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 and supply chain risk management on manufacturing flexibility, and the moderating effect of supply chain risk management on the relationships between internal and external integration, 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 supply chain risk management have a direct effect on manufacturing flexibility. Supply chain risk management moderates the relationship between external integration 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 external integration and increase their flexibility performance, manufacturing firms need to implement different mechanisms of supply chain risk management 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, external integration, supply chain risk management and manufacturing flexibility.

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

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 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.

External (i.e. with suppliers and customers) and internal (i.e. between manufacturing, purchasing and sales) integration have both been associated with supply chain risk. However, research on the association between integration and flexibility has produced 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 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 external integration. Schoenherr and Swink (2012) find that internal integration strengthens the positive impact of external integration 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 external integration 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 supply chain risk management (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 Wallenberg, 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 external integration 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 external integration and SCRM on manufacturing flexibility.
- The possible moderating role of SCRM in the relationships between internal and external integration, respectively, and flexibility.

Literature review

Impact of supply chain integration on performance

Frohlich and Westbrook (2001) demonstrate that higher levels of external integration 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) find supplier integration to affect performance positively. Braunscheidel and Suresh (2009) and Wong et al. (2011) report positive impact of internal and external integration on flexibility. Schoenherr and Swink (2012) report that internal integration strengthens the impact of external integration 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) find that collaboration through information sharing has stronger impact on operational performance than joint-decision making and incentive alignment.

Fabbe-Costes and Jahre (2008), however, find 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) find that internal, supplier and customer integration mediate the relationship between learning orientation and SCRM, while SCRM improves overall logistical performance. Gualandris and Kalchschmidt (2015) argue 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) argue 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? 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 towards risks, which cause disagreements about actions to be taken (Rungtusanatham et al., 2007). 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, 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.* e.g. 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) find 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. While Koufteros et al. (2005) and Giménez and Ventura (2005) find 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.*

External integration 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) find 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) find 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 external integration 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 external integration and flexibility, we hypothesize:

> *H2: External integration with suppliers and customers has a positive effect on manufacturing flexibility.*

Supply chain risk management 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 Hoening, 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 over-abundance 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: Supply Chain Risk Management has a positive effect on manufacturing flexibility.

Moderating effects of SCRM on the integration-flexibility relationship

Supplier related risks include disturbances (e.g. unavailability, 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 et al. (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 external integration 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 agency theory, outcome-based SCRM is more fruitfully regarded as complementary to, and needed to strengthen the impact of, behavior-based internal and external integration:

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 external integration 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 was collected in 2013-2014 by an international team of researchers from different universities around the world, and includes 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 1951 manufacturing plants in China, India, Japan, Malaysia and Taiwan were contacted to participate. Eventually, 342 (42%) 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 was imputed using multiple imputation in SPSS 22.0. Table 1 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, external integration, SCRM and flexibility. Their sources and operationalization are reported in Tables 2 and 3.

Internal integration includes sharing information and joint decision making with the purchasing and the sales department. External integration 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 α, Average Variance Extracted (AVE) and Composite Reliability (CR) of these constructs and underlying items are reported in Table 3.

TABLE 1 HERE

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 2 reports the sources used to operationalize these constructs, Table 3 their standardized factor loadings, Cronbach 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 (WEF) Global Competitiveness Report 2013-2014 (Schwab and Sala-i-Martin, 2013). The extent of external integration 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 external integration 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 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 2 HERE

TABLE 3 HERE

Table 4 reports the descriptive statistics of all the constructs used in this research.

TABLE 4 HERE

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, χ^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 composite reliabilities (CR) 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 average variance extracted (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 4). Thus, both CR and AVE indicate acceptable reliability levels. The results of pairwise χ^2 difference tests (Table 5) show discriminant validity of the constructs.

To test convergent validity, the standardized parameter loadings of the measurement items on their respective constructs, the 90% 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 zero 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).

TABLE 5 HERE

Common method bias (CMB) was minimized using techniques described by Podsakoff et al. (2003). The questions regarding the independent variables (internal and external integration, 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 model with only traits, and the measurement model with both traits and a method factor (Flynn et al., 2010; Zhao et al., 2011). 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 ($\chi2(259)=849.045$, 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% 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 (Paulraj et al., 2008; Flynn et al., 2010; Zhao et al., 2011).

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.

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), customer order decoupling point (CODP), and sales to business-to-business customers (B2B). For each of these variables, we divided the dataset 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 5), in which the regression weights are assumed to be equal for the groups. The results of the chi square difference tests demonstrate measurement equivalence for size, CODP and B2B groups. Next, we conducted a chi square 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 6.

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

TABLE 6 HERE

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

To further understand the interaction effect between SCRM and external integration, the slope of flexibility performance as a function of external integration 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 external integration (EI), SCRM and SCRM x EI, and considering the three values of SCRM, three linear equations of flexibility performance as a function of external integration were generated.

Figure 1 demonstrates that the effect of increasing external integration 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 external integration 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 (external integration) 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 centered variable external integration varies between -2.35 and 1.64; 7.28% of the sample falls below the external integration critical value of -1.41 (the intersection point between the regression lines at low and high SCRM) with an external integration mean value of 0.00.

FIGURE 1 HERE

Figure 1 generates interesting insights. Both the low external integration-low SCRM and the high external integration-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 external integration and SCRM. Misalignment will impact flexibility undesirably: low external integration 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 external integration without the use of SCRM can affect flexibility negatively. Similarly, high SCRM coupled with low external integration will result in low flexibility as well. Clearly, the preferred approach is a combination of high external integration with high SCRM.

Discussion

This study provides a number of valuable insights into the direct and interactive effects of internal integration, external integration and SCRM on manufacturing flexibility. While the role of internal and external integration 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 external integration, 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.

External integration and SCRM

While the relationship between external integration and flexibility performance (H2) is insignificant, SCRM has a moderating effect on that relationship (H4b). Thus, external integration 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) find a low correlation between external integration and flexibility. Terjesen et al. (2012) report that firms may even lose flexibility due to extensive integration. A reason may be that external integration 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 external integration on flexibility performance may be insignificant (going against H2), and suggests that external integration must be combined with SCRM (confirming H4b) in order to achieve positive effects on flexibility performance. Thus, if a firm not only considers external integration 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 external integration 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 external integration, 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, external integration 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 external integration have positive flexibility effects.

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

Contribution to practice

Firms focusing on external integration to mitigate risks and improve flexibility, should recognize that external integration 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 external integration 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, 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 external integration, 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 external integration 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 external integration 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 find 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.

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Table 1 – Sample demographics

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 2 – Sources of constructs

Measurement Items	Sources
Internal Integration:	
Sharing information with purchasing department (about sales forecast, production plans, production progress and stock level)	Ellinger et al., 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., 1997; Spekman, 1988; 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., 2005
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

Table 2 (continued) – Sources of constructs

Measurement items	Based on
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
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 3 – Measurement items

Measurement Items	Standardized factor loading	Cronbach's α	AVE *	CR **
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			

Table 3 (continued) – Measurement items

Measurement Items	**Standardized factor loading**	**Cronbach's α**	**AVE ***	**CR ****
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			
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			

* AVE: Average Variance Extracted

** CR: Composite Reliability

Table 4 – 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**

*p<0.05, ** p<0.01

Square roots of the average variances extracted are shown on the diagonal

Table 5 – Pairwise chi-square difference tests for discriminant validity

	Unconstrained model		Constrained model		
	χ2	df	χ2	df	Δ χ2
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*

* p<0.05, ** p<0.01

Table 6 – Hierarchical regression analysis

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Dependent variable	Flexibility	Flexibility	Flexibility	Flexibility	Flexibility	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 x II					0.04	
SCRM x 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

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

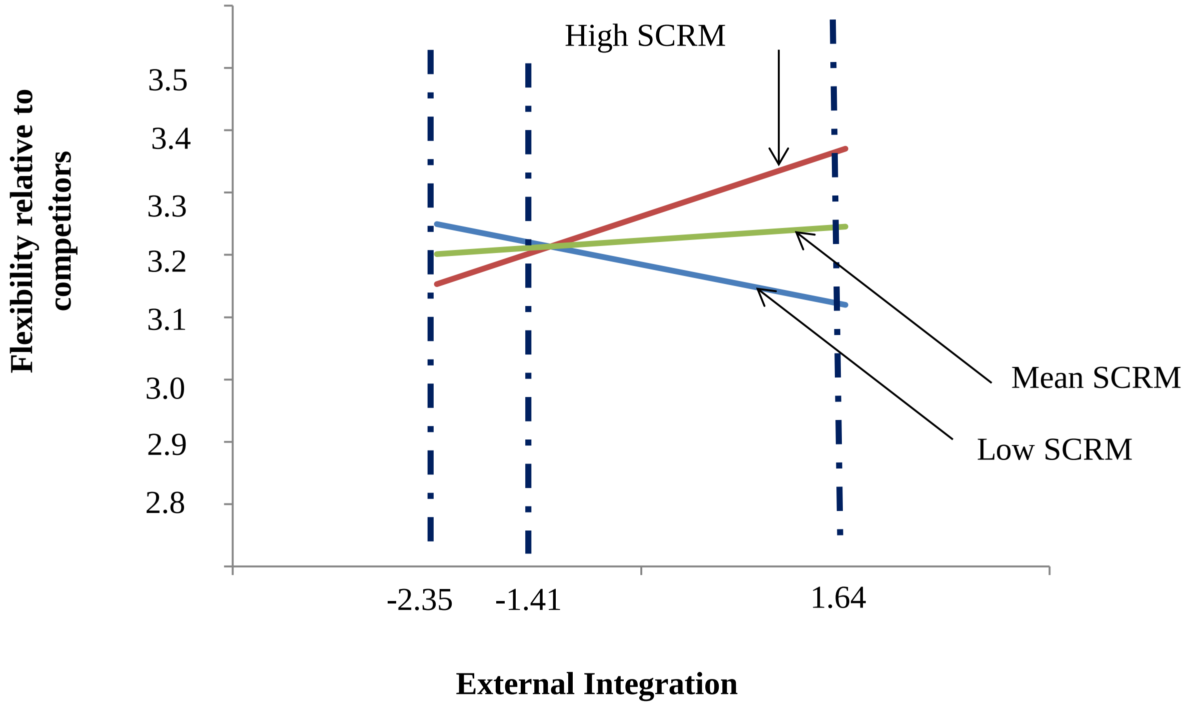

Figure 1 – Slope of flexibility performance with external integration at low, medium and high values of SCRM