

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 to integrate their supply chain to enhance agility performance. Structural equation modeling 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.

1. 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 (Norrmann 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).

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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, this study is one of the first to empirically examine the linkage from firm's supply chain risk to supply chain integration leading 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.

2. Research framework

2.1. 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).

2.2. 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 (Vijayasathya, 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 with 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.

2.3. 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., 2006a, 2006b, 2008). 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

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)		✓		✓	✓	

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).

3. Hypotheses

3.1. 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).

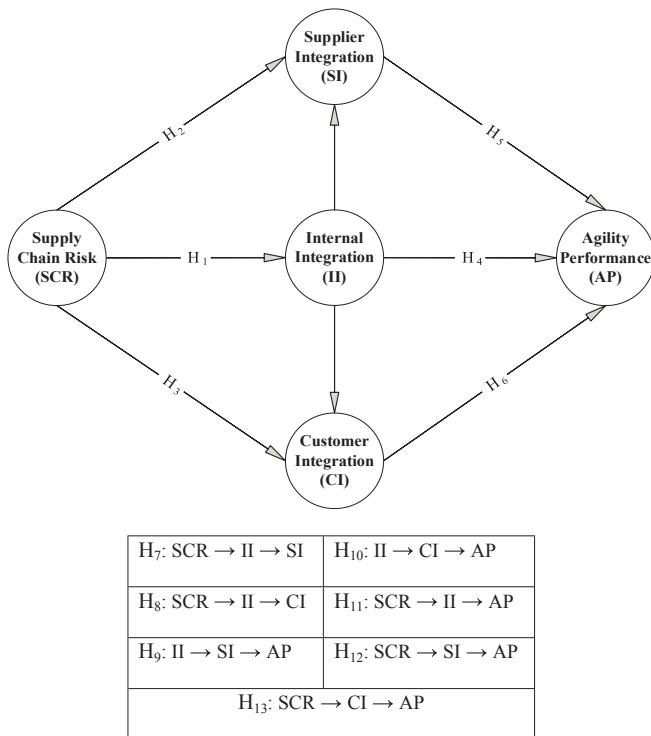
Extending RBV, DCV stresses the importance of the dynamic capability building processes in gaining competitive advantage (Eisenhardt and Martin, 2000; Teece et al., 1997). A Dynamic Capability (DC) can be defined as the firm's ability to integrate, build, and reconfigure internal and external resources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

3.2. 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., 2006, 2007; 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. Fig. 1 illustrates the theoretical



Direction of arrows indicates direction of positive relationship.

Fig. 1. Hypothesized model.

model of this study.

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:

H1. 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:

H2. 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 functionalities), 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, 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

3.3. 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.

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 co-ordinated operations with customers are key inputs in the development of quick and reliable production and delivery systems (Closs 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:

H6. Customer integration has a positive impact on agility performance

3.4. 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 H1, H2, and H3 with earlier findings of the positive relationship of internal integration with supplier integration and customer integration we hypothesize:

H7. Internal integration partially mediates the relationship between firm's supply chain risk and supplier integration

H8. 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 H4, H5, and H6, we hypothesize:

H9. Supplier integration partially mediates the relationship between internal integration and agility performance

H10. 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 H1 through H6, 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:

H11. Internal integration mediates the relationship between firm's supply chain risk and agility performance

H12. Supplier integration mediates the relationship between firm's supply chain risk and agility performance

H13. Customer integration mediates the relationship between firm's supply chain risk and agility performance

4. Method

4.1. 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.

4.2. 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

Table 2
Sample demographics.

Firm size (<i>number of employees</i>)	Number	% of Usable Sample
Small (<i>less than 250</i>)	360	46.75
Medium (<i>251 to 500</i>)	131	17.01
Large (<i>more than 500</i>)	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	16.10
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	4.80
Region^a and Country (<i>country sample size</i>)		
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		

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; Closs et al., 2005; Lau et al., 2010; Braunscheidel and Suresh, 2009; Vijayarath, 2010), collaborative approaches (Devaraj et al., 2007; Closs et al., 2005; Braunscheidel and Suresh, 2009; Vijayarath, 2010), joint decision-making (Lau et al., 2010; Braunscheidel and Suresh, 2009), and systems coupling (Devaraj et al., 2007; Braunscheidel and Suresh, 2009; Vijayarath, 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).

4.3. 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 (χ^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 χ^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 ρ , 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 ρ are greater than 0.70 except design performance (Cronbach's alpha = 0.626, Joreskog ρ = 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

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, AP: Agility performance.

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).

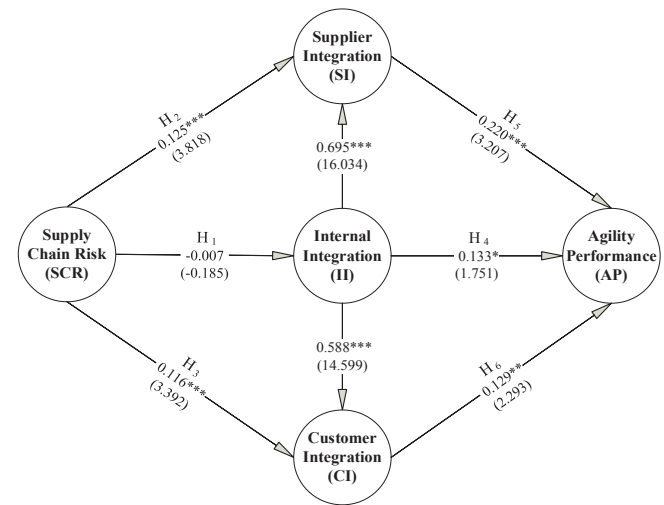
Agility performance construct was operationalized as a second-order construct consisting of flexibility, design, and delivery performance, so additional measurement analysis was carried out to test the validity of this choice (Jarvis et al., 2003). Firstly, the second-order factor loadings provided in 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 χ^2 of first-order single factor model (363.313 at $d.f. = 9$) is significantly (p -level = 0.01) greater than the value of χ^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 ($\chi^2_{336, d.f.} = 920.370$, 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 χ^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 $\chi^2_{351, d.f.} = 954.895$, thus $\Delta\chi^2$ was significant ($\Delta\chi^2_{15, d.f.} = 34.525$, $p = 0.003$) 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 χ^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 χ^2 for the constrained model improved to $\chi^2_{349, d.f.} = 939.046$, thus $\Delta\chi^2_{13, d.f.} = 18.676$ 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).

4.4. 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 Fig. 2 show the path coefficients of the structural



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

Values in parenthesis are t-values.

Direction of arrows indicates direction of positive relationship.

Fig. 2. Results with path coefficients for direct hypotheses testing.

model. The path from supply chain risk to internal integration is insignificant ($\beta = -0.007$, p -value > 0.10), thus rejecting H1. 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 H2 and H3 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 H5 and H6 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 Fig. 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 Fig. 2. Overall the revised model's goodness-of-fit indices ($\chi^2_{226, d.f.} = 1321.271$, 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).

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.,

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
H7	SCR	II	SI	−0.007	0.695***	0.125***	−0.005	0.031	−0.067–0.053
H8	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.

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 H7 and H8 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 H7 and H8.

The indirect effects hypothesized in H9 through H13 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. H9 and customer integration i.e. H10), and (b) the indirect effect of supply chain risk on agility performance is through three parallel mediators (internal integration i.e. H11, supplier integration i.e. H12, and customer integration H13). 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 Table 5 summarize estimated effects and respective 95 percent for each hypothesized relationship.

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 H9 and H10. In addition, the results show that the indirect effect of supply chain risk on agility performance through internal integration is not significant thus rejecting H11. 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 H12 and H13.

5. 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 (H1), independent (H4), or mediating (H7, H8, H11) variable. All the results are summarized in Table 6.

5.1. 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

Table 5
Bootstrapping results for mediation relationship tests (H9 – H13).

Hypothesis	IV	MV	DV	Direct effect	Indirect effect of IV on DV	SE of indirect effects	95% CInt for mean indirect effect
H9	II	SI	AP	0.153**	0.196***	0.048	0.104–0.291
H10	II	CI	AP	0.217***	0.126***	0.032	0.064–0.191
H11	SCR	II	AP	0.054	−0.002	0.015	−0.031–0.027
H12	SCR	SI	AP	0.008	0.045***	0.018	0.012–0.084
H13	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.

Table 6
Hypotheses test results.

Hypothesis	Supported (Yes/WS/No)
H1: Supply chain risk → internal integration	No
H2: Supply chain risk → supplier integration	Yes
H3: Supply chain risk → customer integration	Yes
H4: Internal Integration → agility performance	WS
H5: Supplier Integration → agility performance	Yes
H6: Customer Integration → agility performance	Yes
H7: Supply chain risk → internal integration → supplier integration	No
H8: Supply chain risk → internal integration → customer integration	No
H9: Internal integration → supplier integration → agility performance	Yes
H10: Internal integration → customer integration → agility performance	Yes
H11: Supply chain risk → internal integration → agility performance	No
H12: Supply chain risk → supplier integration → agility performance	Yes
H13: 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.

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 (Fig. 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).

5.2. 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.

5.3. 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.

5.4. 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.

6. 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. - Information sharing → SC visibility. - SC visibility → SC agility, adaptability, and alignment (equitable sharing of risk). - 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 - Consequences of integration	- External capabilities do not → SC resilience. - Integration capabilities and flexibility capabilities → resilience. - External risk negatively moderates the association between external capabilities and resilience but does not moderate between internal/flexibility capabilities and resilience. - Supplier risk negatively moderates the relationship between integration capabilities and resilience but does not

							moderate between external/flexibility capabilities and resilience.
3	Chan et al.	2017	EJOR	Garment manufacturers in emerging Asian countries	Survey	• Antecedents and consequences of agility	• Customer risk does not moderate the relationship between external capabilities, integration capabilities or flexibility capabilities and resilience. • Manufacturing flexibility does not directly → firm performance. • By effectively managing risk and uncertainties: (a) Strategic flexibility → firm performance. (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 • Visibility capabilities does not → agility
6	Gligor et al.	2016	IJPE	Multiple industries from US	Survey	• Consequences of risk • Antecedents of agility	• Environmental uncertainty → market orientation. • Environmental uncertainty does not → SC orientation. • Market orientation → SC orientation. • 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. • Supplier integration → cost and innovation performance. • 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. • 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 • Consequences of integration	• Collaboration → trust (reduced opportunistic behavior and risk) → agility performance. • 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 China	Survey	• Consequences of integration	• Too little or too much SCI can impair financial performance. • The risk associated with the impact of SCI on financial performance can be mitigated by providing top management support for SC management.

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. - Supplier integration → manufacturing flexibility → customer integration → new product performance. - Service capability does not → customer integration. - 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. - IT capability and operational collaboration → SC agility. - SC agility → cost efficiency → performance.
13	Blome et al.	2013a,b	IJPR	Multiple manufacturing industries in Germany	Survey	Antecedents and consequences of agility	- Supply and demand-side competence → SC agility → firm's operational performance. - Indirect positive effects of supply-side competence on operational performance are stronger than that of demand-side competence. - 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 - Antecedents and consequences of integration	- Supply delivery risk is negatively related to supplier, internal and customer integration. - Demand variability risk is negatively related to customer integration. - Supplier integration → customer satisfaction. - 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. - 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 - Antecedents of agility	- SCRM → agility and robustness → customer value. - 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. - Internal SCR have higher likelihood to occur than external SCR. - 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. - Developments towards complexity and efficiency do not affect small and medium-sized enterprises stronger than large-scale enterprises. - 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). - 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. - Item customization do not → probability of supply disruption. - Item customization and importance → magnitude of supply disruption. - Probability and magnitude of supply disruption → overall supply disruption risk. - Overall supply disruption risk → search for alternative source
24	Blos et al.	2009	SCMIJ	Automotive and electronic industries in Brazil	Survey	Consequences of risk	SCRMP 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 - Antecedents of agility	- Market orientation → internal and external integration and external flexibility. - Learning orientation → internal integration. - Learning orientation does not → external integration and external flexibility. - Internal integration → external integration. - Internal and external integration do not → external flexibility. - 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. - 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 • 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 • 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. • 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 modeling	• 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 logistics and transport	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.
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. • 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. • 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

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)

Your manufacturing operations are interrupted affecting your shipments (*SFL* = 0.940, *SE* = 0.062)

Your shipment operations are interrupted affecting your deliveries (*SFL* = 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)

Developing collaborative approaches with key suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements) (*SFL* = 0.820, *SE* = 0.047)

Joint decision making with key suppliers (about product design/modifications, process design/modifications, quality improvement and cost control) (*SFL* = 0.781, *SE* = 0.50)

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)

Joint decision making with purchasing department (about sales forecast, production plans and stock level) (*SFL* = 0.801, *SE* = 0.048)

Sharing information with sales department (about sales forecast, production plans, production progress and stock level) (*SFL* = 0.848, *SE* = 0.047)

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)

Developing collaborative approaches with key customers (e.g. risk/revenue sharing, long-term agreements) (*SFL* = 0.854, *SE* = 0.036)

System coupling with key customers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment) (*SFL* = 0.783, *SE* = 0.040)

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 (*SFL* = 0.757, *SE* = 0.063)

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)

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)

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)

Design Performance (*SFL* = 0.875, *SE* = 0.104)

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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