internal Integration → agility performance | WS |
| $H_5$: Supplier Integration → agility performance | Yes |
| $H_6$: Customer Integration → agility performance | Yes |
| $H_7$: Supply chain risk → internal integration → supplier integration | No |
| $H_8$: Supply chain risk → internal integration → customer integration | No |
| $H_9$: Internal integration → supplier integration → agility performance | Yes |
| $H_{10}$: Internal integration → customer integration → agility performance | Yes |
| $H_{11}$: Supply chain risk → internal integration → agility performance | No |
| $H_{12}$: Supply chain risk → supplier integration → agility performance | Yes |
| $H_{13}$: Supply chain risk → customer integration → agility performance | Yes |

Yes: Supported with p-value < 0.05 or p-value < 0.01, WS: Weak support with p-value < 0.10, No: Not supported

**Supply Chain Risk and Supply Chain Integration**

The examination of implications of firm's supply chain risk with supply chain integration contributes towards the theorization of supply chain integration. Earlier research, mostly qualitative, on the management of supply chain risk has pointed out the importance of communication and joint decision-making with internal and external stakeholders in several different ways (Blos *et al.*, 2009, Ritchie and Brindley, 2007, Diabat *et al.*, 2012, Prater *et al.*, 2001). For example, Blos *et al.* (2009) report that communication and visibility in the supply chain, alignment of processes and objectives with key supply chain actors, and management of trading partners from developing countries are recognized as important elements of supply chain risk management. Similarly, Ritchie and Brindley (2007) argue that when faced

with supply chain risk firms evolve new structure, processes, and information sharing approaches at tactical and operational level to resolve disagreements and maintain product delivery. These practices originating from qualitative research work resonate with the theory of supply chain integration. However, the empirical research on the relationship between supply chain risk and supply chain integration is limited (Zhao *et al.*, 2013, Wong and Boon-itt, 2008). The current paper uses large scale empirical data to examine the extent to which supply chain risk may motivate firms to enhance supply chain integration.

This paper utilizes DCV to argue why firms under supply chain risk may develop more integrative practices within the firm and with important supply chain partners including key suppliers and customers. The findings are consistent with our theorization that firms facing supply chain risk show more integrative behavior with key suppliers and customers. In doing so this paper in a way complements the earlier research arguing for the beneficial effect of integrative practices on supply chain risk. Chen *et al.* (2013), for example, argue that supplier, processes, and customer collaboration have negative impact on supply, process, and demand risk respectively. Whereas, our research finds a positive effect of a firm's supply chain risk on supplier and customer integration. Both the arguments complement each other: i.e., supply chain risk makes firms increase supplier and customer integration (finding of our paper) and supplier, internal, and customer integration reduce a firm's supply chain risk (finding of Chen *et al.* (2013)). This provides empirical evidence for a two-way association between a firm's supply chain risk and supply chain integration suggesting that the extents of a firm's supply chain risk and supply chain integration regulate each other (Norrman and Jansson, 2004, Wong and Boon-itt, 2008, Stonebraker and Liao, 2004, Faisal *et al.*, 2006).

Interestingly, the theorization and findings of our paper, to the extent of relationship between supply chain risk and supply chain integration, are not consistent with the work of Zhao *et al.* (2013). Basically, the points of departure of this study and Zhao *et al.* (2013) are different. The aim of Zhao et al. (2013) is to highlight the barriers and performance benefits of supply chain integration. Zhao *et al.* (2013) highlight supply chain risk as one of the major barriers for supply chain integration. They argue that under high level of risk, firms do not like to share information and invest in joint product/process improvement

initiatives with suppliers and customers. Similarly, presence of supply and demand uncertainties hinder coordination among various functional units of the firm. In this manner, supply and demand risks make supply chain integration difficult and unattractive and thus there is a negative impact of supply and demand risks on supply chain integration. In empirical examination, their study finds a partial evidence for a negative association between supply and demand risks and supply chain integration. Conversely, in this paper we consider supply chain risk as an inevitable reality of a modern business environment and advocate supply chain integration as an organizational response to supply chain risk. Our argument, drawing from DCV and congruent with earlier studies (Gligor *et al.*, 2016, Stonebraker and Liao, 2004, Wong and Boon-itt, 2008), is that a firm's supply chain risk provides the context and motivation to the firm to enhance supply chain integration. Taken together, i.e. considering the work of Zhao *et al.* (2013) vis-à-vis our research, it appears that both studies are theoretically complementary and empirically contradictory and provide an important lead for more research. The theoretical reasoning is complementary in the sense that Zhao *et al.* (2013) base their argument on the *challenges of implementation* of integrative practices when supply chain risk is high. Our hypotheses, on the other hand, argue that firms seek to develop dynamic capabilities, e.g. by implementation of integrative practices, to *capitalize on opportunities and manage threats* when supply chain risk is high (Abrahamsson *et al.*, 2015, Teece, 2007). Congruent with our line of reasoning, scholars argue that increased supply chain risk requires agile and robust supply chains (Wieland, 2013, Christopher and Peck, 2004) and integrative and collaborative practices are means to build such supply chains (Brusset and Teller, 2017, Braunscheidel and Suresh, 2009, Durach *et al.*, 2015). In empirical examination, however, both arguments find incomplete support.

There are a few studies that may lend initial explanation to this inconsistent theorization of relationship between supply chain risk and integration (Stonebraker and Liao, 2004, Wong and Boon-itt, 2008). These studies suggest that the relationship between supply chain risk and integration is moderated by internal and external organizational factors. For example, the conceptual work of Stonebraker and Liao (2004) argues that positive relationship of environmental turbulence with stages, degree, and breadth of supply chain integration is stronger in firms with continuous-process technology (high process continuity)

than in firms with small-batch process technology (low process continuity). Similarly, the case-based work of Wong and Boon-itt (2008) identifies institutional factors as the potential moderators in the relationship between environmental uncertainty (ensuing from suppliers, customers, and technology) and supply chain integration. Wong and Boon-itt (2008) report that institutional norms such as training, information sharing, and culture of collaboration developed by mutual interaction among government, supplier and customers strengthen positive association between environmental uncertainty and supply chain integration. The theorization and findings of our research vis-à-vis Zhao *et al.* (2013) and the works of Wong and Boon-itt (2008) and Stonebraker and Liao (2004) present a motivation and foundation for more research. Potentially, the future research may use empirical data to examine the internal and external conditions (i.e. moderation effects) in which supply chain risk may lead to or hinder supply chain integration.

Contrary to our hypothesis, findings suggest that a firm's supply chain risk has no bearing on internal integration. Though surprising this result partially matches with the findings of Zhao et al (2013) who did not find empirical support for the relationship between demand risk and internal integration. We present two possible explanations. First, this could be because of the general level of organizational maturity of the companies in our sample. Perhaps organizations in our sample or in general have matured and achieved the internal integration, i.e. the first level of supply chain integration, regardless of the firm's supply chain risk (Zhao *et al.*, 2011, Kanter, 1994). The widespread implementation of information technology based management information systems has made internal integration less of a challenge (Olhager and Selldin, 2003). Olhager and Selldin (2003) report that the main benefits of these systems are in the functional areas of internal enterprise. These systems enhance the efficiency and effectiveness of collection and dissemination of information within the organization. Moreover, for most companies supply chain risk or external integration is not the top motivation for implementing these systems (Olhager and Selldin, 2003). However, the presence of these systems enhances internal integration which in turn helps in supplier and customer integration (Riley *et al.*, 2016). Second, this could be because internal integration gives access to internal resources which are comparatively easier to access than supplier and customer resources in situations of supply chain disruption. Thus, organizations may find supplier and customer

integration, instead of internal integration, a more appropriate response to supply chain risk. It would be interesting to explore the relationship between supply chain risk and internal integration in more detail in future research.

Given the missing empirical link from a firm's supply chain risk to internal integration, the rejection of hypotheses regarding the mediating role of internal integration in the relationship between supply chain risk and supplier and customer integration is understandable. The lack of relationship between a firm's supply chain risk and internal integration has a deleterious effect on the empirical support for the mediating role of internal integration (Malhotra *et al.*, 2014). However, strong positive effects of internal integration on supplier and customer integration (Figure 2) suggest that though internally-integrative behavior is indifferent to a firm's supply chain risk, it does provide the needed foundation for a higher level of integration with key suppliers and customers (Braunscheidel and Suresh, 2009). Internal integration provides the in-house coordination and absorptive capacity to benefit from external partners. Thus, our findings endorse the earlier studies arguing that internal integration lends support for supplier and customer integration (Cheng *et al.*, 2016, Gimenez and Ventura, 2005, Childerhouse and Towill, 2011).

**Supply Chain Integration and Agility Performance**

Supplier, internal, and customer integration show a positive impact on agility performance, though the impact of internal integration is weak. These findings are congruent with the earlier studies arguing for a positive impact of integrative practices on various performance dimensions (Danese *et al.*, 2013, Closs *et al.*, 2005, Devaraj *et al.*, 2007). In addition, our study finds that supplier integration has the strongest impact on agility performance followed by customer integration and internal integration respectively. The weak link between internal integration and agility performance is surprising because in most of earlier studies internal integration is found to have positive impact on various dimensions of agility performance (Williams *et al.*, 2013, Lee *et al.*, 2007, Droge *et al.*, 2004, Antonio *et al.*, 2009, Brusset, 2016). These findings however do not undermine the importance of internal integration which, as results suggest, lays a foundation for supplier and customer integration. The strong effect of supplier and customer integration on agility performance supports the idea that key suppliers and customers are the source of information to the supply

and demand markets respectively; thus a weak connection with the key suppliers and customers would delay the access to market information (Lee and Whang, 2000). Delayed access to the information regarding supply and demand markets may dilute the effectiveness and efficiency of internal sense-making (that seeks to utilize the external information) and retard subsequent coordination with key suppliers and customers. Therefore, it makes sense that companies having close knitted relationships with key suppliers and customers and among internal stakeholders enjoy better agility performance.

Internal integration, in addition to a weak direct effect, has positive effects on agility performance through supplier and customer integration. These findings are important, given there is limited research that examines the mediating role of supplier and customer integration in the relationship between internal integration and agility performance. For example, the work of Cheng *et al.* (2016) found a mediation effect of external integration in the relationship between internal integration and operational performance. Most of the studies have either focused on the impact of internal integration on supplier and customer integration or the impact of various dimensions of supply chain integration on different measures of performance. For example, Koufteros *et al.* (2005) and Zhao *et al.* (2011) examine the impact of internal integration on supplier and customer integration. Similarly, some scholars have examined the impact of dimensions of supply chain integration on various dimensions of agility performance such as design, delivery, and flexibility performance (Lau *et al.*, 2010, Droge *et al.*, 2004, Antonio *et al.*, 2009, Williams *et al.*, 2013). The findings of this research extend the earlier research by providing the evidence for the mediation effect of supplier and customer integration in the relationship between internal integration and agility performance.

**Supply Chain Risk, Supply Chain Integration, and Agility Performance**

Disruption in supply, internal, and delivery functions impedes organizational performance in terms of on-time and quick deliveries, meeting requirements of volume and mix variations, and producing customized and new products (Chen *et al.*, 2013, Chopra and Sodhi, 2004). The ability to organize supply chain to outperform competition on these performance dimensions under risky circumstances could be a source of competitive advantage for an organization (Li *et al.*, 2006, Vanpoucke *et al.*, 2014). The challenge

is to appropriately organize supply chain activities to achieve these performance objectives. Our argument, congruent with the literature, suggests that these performance dimensions can be enhanced by agile, resilient, and robust supply chains (Wieland, 2013, Christopher and Peck, 2004) and intra- and inter-organizational integrative and collaborative practices are means to build such supply chains (Brusset and Teller, 2017, Braunscheidel and Suresh, 2009, Durach *et al.*, 2015).

Our study finds that firms facing supply chain risk may achieve these performance objectives through enhanced integration with key suppliers and customers. This implies that supplier and customer integration may provide the competitive advantage to achieve agility performance when a firm faces supply chain risk. Moreover, our findings suggest that the effect of supply chain risk on agility performance through supplier integration is stronger than that through customer integration. The relatively stronger effect through supplier integration further underscores the significance of the firm's connection with key suppliers (Chopra and Sodhi, 2004). On the contrary, supply chain risk does not affect agility performance through internal integration. This is because the relationship between supply chain risk and internal integration is too weak to lend mediation effect to internal integration. It would be interesting to examine the conditions where internal integration may mediate the relationship between supply chain risk and agility performance in future research.

**Managerial Implications**

This paper offers certain insights for operations and supply chain managers. Managers should appreciate the importance of supplier and customer integration when responding to a firm's supply chain risk. Provided the prevalence of supply chain risk, supplier and customer integration offer the structural elements to achieve enhanced agility performance. Key suppliers and customers are the source of supply and demand markets information which is a key input in the organizational sense-making process in risk prone circumstances. Imperfect connection with key suppliers or customers would have weakening and cascading effects on the firm's planning, organizing, and controlling of supply chain activities for agility performance. Thus, managers should develop integrative practices with key suppliers and customers to manage risk and enhance agility performance. In addition, this paper finds that though internal integration

has a weak direct positive impact on agility performance and does not mediate the relationship between supply chain risk and agility performance, internal integration enables supplier and customer integration and positively affects agility performance through supplier and customer integration. Managers should view supplier and customer integration as direct antecedents of agility performance and internal integration as an enabler of supplier and customer integration. Thus, all three elements of supply chain integration have different but important role in enhancing agility performance.

**CONCLUSION AND FUTURE RESEARCH**

This paper extends the empirical research on supply chain risk and supply chain integration in several important ways (Ho *et al.*, 2015). Firstly, the paper uses DCV to argue that supply chain risk encourages firms to enhance their integration with key suppliers, internal functions, and customers. The empirical examination lends strong support to the relationship between firm's supply chain risk and supplier and customer integration, though there is a lack of evidence for the impact of firm's supply chain risk on internal integration. As a result this paper makes one of the initial efforts to fill voids in the empirical research on supply chain risk and supply chain integration by positing and testing whether a firm's supply chain risk leads to supply chain integration (Ho *et al.*, 2015, Wong and Boon-itt, 2008, Stonebraker and Liao, 2004, Sodhi *et al.*, 2012). Given the earlier work that argues and provides partial support for a negative association, i.e. opposite to our line of argument, between supply and demand risks and supply chain integration, our argument and findings are intriguing and complementary (Zhao *et al.*, 2013).

Secondly, this paper provides an empirical examination of the relationship between supply chain integrative practices and agility performance. The paper presents the empirical evidence for strong positive effects of supplier and customer integration and weak positive effect of internal integration on agility performance. The findings regarding supplier and customer integration are consistent with the earlier research arguing for the positive impact of the firm's integrative practices on various performance dimensions (Williams *et al.*, 2013, Flynn *et al.*, 2010, Fynes *et al.*, 2015). It seems that the weak direct effect of internal integration is because internal integration affects agility performance indirectly only, i.e.

through supplier and customer integration. Thus, internal integration provides a foundation for supplier and customer integration to enhance agility performance (Koufteros *et al.*, 2005, Danese *et al.*, 2013).

Thirdly, this paper uses DCV and supply chain management literature to argue for the mediating role of supplier, internal, and customer integration in the relationship between a firm's supply chain risk and agility performance. The empirical examination provides important insight that firms facing supply chain risk can achieve enhanced agility performance through supplier and customer integration. The empirical examination did not find support for the mediation effect of internal integration. In doing so, this paper makes one of the initial attempts to discuss and use large-scale data to examine the adoption of the elements of supply chain integration as a response to supply chain risk for improving agility performance (Ho *et al.*, 2015, Colicchia and Strozzi, 2012).

There are important opportunities for future research emerging from the findings and limitations of this paper. First, the future research may explain the reasoning behind presence of two different views on nature of relationship between supply chain risk and supply chain integration: one arguing for a positive effect of supply chain risk on supply chain integration such as our study, Wong and Boon-itt (2008) and Stonebraker and Liao (2004) and the other arguing for a negative effect of supply chain risk on supply chain integration such as Zhao *et al.* (2013). In this regard, building on the work of Wong and Boon-itt (2008), future research can analyze the contextual factors such as mature versus growing industries, developing versus developed countries, extent of competition, and manufacturing versus service sectors that may affect the relationship between supply chain risk and supply chain integration. Second, the mixed results (i.e. from no support to strong support) of the direct and mediation hypotheses provide opportunities for future research. The future research may discuss the above mentioned contextual factors for the examination of moderation or moderated mediation effects to help explain mixed results found here (Sousa and Voss, 2008). The moderated mediation analysis may attempt to explain if supply chain integration has different levels of utility under various circumstances in the relationship between supply chain risk and agility performance. Third, the data used here is cross-sectional, keeping this research from the examination of dynamic aspects of the proposed relationships. Future research may use longitudinal data or case-based

research to study the relationships between supply chain risk, supply chain integration, and agility performance over time. Finally, future research may use data from other industrial sectors such as service sectors to examine the generalizability of this research.

**Appendix A.** Representative supply chain risk, supply chain integration, and agility performance studies in supply chain risk management literature

| Sr. No. | Author(s) | Year | Journal | Context | Method | Main Focus | Key Pertinent Findings ( "→" = lead(s) to) |
|---|---|---|---|---|---|---|---|
| 1 | Dubey *et al.* | 2018 | IJOPM | Indian auto component manufacturing companies | Survey | • Antecedents of agility | • SC connectivity → information sharing and SC visibility.<br>• Information sharing → SC visibility.<br>• SC visibility → SC agility, adaptability, and alignment (equitable sharing of risk).<br>• Top management commitment moderates the relationship of supply chain visibility with SC agility and SC alignment. |
| 2 | Brusset and Teller | 2017 | IJPE | Multiple industries from France | Survey | • Consequences of risk<br>• Consequences of integration | • External capabilities do not → SC resilience.<br>• Integration capabilities and flexibility capabilities → resilience.<br>• External risk negatively moderates the association between external capabilities and resilience but does not moderate between internal/flexibility capabilities and resilience.<br>• Supplier risk negatively moderates the relationship between integration capabilities and resilience but does not moderate between external/flexibility capabilities and resilience.<br>• Customer risk does not moderate the relationship between external capabilities, integration capabilities or flexibility capabilities and resilience. |
| 3 | Chan *et al.* | 2017 | EJOR | Garment manufacturers in emerging Asian countries | Survey | • Antecedents and consequences of agility | • Manufacturing flexibility does not directly → firm performance.<br>• By effectively managing risk and uncertainties:<br>   (a) Strategic flexibility → firm performance.<br>   (b) Strategic and manufacturing flexibility → SC agility → firm performance. |
| 4 | Kim and Chai | 2017 | IJPE | Multiple manufacturing industries from Korea | Survey | • Antecedents of agility | • Information sharing, supplier innovativeness and strategic sourcing (risk mitigating factor) → SC agility. |

| | | | | | | | • The impact of information sharing, supplier innovativeness and strategic sourcing (risk mitigating factor) on SC agility is stronger in domestic sourcing compared to global sourcing. |
|---|---|---|---|---|---|---|---|
| 5 | Brusset | 2016 | IJPE | Supply chain managers in France | Survey | • Antecedents of agility | • Internal process and external capabilities → agility<br>• Visibility capabilities does not → agility |
| 6 | Gligor *et al.* | 2016 | IJPE | Multiple industries from US | Survey | • Consequences of risk<br>• Antecedents of agility | • Environmental uncertainty → market orientation.<br>• Environmental uncertainty does not → SC orientation.<br>• Market orientation → SC orientation.<br>• Market and SC orientation → SC agility. |
| 7 | Wiengarten *et al.* | 2016 | IJPE | Multiple manufacturing industries from multiple countries | Survey | • Consequences of risk and integration | • Customer integration does not → cost and innovation performance.<br>• Supplier integration → cost and innovation performance.<br>• Rule of law (risk) does not directly moderate integration-performance relationship. |
| 8 | Eckstein *et al.* | 2015 | IJPR | German manufacturing and logistics industries | Survey | • Antecedents and consequences of agility | • SC adaptability (sense and respond to supply and demand risks) → SC agility → cost performance and operational performance.<br>• SC agility and adaptability → cost performance and operational performance, product complexity moderates this relationship for adaptability but doesn't moderate for agility. |
| 9 | Narayanan *et al.* | 2015 | JOM | Institute for Supply Management databases | Survey | • Antecedents of agility<br>• Consequences of integration | • Collaboration → trust (reduced opportunistic behaviour and risk) → agility performance.<br>• Trust, asset specificity, and requirement certainty may enhance the impact of collaboration (coordination to reduce uncertainties) on agility performance. |
| 10 | Zhao *et al.* | 2015 | IMM | Manufacturing companies in multiple industries from | Survey | • Consequences of integration | • Too little or too much SCI can impair financial performance.<br>• The risk associated with the impact of SCI on financial performance can be mitigated by providing top management support for SC management. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | China | | | |
| 11 | He *et al.* | 2014 | IJPE | Multiple manufacturing industries in multiple countries | Survey | • Consequences of integration | • Customer and supplier integration → firm's new product performance, because confidence in a partner's ability reduces the perceived risk.<br>• Supplier integration → manufacturing flexibility → customer integration → new product performance.<br>• Service capability does not → customer integration.<br>• Supplier integration → firm's service capability. |
| 12 | Yang | 2014 | IJPE | Manufacturers from multiple industries in Shanghai | Survey | • Antecedents and consequences of agility | • Information sharing does not → SC agility which is considered as strategy to manage disruption risks.<br>• IT capability and operational collaboration → SC agility.<br>• SC agility → cost efficiency → performance. |
| 13 | Blome *et al.* | 2013 | IJPR | Multiple manufacturing industries in Germany | Survey | • Antecedents and consequences of agility | • Supply and demand-side competence → SC agility → firm's operational performance.<br>• Indirect positive effects of supply-side competence on operational performance are stronger than that of demand-side competence.<br>• Process compliance moderates the effects of supply and demand side competence on SC agility. |
| 14 | Zhao *et al.* | 2013 | SCMIJ | Manufacturing plants in ten countries | Survey | • Consequences of risk<br>• Antecedents and consequences of integration | • Supply delivery risk is negatively related to supplier, internal and customer integration.<br>• Demand variability risk is negatively related to customer integration.<br>• Supplier integration → customer satisfaction.<br>• Internal and customer integration → competitive performance and customer satisfaction. |
| 15 | Grötsch *et al.* | 2013 | IJPR | European automotive firms | Semi-structured interviews | • Consequences of risk | • Mechanistic management control system, a rational cognitive style, and relational buyer–supplier relationships → proactive management of supplier insolvency risks. |

| 16 | Diabat *et al.* | 2012 | IJPR | Food industry in India | Case study | • Antecedents of risk | • Five categories of risks were identified; product/service management risk, macro level risk, demand management risk, supply management risk, and information management risk. |
|----|----------------|------|------|------------------------|------------|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 17 | Kern *et al.* | 2012 | IJPDLM | Manufacturing companies located in Germany | Survey | • Consequences of risk | • SC risk identification → SC risk assessment → SC risk mitigation → SC risk performance.<br>• Continuous improvement → SC risk identification, assessment and mitigation. |
| 18 | Wieland and Wallenburg | 2012 | IJPDLM | Manufacturing companies from multiple industries in Germany, Austria, Switzerland | Survey | • Consequences of risk<br>• Antecedents of agility | • SCRM → agility and robustness → customer value.<br>• Robustness and customer value → business performance. |
| 19 | Thun and Hoenig | 2011 | IJPE | German automotive industry | Survey | • Antecedents and consequences of risk | • Complexity and efficiency → SCR.<br>• Internal SCR have higher likelihood to occur than external SCR.<br>• Degree of SCRM → higher performance. |
| 20 | Thun *et al.* | 2011 | IJPR | Manufacturing plants in the German automotive industry | Survey | • Consequences of risk | • Small and medium-sized enterprises are slightly more vulnerable than large-scale enterprises.<br>• Developments towards complexity and efficiency do not affect small and medium-sized enterprises stronger than large-scale enterprises.<br>• Small and medium-sized enterprises implement reactive instruments of SCRM whereas large-scale enterprises focus on preventive instruments. |
| 21 | Merschmann and Thonemann | 2011 | IJPE | Manufacturing companies in Germany | Survey | • Consequences of risk | • In environments with high uncertainty, companies with high supply chain flexibility perform better. |

| 22 | Tummala and Schoenherr | 2011 | SCMIJ | Conceptual framework | Framework | • Consequences of risk | • Supply chain risks can be managed more effectively when applying the supply chain risk management process (SCRMP).<br>• SCRMP is a tool to provide management with useful and strategic information concerning the SC risk profiles associated with a given situation. |
|----|----|----|----|----|----|----|----|
| 23 | Ellis *et al.* | 2010 | JOM | Multiple US manufacturing industries | Survey | • Antecedents and consequences of risk | • Technological uncertainty and supply market thinness → probability and magnitude of supply disruption.<br>• Item customization do not → probability of supply disruption.<br>• Item customization and importance → magnitude of supply disruption.<br>• Probability and magnitude of supply disruption → overall supply disruption risk.<br>• Overall supply disruption risk → search for alternative source |
| 24 | Blos *et al.* | 2009 | SCMIJ | Automotive and electronic industries in Brazil | Survey | • Consequences of risk | • SCRM practices: a better supply chain communication, SCRM and business continuity management training program, and the creation of a chief risk officer. |
| 25 | Braunscheidel and Suresh | 2009 | JOM | Variety of manufacturing organizations from the database of Institute of Supply Management | Survey | • Consequences of integration<br>• Antecedents of agility | • Market orientation → internal and external integration and external flexibility.<br>• Learning orientation → internal integration.<br>• Learning orientation does not → external integration and external flexibility.<br>• Internal integration → external integration.<br>• Internal and external integration do not → external flexibility.<br>• Internal integration, external integration, and external flexibility → SC agility – a risk management initiative. |

| 26 | Trkman and McCormack | 2009 | IJPE | Automotive industry | Case Study | • Consequences of risk | • Supplier characteristics may entail considerably different risks in different situations.<br>• The focal company should not lock itself in with the suppliers that either cannot cope with the turbulence or do not fit within the SC strategy. |
|----|----------------------|------|------|---------------------|------------|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 27 | Manuj and Mentzer | 2008 | IJPDLM | Literature review and interviews of senior SC executives | Interviews and focus groups | • Antecedents and consequences of risk | • Sources of SCR: supply, operational, and demand risks<br>• Selection of SCRM strategy depends on the design and structure of firm's global supply chain |
| 28 | Wagner and Bode | 2008 | JBL | Management executives in Germany | Survey | • Consequences of risk | • Supply and demand side risks → lower supply chain performance. |
| 29 | Wong and Boon-itt | 2008 | IJPE | Thai automotive industry | Case study | • Consequences of risk | • Environmental uncertainty enhances SCI<br>• Institutional norms moderate the relationship between environmental uncertainty and SCI |
| 30 | Ritchie and Brindley | 2007 | IJOPM | A multinational automobile manufacturer and a contractor in construction industry | Case study | • Antecedents and consequences of risk | • Processes of change in modes of operations and relationships seem to be more revolutionary than evolutionary and, as a consequence, engender an increased sense of uncertainty and risk within all managers operating throughout the various stages of the SC.<br>• Performance measurement in terms of efficiency and effectiveness is linked to SCR and SCRM. |
| 31 | Faisal *et al.* | 2006 | BPMJ | Indian manufacturing SMEs | Interpretive structure modelling | • Consequences of risk | • Trust and information sharing through collaborative relationships → SCRM. |
| 32 | Gaudenzi and Borghesi | 2006 | IJLM | Case study | Case study | • Antecedents of risk | • Key managers' evaluation of impacts and cause-effect relationships → appreciation of SCR. |
| 33 | Jüttner | 2005 | IJLM | UK-based chartered institute for | Survey and focus groups | • Consequences of risk | • Traditional risk management approaches derived from a single company perspective are not ideally suited to accommodate the requirements in a SC context. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | logistics and transport |
| 34 | Norrman and Jansson | 2004 | IJPDLM | Ericsson's supply chain accident | Case study | • Consequences of risk | • Insurance companies might be a driving force for improved SCRM, as the former understand the vulnerability of modern SC. |
| 35 | Christopher and Peck | 2004 | IJLM | Conceptual framework | Framework | • Consequences of risk | • SCRM culture, SC collaborations and agility → SC resilience. |
| 36 | Chopra and Sodhi | 2004 | SMR | Global examples of supply chain risk | Framework | • Consequences of risk | • Managers must create a shared, organization wide understanding of SCR.<br>• They must adapt general risk-mitigation approaches to the circumstances of their particular company. |
| 37 | Christopher and Lee | 2004 | IJPDLM | Conceptual - International examples | Framework | • Consequences of risk | • Improvements in SC confidence (through visibility and control) → breaking the risk spiral and mitigating SCR. |
| 38 | Prater et al. | 2001 | IJOPM | Frame work - case studies | Case study | • Antecedents and consequences of agility | • The speed and flexibility of the SC → firm's agility.<br>• Measures taken to increase agility often lead to increases in complexity, which works against agility. |

SC: Supply Chain, SCI: Supply Chain Integration, SCR: Supply Chain Risk, SCRM: Supply Chain Risk Management
BPMJ: Business Process Management Journal, EJOR: European Journal of Operations Research, IJLM: International Journal of Logistics Management, IJOPM: International Journal of Operations and Production Management, IJPDLM: International Journal of Physical Distribution and Logistics Management, IJPE: International Journal of Production Economics, IJPR: International Journal of Production Research, IMM: Industrial Marketing Management, JBL: Journal of Business Logistics, JOM: Journal of Operations Management, SCMIJ: Supply Chain Management: An International Journal, SMR: Sloan Management Review.

**Appendix B.** Construct measurement

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|---|
| **Supply Chain Risk** (Cronbach's alpha = 0.851, Joreskog ρ = 0.858, CFI = 1.000, AVE = 0.672) |
| A key supplier fails to supply affecting your operations *(SFL = 0.707, SE = 0.038)*<br>Your manufacturing operations are interrupted affecting your shipments *(SFL = 0.940, SE = 0.062)*<br>Your shipment operations are interrupted affecting your deliveries (S*FL = 0.795, SE = 0.052*) |
| **Supplier Integration** (Cronbach's alpha = 0.841, Joreskog ρ = 0.848, CFI = 1.000, AVE = 0.584) |
| Sharing information with key suppliers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level) *(SFL = 0.775, SE = 0.040)*<br>Developing collaborative approaches with key suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements) *(SFL = 0.820, SE =0.047)*<br>Joint decision making with key suppliers (about product design/modifications, process design/modifications, quality improvement and cost control) *(SFL = 0.781, SE = 0.50)*<br>System coupling with key suppliers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment) *(SFL = 0.674, SE = 0.055)* |
| **Internal Integration** (Cronbach's alpha = 0.889, Joreskog ρ = 0.889, CFI = 0.915, AVE = 0.668) |
| Sharing information with purchasing department (about sales forecast, production plans, production progress and stock level) *(SFL = 0.763, SE =0.041)*<br>Joint decision making with purchasing department (about sales forecast, production plans and stock level) *(SFL = 0.801, SE = 0.048)*<br>Sharing information with sales department (about sales forecast, production plans, production progress and stock level) *(SFL = 0.848, SE =0.047)*<br>Joint decision making with sales department (about sales forecast, production plans and stock level) *(SFL = 0.855, SE = 0.050)* |
| **Customer Integration** (Cronbach's alpha = 0.883, Joreskog ρ = 0.885, CFI = 0.988, AVE = 0.660) |
| Sharing information with key customers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level) *(SFL = 0.855, SE =0.047)*<br>Developing collaborative approaches with key customers (e.g. risk/revenue sharing, long-term agreements) *(SFL = 0.854, SE =0.036)*<br>System coupling with key customers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment) *(SFL = 0.783, SE =0.040)*<br>Joint decision making with key customers (about product design/modifications, process design/modifications, quality improvement and cost control) *(SFL = 0.752, SE = 0.037)* |
| **Flexibility Performance** (Cronbach's alpha = 0.747, Joreskog ρ = 0.748, AVE = 0.597) |
| Volume flexibility (S*FL = 0.757, SE =0.063)*<br>Mix flexibility *(SFL = 0.788, SE =0.069)* |
| **Design Performance** (Cronbach's alpha = 0.626, Joreskog ρ = 0.627, AVE = 0.456) |
| Product customization ability *(SFL = 0.664, SE =0.072)*<br>New product introduction ability *(SFL = 0.687, SE =0.089)* |
| **Delivery Performance** (Cronbach's alpha = 0.823, Joreskog ρ = 0.823, AVE = 0.700) |
| Delivery speed *(SFL = 0.845, SE = 0.060)*<br>Delivery reliability *(SFL = 0.828, SE = 0.061)* |
| **Agility Performance** (Joreskog ρ = 0.829, CFI = 0.985, AVE = 0.620) |
| Flexibility Performance *(SFL = 0.803, SE = 0.100)*<br>Design Performance *(SFL = 0.875, SE = 0.104)*<br>Delivery Performance *(SFL = 0.670, SE = 0.081)* |

CFI: Comparative fit index, AVE = Average variance extracted, SFL: Standardized factor loading, SE = Standard error

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