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Supply chain integration, risk management and manufacturing flexibility

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Abstract

Purpose – The purpose of this paper is to investigate the impact of internal integration, external integration (EI), and supply chain risk management (SCRM) on manufacturing flexibility, and the moderating effect of SCRM on the relationships between internal and EI, respectively, and manufacturing flexibility.
Design/methodology/approach – Using hierarchical regression, data are analyzed from a sample of 343 manufacturing plants in Asia collected in 2013-2014 as part of the International Manufacturing Strategy Survey (IMSS VI).
Findings – Internal integration and SCRM have a direct effect on manufacturing flexibility. SCRM moderates the relationship between EI and flexibility.
Research limitations/implications – Further research is needed to generalize beyond the flexibility performance of discrete manufacturing firms in Asia.
Practical implications – To benefit from EI and increase their flexibility performance, manufacturing firms need to implement different mechanisms of SCRM to prevent and deal with supply chain risks including those associated with supply chain integration.
Originality/value – This research contributes to the body of knowledge on the relationships between internal integration, EI, SCRM, and manufacturing flexibility.

Keywords Supply chain risk management, Internal integration, Manufacturing flexibility, Asian manufacturing, External integration

Paper type Research paper

Introduction

With ever more complex, international, and dynamic supply chains, the importance of risk management and supply chain integration is increasingly recognized in both practice and theory. This paper focuses on the interaction between supply chain integration, supply chain risk management (SCRM), and operations performance, in particular flexibility.

Decisions to buy, instead of make, are fundamental to the existence of supply chains, but also create supply chain risks – i.e. events that may occur and, if they do, have a negative impact. Flexibility, the ability to cope with variation (Slack, 2005) without major time and cost implications (Narasimhan and Das, 2000), does not necessarily affect the probability, but may reduce the impact, of risk.

Both external (i.e. with suppliers and customers) and internal (i.e. between manufacturing, purchasing and sales) integration have been associated with supply chain risk. However, research on the association between integration and flexibility has produced

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inconsistent results (Flynn *et al.*, 2010; Mackelprang *et al.*, 2014). Vereecke and Muylle (2006), Braunscheidel and Suresh (2009), and Wong *et al.* (2011) show that internal and external integration (EI) improve flexibility. Frohlich and Westbrook (2001) report that manufacturers focusing on only one side of their supply chain fail to obtain all the benefits of EI. Schoenherr and Swink (2012) found that internal integration strengthens the positive impact of EI on flexibility performance. Koufteros *et al.* (2005) and Fabbe-Costes and Jahre (2008), however, do not find a positive impact of supply chain integration on performance. Flynn *et al.* (2010) attribute the inconsistency in findings to the propensity of researchers to consider only EI while neglecting the importance of internal integration.

A high degree of coordination and information sharing with supply chain partners increases not only complexity and costs, but also risks (Hallikas *et al.*, 2004; Vanpoucke *et al.*, 2009) and may even result in loss of flexibility (Terjesen *et al.*, 2012). Thus, manufacturing firms have started developing SCRM to prevent, detect, mitigate, and respond more adequately to supply chain risks, and use it to improve their agility, i.e. their responsiveness to environmental changes (Wieland and Wallenburg, 2012; Lavastre *et al.*, 2014). While supply chain agility is an externally focused capability, flexibility, an internally focused competency can be considered to be its antecedent (Braunscheidel and Suresh, 2009). This suggests that there should be a relationship between SCRM and flexibility.

However, it is unclear whether the positive effects of supply chain integration outweigh the risks associated with it. Similarly, the extent to which SCRM alone affects flexibility is not clear. Hence, there is a need to analyze the effects of internal and EI as well as SCRM, on manufacturing flexibility in one study, questions that are highly relevant for SCM practice, too. For example, Aryzta, a frozen food producer, uses SCRM to complement its strategic supplier collaboration initiative, which resulted in assured uninterrupted supply of eggs during an avian flu outbreak and provided the necessary flexibility (SCM World, 2016). Going beyond such anecdotal evidence, this paper considers the troublesome relationships between integration, SCRM, and flexibility outlined above, and uses a large-scale study to investigate:

- the direct impact of internal and EI and SCRM on manufacturing flexibility, and
- the possible moderating role of SCRM in the relationships between internal and EI, respectively, and flexibility.

Literature review

Impact of supply chain integration on performance

Frohlich and Westbrook (2001) demonstrated that higher levels of EI improve firm performance. Investments in integrated systems help supply chain members to anticipate possible challenges (Wieland and Wallenburg, 2013). Devaraj *et al.* (2007) and Van der Vaart and Van Donk (2008) found supplier integration to affect performance positively. Braunscheidel and Suresh (2009) and Wong *et al.* (2011) report positive impact of internal and EI on flexibility. Schoenherr and Swink (2012) report that internal integration strengthens the impact of EI on delivery and flexibility performance.

Vereecke and Muylle (2006) observe that modest collaboration with customers or suppliers delivers, at best, piecemeal improvements of performance in isolated areas, whereas a coherent supply chain strategy, consisting of both information exchange and structural collaboration with suppliers and customers, is associated with simultaneous improvements in major performance measures. Wiengarten *et al.* (2010) found that collaboration through information sharing has stronger impact on operational performance than joint decision making and incentive alignment.

Fabbe-Costes and Jahre (2008), however, found that a higher degree of integration does not necessarily improve performance. Supply chain integration can even have negative effects. Accidents are inevitable in complex, tightly coupled systems (Perrow, 1984). Extending this notion to supply networks, multiple authors observe that integration among firms in a supply network will lead to increased interdependencies and, in effect, higher exposure to risk (Hallikas *et al.*, 2004; Wieland and Wallenburg, 2013; Kache and Seuring, 2014). Thus, integration may come at the cost of increased vulnerability to disruptions (Norrman and Jansson, 2004).

Thus, the reports on the impact of integration on performance vary from positive, through differentiated or no effects, to negative effects. Following Kache and Seuring (2014), we conclude that further research is needed to shed light on these conflicting findings.

Need to study the influence of SCRM on the relationship between integration and performance

Differences in context could explain the different findings on the association between integration and performance. The contextual factors that have been studied include relationship dynamics (Fynes *et al.*, 2005), environmental uncertainty (Wong *et al.*, 2011), a country's logistical capabilities (Wiengarten *et al.*, 2014), and risks (Wiengarten *et al.*, 2016). SCRM may be one such contextual factor (Bagchi *et al.*, 2005), but its role in the relationship between integration and performance has largely been ignored in the literature.

Notable exceptions are Ellinger *et al.* (2015), Gualandris and Kalchschmidt (2015), and Wiengarten *et al.* (2016) who, however, take rather different approaches and, in effect, report quite different results. Ellinger *et al.* (2015) found that internal, supplier, and customer integration mediate the relationship between learning orientation and SCRM, while SCRM improves overall logistical performance. Gualandris and Kalchschmidt (2015) argued that stronger integration with strategic suppliers is required to manage uncertainty. In a high-risk context, a balanced use of integration with SCRM approaches such as dual sourcing and revenue sharing contracts can be a source of competitive advantage. Wiengarten *et al.* (2016) show that SCRM practices complement supplier integration efforts in high risk, i.e. weak rule of law, environments, thereby strengthening the impact of supplier integration on performance. However, SCRM does not help in explaining the performance impact of customer integration.

Need to focus on flexibility

Research on the performance impact of integration has focused on a large variety of performance indicators. Although there are some exceptions (e.g. Braunscheidel and Suresh, 2009; Wong *et al.*, 2011; Schoenherr and Swink, 2012), flexibility is relatively under-researched, especially in studies linking collaboration and integration to risk and performance (Kache and Seuring, 2014).

Theoretical basis for studying the effects of SCRM on the supply chain integration-flexibility relationship

Dyer and Singh (1998) argued that organizations engaging in alliances can gain relational rents through relation-specific assets, knowledge-sharing routines, complementary resources and capabilities, and effective governance. Thus, as supply chain integration is a form of alliance, higher levels of integration should be expected to improve performance through increased knowledge exchange. However, can the relational view fully explain the impact of supply chain integration on flexibility? The agency theory and its underlying concepts may provide a more appropriate lens. Two parties have an agency relationship when the principal (e.g. the customer) delegates decisions and/or work to another agent (e.g. a supplier) to act on its behalf (Rungtusanatham *et al.*, 2007). In such relationships, the principal may face an agency problem and a risk-sharing problem. An agency problem occurs when the agent's goals differ from the principal's and the principal finds it difficult or too expensive to verify whether the agent has performed the delegated task appropriately or has the required expertise to perform the task. A risk-sharing problem arises when the principal and agent have different attitudes toward risks, which cause disagreements about actions to be taken (Rungtusanatham *et al.*, 2007). The agency theory prescribes two types of mechanisms – outcome based and behavior based – to address these problem (Rungtusanatham *et al.*, 2007). Outcome-based mechanisms emphasize results (Choi and Liker, 1995), while behavior-based mechanisms emphasize tasks and activities in the agent's processes. Determining which mechanisms are more efficient in managing agency relationships is a critical issue, and the actual choice of mechanisms depends on the relative cost of information sharing or degree of information asymmetry, level of outcome uncertainty, difficulty in measuring outcomes, the supplier's risk attitude with respect to the buyer, and the level of goal conflict between the buyer and the supplier (Eisenhardt, 1989).

Thus, the agency theory suggests that examining and explaining the impact of supply chain integration on flexibility requires considering a combination of outcome- and behavior-based mechanisms. Supply chain integration mechanisms are behavior based and involve information sharing, joint decision making and collaborative approaches, while SCRM focuses on outcomes and includes initiatives taken by a plant to select reliable suppliers for risk prevention, implement risk detection mechanisms, and have backup suppliers to respond to risks and contingency plans for recovering from risks (cf. Zsidisin and Ellram, 2003).

Hypotheses

Internal integration and flexibility

Internal integration refers to cross-functional collaboration and information sharing through interconnected and synchronized processes and systems, and alignment of intra-firm goals (Schoenherr and Swink, 2012).

This research specifically captures the internal integration efforts between the manufacturing, purchasing, and sales functions of manufacturing firms. As flexibility is important for firms to achieve and sustain competitive advantage, purchasing must also adopt appropriate strategies to achieve flexibility goals and sourcing can indeed influence modification, volume, and new product flexibility (Olhager, 1993). Shapiro (1977) recommends cooperation between marketing and manufacturing to take advantage of the firm's manufacturing capability and respond effectively to market needs. Chen *et al.* (1992) examine how firms can incorporate manufacturing flexibility into their marketing/manufacturing strategy. Thomé *et al.* (2012) found that sales and operations planning, which "brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans" (p. 360), may impact various performance measures, including volume and mix flexibility.

Some authors, however, report different effects. Koufteros *et al.* (2005) and Giménez and Ventura (2005) found no direct relationship between internal integration and operational performance. According to Upton (1997), cross-functional teaming may even affect flexibility negatively. As most authors report positive effects of internal integration, we hypothesize:

H1. Internal integration between manufacturing, purchasing, and sales has a positive effect on manufacturing flexibility.

EI and flexibility

Flexibility cannot be achieved by individual firms alone (Christopher and Towill, 2001) but requires inter-firm collaboration (Lin *et al.*, 2006), in the form of closer relationships, integrating processes and information sharing with customers and suppliers (Barratt, 2004).

Rho *et al.* (1994) report a significant association between vendor relationships and manufacturing flexibility. Narasimhan and Das (1999) found that SCM practices can be used for the development of delivery, modification, and volume flexibility. Chang *et al.* (2006) conclude that supplier involvement plays a major role in a firm's manufacturing flexibility. Devaraj *et al.* (2007) and Danese *et al.* (2013) found a positive effect of supplier integration on, amongst others, flexibility performance. According to Scherrer-Rathje *et al.* (2014), supplier capabilities and relationships are important for achieving manufacturing flexibilities through outsourcing. Jayaram *et al.* (2011) report a positive impact of supplier and customer coordination on flexibility. Vereecke and Muylle (2006) confirm that firms achieving major performance improvements on multiple performance measures of, amongst others, flexibility, simultaneously demonstrate a coherent supply chain strategy, consisting of information exchange between, and structural collaboration with, suppliers as well as customers.

Vargas *et al.* (2000), however, report low correlations between EI and order size flexibility. According to Das *et al.* (2006), integration can slow down a firm's response to change and create inflexibility. Moreover, a successfully implemented integration program may create unanticipated costs related to, amongst others, inflexibility (Horwitch and Thietart, 1987). Following the majority of reports on EI and flexibility, we hypothesize:

H2. EI with suppliers and customers has a positive effect on manufacturing flexibility.

SCRM and manufacturing flexibility

Flexibility, a key element in dealing with uncertainty (Manuj and Mentzer, 2008) and disruption (Braunscheidel and Suresh, 2009), has been associated with various forms of risk management. Contingency planning can maximize flexibility (Fawcett *et al.*, 1996). Addressing both upstream and downstream risks (Wieland and Wallenburg, 2012), SCRM can improve the flexibility of supply chains (Jüttner and Maklan, 2011) – firms with a low implementation degree of SCRM perform lower on a range of performance criteria, including flexibility (Thun and Hoenig, 2011). Risk mitigation by adopting information technology to share production plans with suppliers reduces the probability and, then, the severity of disruptions in supply and congestions in the suppliers' production processes, with positive effects on flexibility (Micheli *et al.*, 2014).

Thus, applying risk management may be beneficial; however, an overabundance of risk management processes can be problematic. It can overload the supply chain with too much and time-consuming control and bureaucracy (cf. Taran *et al.*, 2013). Assuming that firms can find the right balance between risk and risk management, we hypothesize:

H3. SCRM has a positive effect on manufacturing flexibility.

Moderating effects of SCRM on the integration-flexibility relationship

Supplier-related risks include disturbances (e.g. unavailability and delay) in the product and information flow (Zsidisin *et al.*, 2004; Sinha *et al.*, 2004; Micheli *et al.*, 2014), lack of price control and supplier commitment (Harland *et al.*, 2003), poor quality, and inability to respond to rapid demand changes (Sinha *et al.*, 2004; Zsidisin *et al.*, 2004; Micheli *et al.*, 2014). Different forms of supplier integration mechanisms can help mitigate these risks. Bonaccorsi and Lipparini (1994) mention joint decision making about product or process designs and modifications, quality improvement, and cost control, Fullerton and McWatters (2001) system coupling with suppliers in the form of VMI or JIT, Harland *et al.* (2003) collaborative approaches with suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements), and Micheli *et al.* (2014) sharing information on forecasts, production plans, order tracking, and delivery status.

Manufacturers and customers can collaborate to jointly develop an understanding of demand at the point of consumption, followed by the creation of mutually agreed replenishment plans in order to ensure that the end customers' requirements are met efficiently (Sahay, 2003). By engaging in system coupling with customers through VMI and direct access to information on customer demands (Tang, 2006), manufacturers can reduce the risk of bullwhip effects.

Lack of appropriate internal integration (e.g. poor communication and working relationships, conflicting goals and directions from senior management) may make it difficult to identify, assess, and mitigate risks (Duhamel *et al.*, 2013). An effective internal environment can strengthen a firm's ability to identify risks early, and "[…] shorten the duration of manifest consequences" (Riley *et al.*, 2016, p. 971).

Supply chain collaboration not only provides opportunities to improve performance (Kajüter, 2003), it may also lead to higher risk exposure (Hallikas *et al.*, 2004; Wieland and Wallenburg, 2013) and failure rates (Ariño and Doz, 2000), due to increased dependency between the links in the chain (Perrow, 1984; Norrman and Jansson, 2004).

So, internal and EI can mitigate some supply chain-related risks. Vice versa, however, perceived risks may also hinder effective supply chain integration (Zhao *et al.*, 2013). A formal SCRM process can help identify an appropriate and balanced set of integration mechanisms (Revilla and Saenz, 2017), which can be used to manage risks including those arising from the integration itself. Following the agency theory, outcome-based SCRM is more fruitfully regarded as complementary to, and needed to strengthen the impact of, behavior-based internal and EI:

H4a. SCRM has a positive moderating effect on the relationship between internal integration and manufacturing flexibility.

H4b. SCRM has a positive moderating effect on the relationship between EI and manufacturing flexibility.

Research design

Instrument and sample demographics

The study uses data from the International Manufacturing Strategy Survey (IMSS). Conducted every four to five years since 1992, the IMSS gathers information about plant-level practices and performances of manufacturing firms. Data for the sixth round were collected in 2013-2014 by an international team of researchers from different universities around the world, and include responses from firms belonging to the ISIC Rev. 4 Divisions 28-35 (metal products, machinery and equipment producers). This paper uses data collected in Asia. A total of 1,951 manufacturing plants in China, India, Japan, Malaysia, and Taiwan were contacted to participate. Eventually, 342 (42 percent) valid responses were obtained from the 814 firms that agreed to participate. The average missing data percentage is 2.5. Little's test was used to establish that the missing data are completely at random, i.e. independent of firm characteristics (e.g. size) and the respondent's responses to other variables ($p = 0.18$). The missing data were imputed using multiple imputation in SPSS 22.0. Table I shows the number of firms per sector per country and the respondents' positions in the firm.

Constructs and measures

The items used in the present research represent the following constructs: internal integration, EI, SCRM, and flexibility. Their sources and operationalization are reported in Tables II and III.

Country	Fabricated metal products	Computer, electronic and optical products	Electrical equipment	Machinery and equipment not elsewhere classified	Motor vehicles, trailers, semi-trailers	Other transport equipment	Total
China	23	29	16	33	20	7	128
India	11	27	18	15	13	7	91
Japan	17	8	32	8	7	10	82
Malaysia	5	3	3	2	1	0	14
Taiwan	7	11	4	3	2	1	28
Total	63	78	73	61	43	25	343

Respondents	Percentage
General manager (e.g. owner, (vice) president, managing director, (deputy, assistant) general manager)	33.9
Head or (senior) manager of manufacturing/operations/R&D/quality	46.9
Other	11.7
Missing	7.5
Total	100.0

Table I.
Sample demographics

Internal integration includes sharing information and joint decision making with the purchasing and the sales department. EI includes sharing of information, developing collaborative approaches, joint decision making, and system coupling (e.g. VMI, JIT, Kanban, and continuous replenishment) with key suppliers and customers. The SCRM construct consists of preventing, detecting, responding to, and recovering from operations risks. The respondents were asked to indicate the current level of implementation of integration and SCRM on a scale ranging from "1 = none" to "5 = high."

The flexibility construct measures volume and mix flexibility. The respondents were asked to indicate their plant's current performance relative to its main competitors on a scale ranging from "1 = much lower" to "5 = much higher."

The standardized factor loadings, Cronbach's α, average variance extracted (AVE) and composite reliability (CR) of these constructs and underlying items are reported in Table III.

Control variables

A range of control variables was implemented.

Uncertainty, operationalized as fluctuations in the mix and volume of supply, manufacturing and demand, product specifications, was assessed using a five-point scale ranging from "1 = not at all" to "5 = to a great extent." Disruptions in supply, manufacturing, and shipments were as assessed by multiplying the probability of their occurrence with their impact (Sinha *et al.*, 2004). Probability and impact were both captured on a five-point scale with "1 = low" and "5 = high." Table II reports the sources used to operationalize these constructs, and Table III reports their standardized factor loadings, Cronbach's α, AVE, and CR.

Firm size is measured as the logarithm of the number of employees. In order to determine the supply chain infrastructure of the plant's country of location, the average scores are used of the country's quality of roads, railroad infrastructure, port and air transport infrastructure, and local supplier quantity and quantity. These items are reported in The World Economic Forum Global Competitiveness Report 2013-2014 (Schwab and Sala-i-Martin, 2013). The extent of EI may be influenced by the position of the firm in the supply network. To control for this effect, the percentage of sales to manufacturers of sub-systems, manufacturers of finished products, wholesalers, and distributors are added up to indicate sales to business-to-business (B2B) customers. Considering that the level of internal and EI may be affected by a plant's customer order decoupling point (CODP), the percentage of customer orders that are designed/engineered, manufactured, or assembled to order is used as

Measurement items	Sources
Internal integration	
Sharing information with purchasing department (about sales forecast, production plans, production progress and stock level)	Ellinger (2000), Thomé *et al.* (2012)
Joint decision making with purchasing department (about sales forecast, production plans and stock level)	Thomé *et al.* (2012)
Sharing information with sales department (about sales forecast, production plans, production progress and stock level)	Thomé *et al.* (2012)
Joint decision making with sales department (about sales forecast, production plans and stock level)	Thomé *et al.* (2012)
External integration	
Sharing information with key suppliers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	Cagliano *et al.* (2006), Flynn *et al.* (2010)
Developing collaborative approaches with key suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements)	Ragatz *et al.*, Spekman, Lambert *et al.* (1999), Dröge *et al.* (2004)
Joint decision making with key suppliers (about product design/modifications, process design/modifications, quality improvement and cost control)	Narasimhan and Das (1999), Koufteros *et al.* (2005), Petersen *et al.*
System coupling with key suppliers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	Frohlich and Westbrook (2001), Cagliano *et al.* (2006), Vereecke and Muylle (2006)
Sharing information with key customers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	Zhao *et al.* (2008), Flynn *et al.* (2010)
Developing collaborative approaches with key customers (e. g. risk/revenue sharing, long-term agreements)	Lambert *et al.* (1999)
System coupling with key customers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	Frohlich and Westbrook (2001)
Joint decision making with key customers (about product design/modifications, process design/modifications, quality improvement and cost control)	Lengnick-Hall (1996)
Supply chain risk management	
Preventing operations risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance)	Tomlin (2006)
Detecting operations risks (e.g. internal or supplier monitoring, inspection, tracking)	Sinha *et al.* (2004), Zsidisin *et al.* (2004), Manuj and Mentzer (2008)
Responding to operations risks (e.g. backup suppliers, extra capacity, alternative transportation modes)	Sheffi and Rice (2005)
Recovering from operations risks (e.g. task forces, contingency plans, clear responsibility)	Norrman and Jansson (2004)
Flexibility relative to competitors	
Volume flexibility	Hallgren and Olhager (2009), Jayaram *et al.* (2011), Danese *et al.* (2013), Van der Vaart *et al.* (2012), Scherrer-Rathje *et al.* (2014)
Mix flexibility	Hallgren and Olhager (2009), Jayaram *et al.* (2011), Danese *et al.* (2013), Van der Vaart *et al.* (2012), Scherrer-Rathje *et al.* (2014)

(*continued*)

Table II.
Sources of constructs

Measurement items	Sources
Uncertainty	
Your demand fluctuates drastically from week to week	Chen and Paulraj (2004), Tachizawa and Giménez (2010)
Your total manufacturing volume fluctuates drastically from week to week	Chen and Paulraj (2004), Tachizawa and Giménez (2010)
The mix of products you produce changes considerably from week to week	Chen and Paulraj (2004), Tachizawa and Giménez (2010)
Your supply requirements (volume and mix) vary drastically from week to week	Chen and Paulraj (2004), Tachizawa and Giménez (2010)
Your products are characterized by a lot of technical modifications	Ellis *et al.* (2010)
Disruption	
A key supplier fails to supply affecting your operations	Sheffi and Rice (2005), Tomlin (2006), Ellis *et al.* (2010)
Your manufacturing operations are interrupted affecting your shipments	Tomlin (2006)
Your shipment operations are interrupted affecting your deliveries	Tomlin (2006)

Table II.

a control variable. Finally, as supply chain risks may increase with increased offshore outsourcing, the percentage of value of raw materials, parts/components, and subassemblies/systems sourced outside the country of location is controlled for, too.

Table IV reports the descriptive statistics of all the constructs used in this research.

Validation of measures

Confirmatory factor analysis (CFA) using AMOS was conducted to examine the unidimensionality, convergent, and divergent validity of the constructs used. The results, $\chi^2 = 849.045$, df = 284, χ^2/df = 2.99, CFI = 0.916, TLI = 0.904, RMSEA = 0.076, SRMR = 0.047, show good fit. The CRs range from 0.832 to 0.932, implying that the variance captured by the factors is significantly more than the variance indicated by their error components. The AVE ranges from 0.631 to 0.743, which should be (Fornell and Larcker, 1981) and is greater than the correlation among the latent variables. The square roots of AVE for the constructs are greater than the correlations amongst each of them (Table IV). Thus, both CR and AVE indicate acceptable reliability levels. The results of pairwise χ^2 difference tests (Table V) show discriminant validity of the constructs.

To test the convergent validity, the standardized parameter loadings of the measurement items on their respective constructs, the 90 percent bias-corrected bootstrap confidence interval of the loadings and the *p*-values were used. Ranging from 0.683 to 0.954, all the estimates exceed 0.5, none of the confidence intervals include 0 and all the corresponding *p*-values are significant (the highest *p*-value is 0.03). These results provide support for convergent validity, which, together with a good overall model fit, demonstrates the unidimensionality of the scales (Hair *et al.*, 1998).

Common method bias (CMB) was minimized using techniques described by Podsakoff *et al.* (2003). The questions regarding the independent variables (internal and EI, and SCRM) were separated from each other and from the dependent variable, flexibility performance. The IMSS questionnaire also maintains anonymity of the respondent and her/his firm, which eliminates incentives for socially favorable answers. In order to reduce ambiguity, all questions incorporated objective concepts and explanations. After data collection, we assessed the occurrence of CMB by comparing the fit between the one-factor model, the

Measurement items	Standardized factor loading	Cronbach's α	AVE[a]	CR[b]
Internal integration: indicate the current level of implementation of action programs related to internal integration (1 = none, 5 = high)		0.915	0.729	0.915
Sharing information with purchasing department (about sales forecast, production plans, production progress and stock level)	0.826			
Joint decision making with purchasing department (about sales forecast, production plans and stock level)	0.851			
Sharing information with sales department (about sales forecast, production plans, production progress and stock level)	0.844			
Joint decision making with sales department (about sales forecast, production plans and stock level)	0.892			
External integration: indicate the current level of implementation of action programs related to external integration (1 = none, 5 = high)		0.931	0.631	0.932
Sharing information with key suppliers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	0.760			
Developing collaborative approaches with key suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements)	0.801			
Joint decision making with key suppliers (about product design/modifications, process design/modifications, quality improvement and cost control)	0.735			
System coupling with key suppliers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	0.745			
Sharing information with key customers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	0.843			
Developing collaborative approaches with key customers (e.g. risk/revenue sharing, long-term agreements)	0.846			
System coupling with key customers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	0.818			
Joint decision making with key customers (about product design/modifications, process design/modifications, quality improvement and cost control)	0.801			
Supply chain risk management: indicate the current level of implementation of action programs related to: (1 = none, 5 = high)		0.901	0.693	0.900
Preventing operations risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance)	0.754			
Detecting operations risks (e.g. internal or supplier monitoring, inspection, tracking)	0.854			
Responding to operations risks (e.g. backup suppliers, extra capacity, alternative transportation modes)	0.854			
Recovering from operations risks (e.g. task forces, contingency plans, clear responsibility)	0.863			
Flexibility relative to competitors: how does your current performance compare with that of your main competitor(s): 1 = much lower, 5 = much higher)?		0.831	0.713	0.832
Volume flexibility	0.811			
Mix flexibility	0.876			

(*continued*)

Table III.
Measurement items

Measurement items	Standardized factor loading	Cronbach's α	AVE[a]	CR[b]
Uncertainty (control variable): to what extent do you agree with the following statements (1 = not at all, 5 = to a great extent)?		0.914	0.688	0.916
Your demand fluctuates drastically from week to week	0.845			
Your total manufacturing volume fluctuates drastically from week to week	0.869			
The mix of products you produce changes considerably from week to week	0.855			
Your supply requirements (volume and mix) vary drastically from week to week	0.878			
Your products are characterized by a lot of technical modifications	0.683			
Disruption: please evaluate the probability of occurrence and impact of the following risks (probability: 1 = low, 5 = high; impact: 1 = low, 5 = high)		0.892	0.743	0.896
A key supplier fails to supply affecting your operations	0.769			
Your manufacturing operations are interrupted affecting your shipments	0.954			
Your shipment operations are interrupted affecting your deliveries	0.853			

Notes: [a]AVE, average variance extracted; [b]CR, composite reliability

Table III.

measurement model with only traits, and the measurement model with both traits and a method factor (Flynn *et al.*, 2010). The one-factor model yielded fit indices ($\chi^2(299) = 3845.471$; CFI = 0.471; IFI = 0.473; NFI = 0.453; NNFI = 0.425; RMSEA = 0.186), which were unacceptable and significantly worse than those of the measurement model with only traits ($\chi^2(259) = 849.045$, CFI = 0.916, IFI = 0.916, NFI = 0.879, NNFI = 0.904, RMSEA = 0.076). Although the results of the measurement model with both traits and a method factor marginally improved the model fit of the measurement model with only traits (NFI by 0.032, NNFI by 0.028, CFI by 0.029), the model fit accounted for only 6.5 percent of the total variance. In addition, the path coefficients and their significance were similar between the two measurement models, suggesting that they are robust despite the inclusion of a method factor (Flynn *et al.*, 2010).

Measurement equivalence

We assessed measurement equivalence in the design and data collection stages, as well as statistically, in the analysis stage of the research. Construct, translation, and data collection equivalence were dealt with following the recommendations from Knoppen *et al.* (2015). Construct equivalence was ensured by targeting the survey to one group of respondents, production managers or similar, all working in the assembly industry and, in the case of our subsample, international firms. Furthermore, all scales stem from, and have been validated in, previous research among similar target groups. Finally, the questionnaire was pre-tested with industry representatives for clarity and consistency. As to translation equivalence, wherever needed, the English language questionnaire was translated into local language by the researchers involved, using double and/or reverse translation. In order to ensure data collection equivalence, official databases were used in each country to sample manufacturing firms belonging to the ISIC Rev. 4 Divisions 28-35. The production managers of these firms were then contacted; if they agreed to participate, the questionnaire was sent out. Follow-up calls and/or e-mailed reminders were used to increase the response rate. Each response was checked for missing and incorrect data; if needed, the respondent was contacted again.

Table IV. Descriptive statistics

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
1. Country supply chain infrastructure	5.03	0.58	1										
2. Size (log number of employees)	6.33	1.71	0.08	1									
3. CODP	0.79	0.28	0.09	−0.07	1								
4. B2B	0.77	0.33	0.12*	0.11*	−0.16*	1							
5. Outside country sourcing	0.19	0.22	0.25**	0.25**	0.02	0.05	1						
6. Uncertainty	2.65	0.97	0.2**	0.06	0.18**	0.05	0.21**	*0.83*					
7. Disruption	10.30	5.99	0.10	0.06	0.04	0.002	0.11*	0.37**	*0.86*				
8. Internal integration	3.76	0.82	−0.22**	0.17**	−0.04	0.14**	0.15**	0.12*	0.03	*0.85*			
9. External Integration	3.35	0.87	−0.14*	0.22**	−0.01	0.11*	0.18**	0.30**	0.22**	0.46**	*0.79*		
10. Supply chain risk management	3.56	0.87	−0.32**	0.19**	−0.07	0.11*	0.08	0.16**	0.20**	0.63**	0.56**	*0.83*	
11. Flexibility relative to competitors	3.43	0.75	−0.09	0.05	−0.06	0.12*	0.02	0.07	0.11*	0.40**	0.31**	0.32**	*0.84*

Notes: Square roots of the average variances extracted are shown on the diagonal. $^{*}p < 0.05$; $^{**}p < 0.01$

Table V.
Pairwise χ^2 difference tests for discriminant validity

	Unconstrained model		Constrained model		
	χ^2	df	χ^2	df	$\Delta\chi^2$
Internal integration					
External integration	331.88	53	365.77	54	33.89**
Supply chain risk management	117.88	19	185.87	20	67.99**
Flexibility	36.35	8	144.94	9	108.59**
Uncertainty	86.87	26	204.79	27	117.92**
Disruption	33.9	13	52.79	14	18.89**
External integration					
Supply chain risk management	350.32	53	380.08	54	29.76**
Flexibility	236.53	34	338.68	35	102.15**
Uncertainty	272.49	64	331.61	65	59.12**
Disruption	262.22	43	283.32	44	21.10**
Supply chain risk management					
Flexibility	65.39	8	173.13	9	107.74**
Uncertainty	121.55	26	217.61	27	96.06**
Disruption	109.84	13	129.90	14	20.06**
Flexibility					
Uncertainty	38.24	13	190.14	14	151.90**
Disruption	9.65	4	28.44	5	18.79**
Demand-supply fluctuation					
Disruption	41.58	19	57.81	20	16.23*

Notes: $*p < 0.05$; $**p < 0.01$

We tested for measurement equivalence statistically using multi-group CFA (cf. Vandenberg and Lance, 2000; Knoppen *et al.*, 2015) for three of the control variables: firm size (size), CODP, and sales to B2B customers. For each of these variables, we divided the data set into two groups of respondents scoring high and low on the variable, and used multi-group CFA for each variable, by running both the unconstrained and the constrained model (see Table V), in which the regression weights are assumed to be equal for the groups. The results of the χ^2 difference tests demonstrate measurement equivalence for size, CODP, and B2B groups. Next, we conducted a χ^2 contingency test to verify whether country distributions vary between the size, B2B, and the CODP groups. The country distributions appear to vary for firm size and CODP but not for B2B. Thus, we can also indirectly demonstrate measurement equivalence by country.

Analysis and results

In order to test the hypotheses, hierarchical regression analyses were conducted. Mean centered data for independent variables were used as recommended by Cohen *et al.* (2003), as this approach helps in minimizing multicollinearity (Parthasarthy and Hammond, 2002). The results are shown in Table VI.

In Model 0, all the control variables were added. Country supply chain infrastructure and B2B percentage appear to be significant. In Models 1-3, internal integration, EI, and SCRM were added one after another. Internal integration is significant in all three models. EI is insignificant in Model 2, where it is introduced, and in Model 3. SCRM is significant in Model 3, where it is introduced.

These results suggest that internal integration and SCRM are key enablers of flexibility performance. EI alone does not explain flexibility performance but interacts with SCRM to generate an additional positive influence on flexibility performance.

Dependent variable	Model 0 Flexibility	Model 1 Flexibility	Model 2 Flexibility	Model 3 Flexibility	Model 4 Flexibility	Model 5 Flexibility
Constant	3.43***	3.43***	3.43***	3.43***	3.42***	3.38***
Country supply chain infrastructure	0.16*	0.005	0.004	0.06	0.05	0.06
Size	−0.01	−0.01	−0.01	−0.02	−0.02	−0.02
CODP	−0.12	−0.11	−0.11	−0.10	−0.11	−0.12
B2B	0.26*	0.12	0.12	0.10	0.10	0.07
Outside country sourcing percentage	−0.06	−0.16	−0.17	−0.18	−0.17	−0.15
Uncertainty	−0.05	−0.005	−0.007	−0.01	−0.005	−0.004
Disruption	0.01	0.01	0.01	0.009	0.009	0.01
Internal integration (II)		0.36***	0.32***	0.30***	0.32***	0.32***
External integration (EI)			0.07	0.01	0.02	0.02
Supply chain risk management (SCRM)				0.15**	0.14**	0.15**
SCRM × II					0.04	
SCRM × EI						0.11**
R^2	0.044	0.178	0.182	0.199	0.201	0.216
Adjusted R^2	0.024	0.159	0.160	0.175	0.175	0.190
F change	2.2	54.6	1.372	7.066	0.992	7.389
Sig. *F* change	0.034	0.00	0.242	0.008	0.320	0.007

Notes: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

Table VI. Hierarchical regression analysis

To further understand the interaction effect between SCRM and EI, the slope of flexibility performance as a function of EI was computed using different values of SCRM. Following Cohen *et al.* (2003), the mean value and one standard deviation below and above the mean were considered as medium, low, and high value of SCRM. Using the constant term, the coefficients of EI, SCRM, and SCRM × EI, and considering the three values of SCRM, three linear equations of flexibility performance as a function of EI were generated.

Figure 1 demonstrates that the effect of increasing EI on flexibility is negative at low levels of SCRM, virtually zero at medium levels of SCRM, and positive at high levels of SCRM. Thus, the interaction between EI and SCRM can be considered to be "cross-over interaction," a particular type of disordinal interaction, where the effects work in opposite directions (Cohen *et al.*, 2003). For such interactions, the linear equation relating an independent variable (EI) with a dependent variable (flexibility performance) for a given level of moderator (e.g. low SCRM) intersects with the corresponding linear equation for a different level of the moderator (e.g. high SCRM). Analysis of the data reveals that the

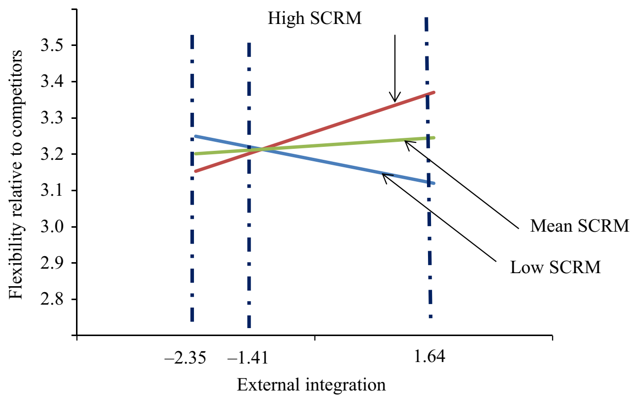

Figure 1. Slope of flexibility performance with external integration at low, medium, and high values of SCRM

centered variable EI varies between −2.35 and 1.64; 7.28 percent of the sample falls below the EI critical value of −1.41 (the intersection point between the regression lines at low and high SCRM) with an EI mean value of 0.00.

Figure 1 generates interesting insights. Both the low EI-low SCRM and the high EI-high SCRM combination result in higher flexibility performance than achieved with the low integration-high SCRM and high integration-low SCRM combinations. This finding stresses the importance of ensuring fit between EI and SCRM. Misalignment will impact flexibility undesirably: low EI circumstances may well achieve some level of flexibility, which, however, is more likely to be attributable to the internal integration activities than to SCRM. However, attempts to increase EI without the use of SCRM can affect flexibility negatively. Similarly, high SCRM coupled with low EI will result in low flexibility as well. Clearly, the preferred approach is a combination of high EI with high SCRM.

Discussion

This study provides a number of valuable insights into the direct and interactive effects of internal integration, EI, and SCRM on manufacturing flexibility. While the role of internal and EI has been relatively widely researched (Vereecke and Muylle, 2006; Devaraj *et al.*, 2007; Braunscheidel and Suresh, 2009; Wong *et al.*, 2011), conflicting results on the association of integration with flexibility have been reported (Flynn *et al.*, 2010; Mackelprang *et al.*, 2014). Moreover, the possible direct effects of SCRM on flexibility, and the moderating effects of SCRM on the relationships between internal and EI, respectively, and flexibility performance are not well understood either.

Internal integration and SCRM

Flexibility enhances a firm's ability to effectively cope with fluctuations and disruptions (Swafford *et al.*, 2006). The results confirm that internal integration (between manufacturing, purchasing and sales) and SCRM are key determinants of manufacturing flexibility performance relative to competitors (*H1* and *H3*).

SCRM does not appear to moderate the relationship between internal integration and manufacturing flexibility (*H4a*). There can be two possible explanations for this, each requiring further research. First, SCRM is primarily aimed at dealing with external rather than firm-internal risks. Applying an alternative solution, for example enterprise risk management (ERM) (e.g. Hoyt and Liebenberg, 2011), could be a better approach to mitigating internal risks. While ERM promotes organizational flexibility (e.g. Taran *et al.*, 2013), the effects of ERM on the relationship between internal integration and manufacturing flexibility, and the connection between external SCRM with internal ERM process activities are less clear. Another possible explanation for the rejection of *H4a* could be related to the bureaucracy and complexity (e.g. Zaltman *et al.*, 1973) associated with formal management systems, which, in effect, reduce flexibility. In practice, this would imply that if a firm seeks to improve its flexibility performance, developing robust internal integration mechanisms can contribute to that – the firm does not necessarily need to rely on an internally focused ERM system to achieve that objective.

EI and SCRM

While the relationship between EI and flexibility performance (*H2*) is insignificant, SCRM has a moderating effect on that relationship (*H4b*). Thus, EI affects flexibility performance provided that appropriate SCRM efforts in terms of preventing, detecting, responding, and recovering from risks are put in place.

Vargas *et al.* (2000) found a low correlation between EI and flexibility. Terjesen *et al.* (2012) report that firms may even lose flexibility due to extensive integration. A reason may be that EI adds risks (e.g. Hallikas *et al.*, 2004) and increases complexity (Sivadasan *et al.*, 2010), which, inevitably, reduces flexibility if not managed adequately. This explains that the net direct effect of EI on flexibility performance may be insignificant (going against *H2*), and suggests that EI must be combined with SCRM (confirming *H4b*) in order to achieve positive effects on flexibility performance. Thus, if a firm not only considers EI as strategically important, but also implements SCRM in order to safeguard the downsides of integration, it is more likely to reap the benefits pursued. As the analysis depicted in Figure 1 shows, a high level of EI combined with a high level of SCRM implementation does indeed yields the highest level of flexibility performance.

Conclusion

Contribution to theory

This paper focuses on the relationships between internal and EI, and manufacturing flexibility, and the influence of SCRM on these relationships.

The analyses confirm that internal integration (*H1*) and SCRM (*H3*) have a positive effect on flexibility performance. Going against *H4b*, the combined implementation of internal integration and SCRM does not affect flexibility performance. Equally unexpectedly, EI does not affect flexibility performance (*H2*) either, and only has impact if it is combined with SCRM (*H4b*). These results are largely independent of a range of control variables and are therefore valid across a wide range of contexts.

The present study supports previous research on the association between internal integration and flexibility performance (Frohlich and Westbrook, 2001; Vereecke and Muylle, 2006; Devaraj *et al.*, 2007; Braunscheidel and Suresh, 2009; Wong *et al.*, 2011; Schoenherr and Swink, 2012), and adds two new findings: both SCRM and the joint implementation of SCRM and EI have positive flexibility effects.

The observations that EI alone (*H2*) and internal integration combined with SCRM (*H4a*) do not affect flexibility performance need further research.

Contribution to practice

Firms focusing on EI to mitigate risks and improve flexibility should recognize that EI in itself may be fraught with risks (Hallikas *et al.*, 2004; Norrman and Jansson, 2004; Wieland and Wallenburg, 2013), and may fail to deliver desired results if these risks are not addressed adequately. The choice of appropriate collaborative arrangements with suppliers and customers requires understanding of the potential benefits of, and the risks involved in, the collaboration, as the interests of the partners involved may not be aligned. Sharing of proprietary supplier or customer information, for example, can be beneficial for joint planning but requires mutual trust. Thus, a formal SCRM process helps managers to identify problematic issues and put explicit plans and timetables into place for resolving/reducing the risks identified in their supply chains, including the selection of appropriate EI mechanisms. For example, while implementing a collaboration network for the F-35 program, Lockheed Martin also implemented security safeguards to ensure International Traffic in Arms Regulations compliance (Behrens, 2010). Medtronic, a medical device manufacturer, employs detailed and predictive supply base risk management processes and expects the suppliers to also formalize a risk mitigation strategy and collaborate with Medtronic to proactively address risks identified (Medtronic, 2015). These examples demonstrate the need for manufacturing firms to ensure that supply chain integration and risk management should indeed be tightly linked to each other.

Managers should also bear in mind that SCRM may not enhance the flexibility effects of internal integration. Adopting an internally oriented risk management system, e.g. ERM, could be a solution to address internal (e.g. strategic, operational) risks. How a firm organizes its risk management efforts (i.e. combination of ERM and SCRM, or only SCRM) best depends on factors such as the firm's risk appetite, its structure, and overall risk-management philosophy, as well as economies of scale, industry-specific challenges, and stakeholder pressures (Economist Intelligence Unit, 2013).

Limitations and further research

There are some limitations to this study. It uses data only from Asian countries collected from discrete manufacturing industries. Furthermore, only manufacturing flexibility performance was considered, which was, moreover, operationalized using only two items – volume and mix flexibility. Future research should consider using a global database, and although volume and mix flexibility are the most commonly used measures of flexibility at plant level (Hallgren and Olhager, 2009; Jayaram *et al.*, 2011; Danese *et al.*, 2013; Van der Vaart *et al.*, 2012; Scherrer-Rathje *et al.*, 2014), also analyze measure manufacturing flexibility more comprehensively, and include other performance measures such as cost, quality, and delivery (speed).

Furthermore, we consistently considered EI, internal integration, and SCRM as improvement initiatives by the manufacturing plant, which then gets translated into specific actions on the individual items. Hence, we assumed that these constructs can be modeled reflectively: the initiatives captured by the individual items cannot be put into action unless the plant strategically decides to invest in the improvement initiatives captured by the constructs. It should be interesting to see if modeling these constructs formatively leads to different conclusions.

Then, while the combined effect of EI and SCRM has been demonstrated in this paper, future research should focus on identifying the specific mechanisms through which SCRM and supplier and customer integration can support each other and enhance performance. There is an increasing need to approach risk management collaboratively (Li *et al.*, 2015); some EI activities should also be devoted to ensuring visibility of risks across supply chain partners and joint decision making for risk management. This is in line with Revilla and Saenz (2017), who found that firms pursuing an inter-organizational orientation to risk management face the lowest levels of supply chain disruption. Hence, future research can test the effect of information sharing, collaboration, and supply chain integration on the effectiveness of risk management and, consequently, on performance outcomes.

Another important area for further research concerns the possible moderating effect of ERM on internal integration-flexibility performance. While SCRM does not strengthen that relationship, a more internally oriented risk management system (e.g. ERM) could.

Finally, although this paper suggests that the findings are valid for a wide range of contexts, the influence of contingencies not included in the analyses presented here should be investigated (Van der Vaart *et al.*, 2012; Mackelprang *et al.*, 2014). Especially the use of certified quality management systems (Tamayo-Torres *et al.*, 2014) as a risk management mechanism could provide important insight.

References

Ariño, A. and Doz, Y. (2000), "Rescuing troubled alliances … before it's too late", *European Management Journal*, Vol. 18 No. 2, pp. 173-182.

Bagchi, P.K., Ha, B.C., Skjoett-Larsen, T. and Soerensen, L.B. (2005), "Supply chain integration: a European survey", *International Journal of Logistics Management*, Vol. 16 No. 2, pp. 275-294.

Barratt, M. (2004), "Understanding the meaning of collaboration in the supply chain", *Supply Chain Management: An International Journal*, Vol. 9 No. 1, pp. 30-42.

Behrens, A. (2010), "Managing the supply chain across aerospace lifecycle", available at: www.plm.automation.siemens.com/zh_tw/Images/21676_tcm943-99260.pdf (accessed November 5, 2015).

Bonaccorsi, A. and Lipparini, A. (1994), "Strategic partnerships in new product development: an Italian case study", *Journal of Product Innovation Management*, Vol. 11 No. 2, pp. 134-145.

Braunscheidel, M.J. and Suresh, N.C. (2009), "The organizational antecedents of a firm's supply chain agility for risk mitigation and response", *Journal of Operations Management*, Vol. 27 No. 2, pp. 119-140.

Cagliano, R., Caniato, F. and Spina, G. (2006), "The linkage between supply chain integration and manufacturing improvement programmes", *International Journal of Operations & Production Management*, Vol. 26 No. 3, pp. 282-299.

Chang, S., Chen, R., Lin, R., Tien, S. and Sheu, C. (2006), "Supplier involvement and manufacturing flexibility", *Technovation*, Vol. 26 No. 1, pp. 1136-1146.

Chen, I.J. and Paulraj, A. (2004), "Towards a theory of supply chain management: the constructs and measurements", *Journal of Operations Management*, Vol. 22 No. 2, pp. 119-150.

Chen, I.J., Calantone, R.J. and Chung, C.H. (1992), "The marketing-manufacturing interface and manufacturing flexibility", *Omega*, Vol. 20 No. 4, pp. 431-443.

Choi, T.Y. and Liker, J.K. (1995), "Bringing Japanese continuous improvement approaches to US manufacturing: the roles of process orientation and communications", *Decision Sciences*, Vol. 26 No. 5, pp. 589-620.

Christopher, M. and Towill, D. (2001), "An integrated model for the design of agile supply chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 31 No. 4, pp. 235-246.

Cohen, J., Cohen, P., West, S.G. and Aiken, L.S. (2003), *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*, Lawrence Erlbaum Associates, Mahwah, NJ.

Danese, P., Romano, P. and Formentini, M. (2013), "The impact of supply chain integration on responsiveness: the moderating effect of using an international supplier network", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 49 No. 1, pp. 125-140.

Das, A., Narasimhan, R. and Talluri, S. (2006), "Supplier integration – finding an optimal configuration", *Journal of Operations Management*, Vol. 24 No. 5, pp. 563-582.

Devaraj, S., Krajewski, L. and Wei, J.C. (2007), "Impact of eBusiness technologies on operational performance: the role of production information integration in the supply chain", *Journal of Operations Management*, Vol. 25 No. 6, pp. 1199-1216.

Dröge, C., Jayaram, J. and Vickery, S.K. (2004), "The effects of internal versus external integration practices on time-based performance and overall firm performance", *Journal of Operations Management*, Vol. 22 No. 6, pp. 557-573.

Duhamel, F., Valentina, C. and Valérie, M. (2013), "The impact of internal and external collaboration on the performance of supply chain risk management", *International Journal of Logistics Systems and Management*, Vol. 23 No. 4, pp. 534-557.

Dyer, J.H. and Singh, H. (1998), "The relational view: cooperative strategy and sources of interorganizational competitive advantage", *Academy of Management Review*, Vol. 23 No. 4, pp. 660-679.

Economist Intelligence Unit (2013), "Strategies for managing customer and supplier risks", available at: www.economistinsights.com/sites/default/files/EIU%20D%26B%20paper%20FINAL%20Nov%2021%20with%20new%20logo.pdf (accessed December 7, 2015).

Eisenhardt, K.M. (1989), "Agency theory: an assessment and review", *Academy of Management Review*, Vol. 14 No. 1, pp. 57-74.

Ellinger, A.E. (2000), "Improving marketing/logistics cross-functional collaboration in the supply chain", *Industrial Marketing Management*, Vol. 29 No. 1, pp. 85-96.

Ellinger, A.E., Chen, H., Tian, Y. and Armstrong, C. (2015), "Learning orientation, integration, and supply chain risk management in Chinese manufacturing firms", *International Journal of Logistics Research And Applications*, Vol. 18 No. 6, pp. 476-493.

Ellis, S.C., Henry, R.M. and Shockley, J. (2010), "Buyer perceptions of supply disruption risk: a behavioral view and empirical assessment", *Journal of Operations Management*, Vol. 28 No. 1, pp. 34-46.

Fabbe-Costes, N. and Jahre, M. (2008), "Supply chain integration and performance: a review of the evidence", *The International Journal of Logistics Management*, Vol. 19 No. 2, pp. 130-154.

Fawcett, S.E., Calantone, R. and Smith, S.R. (1996), "An investigation of the impact of flexibility on global reach and firm performance", *Journal of Business Logistics*, Vol. 17 No. 2, pp. 167-196.

Flynn, B.B., Huo, B. and Zhao, X. (2010), "The impact of supply chain integration on performance: a contingency and configuration approach", *Journal of Operations Management*, Vol. 28 No. 1, pp. 58-71.

Fornell, C. and Larcker, D.F. (1981), "Evaluating structural equation models with unobservable variables and measurement error", *Journal of Marketing Research*, Vol. 18 No. 1, pp. 39-50.

Frohlich, M.T. and Westbrook, R. (2001), "Arcs of integration: an international study of supply chain strategies", *Journal of Operations Management*, Vol. 19 No. 2, pp. 185-200.

Fullerton, R.R. and McWatters, C.S. (2001), "The production performance benefits from JIT implementation", *Journal of Operations Management*, Vol. 19 No. 1, pp. 81-96.

Fynes, B., Voss, C. and de Búrca, S. (2005), "The impact of supply chain relationship dynamics on manufacturing performance", *International Journal of Operations & Production Management*, Vol. 25 No. 1, pp. 6-19.

Giménez, C. and Ventura, E. (2005), "Logistics-production, logistics-marketing and external integration: their impact on performance", *International Journal of Operations & Production Management*, Vol. 25 No. 1, pp. 20-38.

Gualandris, J. and Kalchschmidt, M. (2015), "Supply risk management and competitive advantage: a misfit model", *The International Journal of Logistics Management*, Vol. 26 No. 3, pp. 459-478.

Hair, J.F., Anderson, R.L. and Black, W.C. (1998), *Multivariate Data Analysis*, Prentice Hall, Upper Saddle River, NJ.

Hallgren, M. and Olhager, J. (2009), "Flexibility configurations: empirical analysis of volume and product mix flexibility", *Omega*, Vol. 37 No. 4, pp. 746-756.

Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V. and Tuominen, M. (2004), "Risk management processes in supplier networks", *International Journal of Production Economics*, Vol. 90 No. 1, pp. 47-58.

Harland, C., Brenchley, R. and Walker, H. (2003), "Risk in supply networks", *Journal of Purchasing and Supply Management*, Vol. 9 No. 2, pp. 51-62.

Horwitch, M. and Thietart, R.A. (1987), "The effect of business interdependencies on product R&D-intensive business performance", *Management Science*, Vol. 33 No. 2, pp. 178-197.

Hoyt, R.E. and Liebenberg, A.P. (2011), "The value of enterprise risk management", *The Journal of Risk and Insurance*, Vol. 78 No. 4, pp. 795-822.

Jayaram, J., Xu, K. and Nicolae, M. (2011), "The direct and contingency effects of supplier coordination and customer coordination on quality and flexibility performance", *International Journal of Production Research*, Vol. 49 No. 1, pp. 59-85.

Jüttner, U. and Maklan, S. (2011), "Supply chain resilience in the global financial crisis: an empirical study", *Supply Chain Management: An International Journal*, Vol. 16 No. 4, pp. 246-259.

Kache, F. and Seuring, S. (2014), "Linking collaboration and integration to risk and performance in supply chains via a review of literature reviews", *Supply Chain Management an International Journal*, Vol. 19 Nos 5/6, pp. 664-682.

Kajüter, P. (2003), "Risk management in supply chains", in Seuring, S., Müller, M., Goldbach, M. and Schneidewind, U. (Eds), *Strategy and Organization in Supply Chains*, Physica, Heidelberg, pp. 321-336.

Knoppen, D., Ateş, M.A., Brandon-Jones, A., Luzzini, D., Van Raaij, E. and Wynstra, F. (2015), "A comprehensive assessment of measurement equivalence in operations management", *International Journal of Production Research*, Vol. 53 No. 1, pp. 166-182.

Koufteros, X., Vonderembse, M. and Jayaram, J. (2005), "Internal and external integration for product development: the contingency effects of uncertainty, equivocality, and platform strategy", *Decision Sciences*, Vol. 36 No. 1, pp. 97-133.

Lambert, D.M., Emmelhainz, M.A. and Gardner, J.T. (1999), "Building successful logistics partnerships", *Journal of Business Logistics*, Vol. 20 No. 1, pp. 118-165.

Lavastre, O., Gunasekaran, A. and Spalanzani, A. (2014), "Effect of firm characteristics, supplier relationships and techniques used on supply chain risk management (SCRM): an empirical investigation on French industrial firms", *International Journal of Production Research*, Vol. 52 No. 11, pp. 3381-3403.

Lengnick-Hall, C.A. (1996), "Customer contributions to quality: a different view of the customer-oriented firm", *Academy of Management Review*, Vol. 21 No. 3, pp. 791-824.

Li, G., Fan, H., Lee, P.K. and Cheng, T.C.E. (2015), "Joint supply chain risk management: an agency and collaboration perspective", *International Journal of Production Economics*, Vol. 164 No. 6, pp. 83-94.

Lin, C., Chiu, H. and Chu, P. (2006), "Agility index in the supply chain", *International Journal of Production Economics*, Vol. 100 No. 2, pp. 285-299.

Mackelprang, R., Bernardes, A.W., Webb, J.L. and Ednilson, S.G. (2014), "The relationship between strategic supply chain integration and performance: a meta-analytic evaluation and implications for supply chain management research", *Journal of Business Logistics*, Vol. 35 No. 1, pp. 71-96.

Manuj, I. and Mentzer, J.T. (2008), "Global supply chain risk management strategies", *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 3, pp. 192-223.

Medtronic (2015), "Supplier quality and excellence manual", available at: www.medtronic.com/about-us/corporate-social-responsibility/suppliers/supply-chain-collaboration/ (accessed December 7, 2015).

Micheli, G.J., Mogre, R. and Perego, A. (2014), "How to choose mitigation measures for supply chain risks", *International Journal of Production Research*, Vol. 52 No. 1, pp. 117-129.

Narasimhan, R. and Das, A. (1999), "An empirical investigation of the contribution of strategic sourcing to manufacturing flexibilities and performance", *Decision Sciences*, Vol. 30 No. 3, pp. 683-718.

Narasimhan, R. and Das, A. (2000), "An empirical examination of sourcing's role in developing manufacturing flexibilities", *International Journal of Production Research*, Vol. 38 No. 4, pp. 875-893.

Norrman, A. and Jansson, U. (2004), "Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident", *International Journal of Physical Distribution & Logistics Management*, Vol. 34 No. 5, pp. 434-456.

Olhager, J. (1993), "Manufacturing flexibility and profitability", *International Journal of Production Economics*, Vol. 30 No. 7, pp. 67-78.

Parthasarthy, R. and Hammond, J. (2002), "Product innovation input and outcome: moderating effect on the innovation process", *Journal of Engineering & Technology Management*, Vol. 19 No. 1, pp. 75-91.

Perrow, C. (1984), *Normal Accidents: Living with High-Risk Technologies*, Princeton University Press, Princeton, NJ.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y. and Podsakoff, N.P. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88 No. 5, pp. 879-903.

Revilla, E. and Saenz, M.J. (2017), "The impact of risk management on the frequency of supply chain disruptions: a configurational approach", *International Journal of Operations & Production Management*, Vol. 37 No. 5, pp. 557-576.

Rho, B., Hahm, Y. and Yu, Y. (1994), "Improving interface congruence between manufacturing and marketing in industrial-product manufacturers", *International Journal of Production Economics*, Vol. 37 No. 1, pp. 27-40.

Riley, M.J., Klein., R., Miller, J. and Sridharan, V. (2016), "How internal integration, information sharing, and training affect supply chain risk management capabilities", *International Journal of Physical Distribution & Logistics Management*, Vol. 46 No. 10, pp. 953-980.

Rungtusanatham, M., Rabinovich, E., Ashenbaum, B. and Wallin, C. (2007), "Vendor-owned inventory management arrangements in retail: an agency theory perspective", *Journal of Business Logistics*, Vol. 28 No. 1, pp. 111-135.

Sahay, B.S. (2003), "Supply chain collaboration: the key to value creation", *Work Study*, Vol. 52 No. 2, pp. 76-83.

Scherrer-Rathje, M., Deflorin, P. and Anand, G. (2014), "Manufacturing flexibility through outsourcing: effects of contingencies", *International Journal of Operations & Production Management*, Vol. 34 No. 9, pp. 1210-1242.

Schoenherr, T. and Swink, M. (2012), "Revisiting the arcs of integration: cross-validations and extensions", *Journal of Operations Management*, Vol. 30 No. 1, pp. 99-115.

Schwab, K. and Sala-i-Martin, X. (2013), "The Global Competitiveness Report 2013-2014", World Economic Forum, Geneva.

SCM World (2016), "Baking value into a supplier management programme", available at: https://member.scmworld.com/pluginfile.php/36709/mod_resource/content/1/Baking%20value%20into%20a%20supplier%20management%20programme.pdf (accessed April 26, 2016).

Shapiro, B.P. (1977), "Can marketing and manufacturing coexist?", *Harvard Business Review*, Vol. 55, September-October, pp. 104-114.

Sheffi, Y. and Rice, J.B. (2005), "A supply chain view of the resilient enterprise", *MIT Sloan Management Review*, Vol. 47 No. 1, pp. 41-48.

Sinha, P.R., Whitman, L.E. and Malzahn, D. (2004), "Methodology to mitigate supplier risk in an aerospace supply chain", *Supply Chain Management: An International Journal*, Vol. 9 No. 2, pp. 154-168.

Sivadasan, S., Smart, J., Huatuco, L.H. and Calinescu, A. (2010), "Operational complexity and supplier-customer integration: case study insights and complexity rebound", *Journal of the Operational Research Society*, Vol. 61 No. 12, pp. 1709-1718.

Slack, N. (2005), "The flexibility of manufacturing systems", *International Journal of Operations & Production Management*, Vol. 25 No. 12, pp. 1190-1200.

Swafford, P., Ghosh, S. and Murthy, N. (2006), "The antecedents of supply chain agility of a firm: scale development and model testing", *Journal of Operations Management*, Vol. 24 No. 2, pp. 170-188.

Tachizawa, E.M. and Giménez, C. (2010), "Supply flexibility strategies in Spanish firms: results from a survey", *International Journal of Production Economics*, Vol. 124 No. 1, pp. 214-224.

Tamayo-Torres, J., Barrales-Molina, V. and Nieves Perez-Arostegui, M. (2014), "The influence of manufacturing flexibility on strategic behaviours: a study based in certified quality management systems", *International Journal of Operations & Production Management*, Vol. 34 No. 8, pp. 1028-1054.

Tang, C.S. (2006), "Perspectives in supply chain risk management", *International Journal of Production Economics*, Vol. 103 No. 2, pp. 451-488.

Taran, Y., Boer, H. and Lindgren, P. (2013), "Incorporating enterprise risk management in the business model innovation process", *Journal of Business Models*, Vol. 1 No. 1, pp. 38-60.

Terjesen, S., Patel, P.C. and Sanders, N.R. (2012), "Managing differentiation-integration duality in supply chain integration", *Decision Sciences*, Vol. 43 No. 2, pp. 303-339.

Thomé, A.M.T., Scavarda, L.F., Fernandez, N.S. and Scavarda, A.J. (2012), "Sales and operations planning and the firm performance", *International Journal of Productivity and Performance Management*, Vol. 61 No. 4, pp. 359-381.

Thun, J. and Hoenig, D. (2011), "An empirical analysis of supply chain risk management in the German automotive industry", *International Journal of Production Economics*, Vol. 131 No. 1, pp. 242-249.

Tomlin, B. (2006), "On the value of mitigation and contingency strategies for managing supply chain disruption risks", *Management Science*, Vol. 52 No. 5, pp. 639-657.

Upton, D.M. (1997), "Process range in manufacturing ", *Management Science*, Vol. 43 No. 8, pp. 1079-1092.

Vandenberg, R.J. and Lance, C.E. (2000), "A review and synthesis of the measurement invariance literature: suggestions, practices, and recommendations for organizational research", *Organizational Research Methods*, Vol. 3 No. 1, pp. 4-70.

Van der Vaart, T. and Van Donk, D.P. (2008), "A critical review of survey-based research in supply chain integration", *International Journal of Production Economics*, Vol. 111 No. 1, pp. 42-55.

Van der Vaart, T., Van Donk, D.P., Giménez, C. and Sierra, V. (2012), "Modelling the integration-performance relationship: collaborative practices, enablers and contextual factors", *International Journal of Operations & Production Management*, Vol. 32 No. 9, pp. 1043-1074.

Vanpoucke, E., Boyer, K.K. and Vereecke, A. (2009), "Supply chain information flow strategies: an empirical taxonomy", *International Journal of Operations & Production Management*, Vol. 29 No. 12, pp. 1213-1241.

Vargas, G., Cardenas, L. and Matarranz, J.L. (2000), "Internal and external integration of assembly manufacturing activities", *International Journal of Operations & Production Management*, Vol. 20 No. 7, pp. 809-822.

Vereecke, A. and Muylle, S. (2006), "Performance improvement through supply chain collaboration in Europe", *International Journal of Operations & Production Management*, Vol. 26 No. 11, pp. 176-198.

Wieland, A. and Wallenburg, C.M. (2012), "Dealing with supply chain risks: linking risk management practices and strategies to performance", *International Journal of Physical Distribution & Logistics Management*, Vol. 42 No. 10, pp. 887-905.

Wieland, A. and Wallenburg, C.M. (2013), "The influence of relational competencies on supply chain resilience: a relational view", *International Journal of Physical Distribution & Logistics Management*, Vol. 43 No. 4, pp. 300-320.

Wiengarten, F., Pagell, M., Ahmed, M.U. and Giménez, C. (2014), "Do a country's logistical capabilities moderate the external integration performance relationship?", *Journal of Operations Management*, Vol. 32 No. 1, pp. 51-63.

Wiengarten, F., Humphreys, P., Giménez, C. and McIvor, R. (2016), "Risk, risk management practices, and the success of supply chain integration", *International Journal of Production Economics*, Vol. 171 No. 3, pp. 361-370.

Wiengarten, F., Humphreys, P., Cao, G., Fynes, B. and McKittrick, A. (2010), "Collaborative supply chain practices and performance: exploring the key role of information quality", *Supply Chain Management: An International Journal*, Vol. 15 No. 6, pp. 463-473.

Wong, C.Y., Boon-Itt, S. and Wong, C.W.Y. (2011), "The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance", *Journal of Operations Management*, Vol. 29 No. 6, pp. 604-615.

Zaltman, G., Duncan, R. and Holbek, J. (1973), *Innovations and Organizations*, John Wiley & Sons, New York, NY.

Zhao, L., Huo, B., Sun, L. and Xiande, Z. (2013), "The impact of supply chain risk on supply chain integration and company performance: a global investigation", *Supply Chain Management: An International Journal*, Vol. 18 No. 2, pp. 115-131.

Zsidisin, G.A. and Ellram, L.M. (2003), "An agency theory investigation of supply risk management", *Journal of Supply Chain Management*, Vol. 39 No. 3, pp. 15-27.

Zsidisin, G.A., Ellram, L.M., Carter, J.R. and Cavinato, J.L. (2004), "An analysis of supply risk assessment techniques", *International Journal of Physical Distribution & Logistics Management*, Vol. 34 No. 5, pp. 397-413.

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