Supply chain integration and risk management: the moderating effect of manufacturing networks

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Abstract

This paper examines the enabling role of supply chain integration (SCI) in the implementation of supply chain risk management (SCRM). Moreover, this study explores the moderating effects of different configurations of manufacturing network (MN) on the relationship between SCI and SCRM as well as on the effectiveness of SCRM on operational performance. The results indicate the negative moderating effects of the geographic scope of MN on the SCI-SCRM and SCRM-operational performance relationships. This paper broadens the study of manufacturing networks and provides managerial insights for SCRM.

Keywords: Supply chain integration, Risk management, Manufacturing network

Introduction

Firms have been broadening the geographic scope of their manufacturing networks (MNs) as well as supply chain networks (Rudberg and Olhager, 2003) in order to purse lower cost, higher profit and faster responsiveness. However, the extended geographic scope of MNs and supply chains leads to increasingly complicated environments and spatial complexity, which makes firms more vulnerable to operations and supply chain disruption risks (Bode and Wagner, 2015). As a result, supply chain risk management (SCRM) are widely adopted nowadays to cope with the increased complexity and disruption risks (Manuj et al., 2014). Since SCRM is an information-intensive process (Srinivasan and Swink, 2015), its successful implementation requires a large amount of information on internal operations and external supply chains to identify, assess, mitigate and monitor risks (Kauppi et al., 2016; Tang, 2006). Defined as the coordination and collaboration of multiple functions of a firm as well as supply chain partners to facilitate the flows of information, material, and money efficiently and

effectively (Flynn et al., 2010), supply chain integration (SCI) offers the potential to provide rich information in dispersed manufacturing networks and supply chains (Leuschner et al., 2013). Therefore, SCI is supposed to facilitate the implementation of SCRM. However, there are limited studies that have empirically investigated the effects of SCI on SCRM.

There is an extensive body of studies on the dimensions of SCI (e.g. Flynn et al., 2010; Leuschner et al., 2013). The extant classifications of SCI mainly focus on the intra- and inter-firm scope (cross-functional integration and external integration) but neglect the distinctive aspects of inter-plant integration (Demeter et al., 2016; Szász et al., 2016). Firms with multiple plants implement integrated activities to coordinate their manufacturing networks, which indicates a form of intra-firm integration, i.e. manufacturing network integration (MNI) (Cheng et al., 2016). However, there are lack of in-depth studies on the simultaneous effect of three dimensions of SCI on SCRM. Consequently, this study intends to analyze the role of three dimensions of SCI in SCRM in the context of global manufacturing networks, including cross-functional integration (CFI) at intra-plant level, MNI at inter-plant level, and external integration (EI) at inter-firm level. Based on what has been illustrated above, the first research question of this paper is:

RQ1: What are the effects of three dimensions of SCI (i.e., CFI, MNI and EI) on SCRM?

Moreover, firms adopt different configurations of MN such as multiple plants in one country, multiple plants in one continent and multiple plants in multiple continents. According to the well-studied international business and strategy literature, the configurations of MN denote whether the plants and facilities are geographically concentrated or dispersed (Roth, 1992). Hence, the configurations of MN indicate the geographic scope of MN, including the levels of geographical dispersion and country environment diversity (Goerzen and Beamish, 2003), which may hinder the operations and managerial information sharing and joint decision-making with other plants and firms (Goerzen and Beamish, 2003; Zaheer and Hernandez, 2011). Consequently, it can be conjectured that the configurations of MN may influence the effectiveness of SCI on SCRM. However, to our best knowledge, there is no empirical research on the influence of different configurations of MN, viz., geographic scope of MN, on the SCI-SCRM relationship. In addition, previous research has investigated the positive effects of SCRM on operational performance (i.e., operational efficiency and flexibility). The geographical dispersion and country environment diversity of different configurations of MN could change the information processing needs for managerial and operations information and information processing capability (Qian et al., 2010; Zaheer and Hernandez, 2011). Therefore, different configurations of MN may affect the positive impacts of SCRM on both operational efficiency and operational flexibility. However, the influence of the geographic scope of MN on the relationship between SCRM and operational performance has not been studied explicitly. To close this research gaps, this paper aims to answer the second research question:

RQ2: How do different configurations of MN moderate the relationship between SCI and SCRM and the relationship between SCRM and operational performance?

This study contributes to several streams of literature. First, this study extends the literature of information processing theory (IPT) by linking the geographic scope of MN to SCI and SCRM. Second, this study contributes to both the SCI and SCRM literature by proposing the enabling roles of three dimensions of SCI at different levels (i.e., CFI, MNI and EI) in SCRM. Third and most importantly, this paper contributes to manufacturing network literature by identifying the moderating effects of configurations of MN on SCI-

SCRM relationship and SCRM-operational performance relationship. In addition, this paper also provides insightful managerial implications.

Literature review and hypotheses development

Supply chain integration

There is an extensive body of studies on the dimensions of SCI (Flynn et al., 2010; Leuschner et al., 2013). While some researchers examined SCI as a unidimensional construct, others explored the multi-dimensional attributes of SCI and proposed more detailed dimensions of SCI by divided external integration into customer and supplier integration (Srinivasan and Swink, 2015). However, the extant classifications of SCI mainly focus on the intra- and inter-firm scope and fail to capture the inter-plant scope of integration. In recent decades, due to the explosive development of international business and foreign investment, many manufacturers work as MNs (Rudberg and Olhager, 2003), which have become important institutions to link single plants with global supply chains. Firms with multiple plants implement integrated activities (e.g. information sharing, joint decision-making, joint innovation activities and etc.) to coordinate their MNs (Demeter et al., 2016; Szász et al., 2016), which indicates a form of inter-plant integration, i.e. MNI. In spite of the extensive existence of MNI applied by firms with multiple plants, this distinctive aspect of inter-plant integration is somehow overlooked by extant literature and has not been studied sufficiently. To our best knowledge, only a few studies have identified and examined MNI. Consequently, this study proposes three dimensions of SCI, i.e. CFI at intra-plant level, MNI at inter-plant level, and EI at inter-firm level. Furthermore, according to the studies of subsidiary integration and inter-plant coordination, we define MNI as the coordination and collaboration across multiple plants in a manufacturing network (Cheng et al., 2016; Szász et al., 2016).

Supply chain integration and supply chain risk management

Since SCRM is an information-intensive process, three dimensions of SCI, which offers the potential to provide rich and high-quality information on internal operations and external supply chain members (Leuschner et al., 2013), are supposed to promote the implementation of SCRM in terms of reducing information processing requirements and increasing information processing capability. First, CFI incorporates the multiple functions of a firm and facilitates the internal operations information acquisition from different functions and departments (Schoenherr and Swink, 2012), which reduces the information processing requirements and further facilitates the identification of operations risk. Second, for firms that have manufacturing networks, better MNI enables the gathering and assimilation of operations information across plants (Szász et al., 2016). Thus, these firms are more capable to identify and assess risks and take risk management actions proactively. Third, EI ensures the external information accessibility and accuracy. The rich and accurate real-time upstream and downstream information acquired from the collaboration and coordination with supply chain partners helps reduce the uncertainties and improve the risk identification, assessment and mitigation. Therefore, we hypothesize that:

H1a: CFI is positively associated with SCRM.

H1b: MNI is positively associated with SCRM.

H1c: EI is positively associated with SCRM.

The moderating role of manufacturing networks

In the trend of globalization, firms adopt different configurations of MN such as multiple plants in one country, multiple plants in one continent and multiple plants in multiple continents to pursue lower cost and gain competitive advantage (Leuschner et al., 2013). Different configurations of MN indicate different geographic scopes of MN including the geographical dispersion and country environment diversity, which may hinder the production and managerial information sharing and joint decision-making with other plants and firms (Bode and Wagner, 2015). Consequently, it is conjectured that different configurations of MN may influence the effectiveness of SCI on SCRM.

For firms that incorporate with a broader geographic scope of MN, the effectiveness and efficiency of CFI on SCRM may decrease due to the delayed operations and managerial information from external sources. First, a broader geographic scope of MN indicates the geographical dispersion and spatial complexity, which increases the operations information processing requirements of the firm and impedes the gathering of intra-network operations information and external supply chain information. Since plants need to process both internal and external operations information, the inaccurate and delayed information impedes the effective processing of information from multiple functions within a firm. Second, the broader geographic scope of MN also creates administrative burden in that it increases managerial information processing demands due to the higher level of the country environment diversity associated with a broader geographic scope of MN (Goerzen and Beamish, 2003; Zaheer and Hernandez, 2011). Thus, the effectiveness of CFI on SCRM may decrease due to lack of operations and supply chain information.

A broader geographic scope of MN may decrease the effectiveness of MNI on SCRM as a result of the decreased quality and transparency of operations information at intra-network level. First, less accurate and delayed information may be gathered from a more geographically dispersed MN, which will weaken the positive impact of MNI on SCRM. Furthermore, the country environment diversity and culture differences create administrative barriers to transferring managerial information fast and timely (Goerzen and Beamish, 2003). Besides, the geographical dispersion and environment diversity also weaken information processing capability (Qian et al., 2010). Therefore, the delayed information and weaker information processing capability together hinder timely detection, assessment and mitigation of supply chain risks.

The geographic scope of MN may also weaken the effectiveness of EI on SCRM in several ways. First, a broader geographic scope of MN implies dispersed and diversified supply chains cooperating with multiple plants, which increases the difficulty for the subsidiaries to acquire external supply chain information such as inventory and lead time. Second, the accuracy of operations information acquired by a dispersed MN is much lower compared to a concentrated MN. Hence, it is difficult for firms with dispersed MNs to accurately detect supply chain risks. In addition, the geographical distance also weakens a firm's information processing ability in that there are less face-to-face communications and larger cultural differences across dispersed distributed plants, which requires more managerial skills and efforts and creates administrative burdens (Goerzen and Beamish, 2003; Zaheer and Hernandez, 2011). Based on what have been demonstrated above, we propose:

H2a: The broader the geographic scope of the MN, the weaker the effectiveness of CFI on SCRM.

H2b: The broader the geographic scope of the MN, the weaker the effectiveness of MNI

on SCRM.

H2c: The broader the geographic scope of the MN, the weaker the effectiveness of EI on SCRM.

Previous studies have evidenced the positive effect of SCRM on operational performance, i.e., operational efficiency and flexibility (Kauppi et al., 2016; Manuj et al., 2014). Specifically, it is argued that firms can improve operational efficiency through acquiring and processing rich and accurate operations and supply chain information (e.g. information related to inventory, logistics, quality control, cost, supply, demand, and etc.) obtained from SCRM practices (Kauppi et al., 2016). The buffer strategies and reliable procedures provided by SCRM leads to lower operational cost and shorter lead time in production. In addition, the information processing capability created by SCRM practices contributes to operational efficiency in that firms can better deal with operations information, decrease the resources waste and time loss, and prevent operations risks. Operational flexibility can be achieved through SCRM practices (e.g. flexible production processes, alternative transportation modes, and multiple and back-up suppliers) in terms of rich buffering information and faster response (Williams et al., 2013). Moreover, previous research also argued that higher information processing capability generated from SCRM practices increases the quick response and customization ability to meet customer requirements (Fan et al., 2017).

Different configurations of MN may also influence the effectiveness of SCRM on operational efficiency and flexibility respectively in terms of the increased information processing requirements and decreased information processing capability induced by the broader geographic scope of MN (Bode and Wagner, 2015; Goerzen and Beamish, 2003). For firms that operate in a broader geographic scope of MN, the effectiveness of SCRM on operational efficiency may decrease due to the relatively inaccurate and delayed operations information from external sources and the associated demand and supply uncertainty induced by a higher level of geographical dispersion and spatial complexity (Bode and Wagner, 2015). Besides, a broader geographic scope of MN requires more buffering which will increase the production cost and lead time. Furthermore, the spatial complexity of a dispersed MN undermines firm's information processing capability and further decrease the effectiveness of operational efficiency (Goerzen and Beamish, 2003). Therefore, the effectiveness of CFI on SCRM may decrease in more geographically dispersed MNCs.

Similarly, a broader geographic scope of MN may also decrease the effectiveness of SCRM on operational flexibility. First, it is difficult to maintain flexible SCRM practices such as production, alternative transportation modes in a geographically dispersed MN (Bode and Wagner, 2015; Williams et al., 2013). Second, the country environment diversity generated from a broader geographic scope of MN increases the administrative barrier to information processing and impedes the effective processing of the inaccurate and delayed information (Goerzen and Beamish, 2003), which leads to weakened effectiveness of SCRM on operational flexibility. Based on what have been demonstrated above, we hypothesize that:

H3: The broader the geographic scope of the MN, the weaker the effectiveness of SCRM on the firm's (a) operational efficiency and (b) operational flexibility.

Research Method

Sample

The empirical analysis of this study is based on the database of the sixth round International Manufacturing Strategy Survey (IMSS), which was collected from manufacturing plants that

have more than 50 employees during the year 2013 to 2014. The survey is administered by an international group of senior operations management scholars and completed by operations or general managers from manufacturing companies in the assembly industries (ISIC 25-30). 931 valid questionnaires were collected from 22 countries and the average response rate was 36%. Since this study focuses on three levels of SCI including intra-network level, responses with only one plant were dropped. The final sample has 442 responses from 22 countries after deleting responses with missing data in this study.

A uniform protocol was used to control the non-response and late-response biases by each local research group. No non-response and late-response biases were observed and reported. We conducted Harmon's single factor test to assess the impact of common method variance (CMV). The result of Harmon's single factor analysis test revealed six distinct factors with eigenvalues above 1.0, explaining 67.23% of the total variance. Further, we applied confirmatory factor analysis (CFA) to Harmon's single factor test (Podsakoff et al., 2003). The fit indices of the one-factor model were unacceptable (χ^2/df=8.616; RMSEA=0.131; CFI=0.608; TLI=0.577; SRMR=0.098) compared to the measurement model used in our study (χ^2/df=3.036; RMSEA=0.068; CFI=0.900; TLI=0.887; SRMR=0.049). The results showed that CMV was not a major concern in this study.

Measures

SCRM and the three dimensions of SCI (i.e., CFI, MNI and EI) are all measured by five-point Likert scales where one point denotes the lowest level of implementation and five point denotes the highest level. Specifically, SCRM is measured through the implementation of the prevention, detection, respond to, and recovery from supply chain and operations risks (Kauppi et al., 2016).

Prior research has extensively studied CFI and provided with mature measurement which mainly covers information sharing and joint decision-making across multiple functions. In this study, CFI was measured through the current implementation of information sharing and joint decision making with different departments. MNI was measured through five factors including the current level of implementation of information sharing, joint decision making, joint innovation, technological support to communication, and network performance management system at inter-plant level. EI is defined as "the degree to which a manufacturer partners with its external partners to structure inter-organizational strategies, practices and processes into collaborative, synchronized processes" (Flynn et al., 2010, pp. 59). Therefore, EI was measured by eight items which reflect the current level of adoption by focal firms in terms of the information sharing, collaboration, joint decision making and system coupling with suppliers and customers respectively.

MNC refers to the geographical distribution of focal firm's manufacturing network. This study measures MNC as a categorical variable consisting of three types of configurations, i.e., multiple plants in one country, multiple plants in one continent, and global plants.

In addition, this study includes firm size as a control variable because larger firms have more resources for SCRM.

Reliability and validity

We assessed the validity of our study in terms of content, convergent and discriminant validity. Content validity was first guaranteed since the sixth round IMSS is developed by a team of senior researchers and extracted from solid operations literature. IBM SPSS 22.0 was

used to analyze the reliability of the constructs. The Cronbach's alpha values of the constructs are greater than 0.70, which confirms the internal consistent reliability of the measurements. CFA was conducted using Mplus 7.4 to test the validity and reliability of the measurements of the constructs. The CFA results show an acceptable fit of the measurement model (χ^2/df=3.036; RMSEA=0.068; CFI=0.900; TLI=0.887; SRMR=0.049). All factor loadings are above 0.50 and the *p*-values are all significant at the level of 0.001. Besides, the standardized coefficients for all items are greater than twice their standard errors. The CFA results indicate the convergent validity of the measures. The composite reliability (CR) value of each construct is greater than 0.70. The estimates of average variance extracted (AVE) for all the constructs are greater than 0.45 and all AVE estimates are less than the corresponding CR values. The above-mentioned results indicate the convergent validity of our study.

Finally, the inter-construct correlations were calculated and confirmed the discriminant validity of the measures. The square root of AVE value for each construct is larger than any corresponding correlation coefficient.

Results

In this study, structural equation modeling (SEM) was used to test the proposed H1a-c in order to get the estimations of the hypothesized paths simultaneously. Since the moderator is measured by a categorical variable, multi-group analysis is suitable to test the moderating effects of configurations of MN on the relationship between SCI and SCRM. Specifically, the sample was split into two groups according to the different configurations of MN. We combine the firms that have plants in one country and the firms that have plants in one continent into one group. It is appropriate because a large portion of countries in our sample are from Europe where firms commonly operate plants across the whole continent. The second group includes firms that have global manufacturing plants. Mplus 7.4 was used to run the SEM and multi-group analysis in this study.

The relative and absolute indices of model fit are χ^2/df=2.610, Comparative Fit Index = 0.914, TLI=0.904, RMSEA=0.060, SRMR=0.063, which indicates that the SEM model fits well to the data. CFI significantly facilitates SCRM with the standardized coefficient being 0.122 and the *p*-value being 0.018. MNI promotes SCRM with the standardized coefficient being 0.316, which is significant at the level of 0.001. The standardized coefficient of EI on SCRM is 0.351, which is significant at the level of 0.001. Therefore, H1a, H1b and H1c are all supported. SCRM positively influences both operational efficiency and flexibility at the 0.001 significance level. The results are shown in Figure 1.

To further test the proposed moderating effects of the configurations of MN on the SCI-SCRM relationship, we conducted multi-group analysis. The results of the multi-group analysis show that the configurations of MN moderate the relationship between MNI and SCRM with the p-value being 0.017. However, the configurations of MN do not moderate the relationship between CFI and SCRM and the relationship between EI and SCRM. We further conducted SEM using data from two groups respectively to examine the specific effects of different manufacturing networks on the MNI-SCRM relationship. We find that the broader geographic scope of MN, the weaker the effect of MNI on SCRM. Consequently, H2b is confirmed whereas H2a and H2c are not supported. Similarly, we conducted multi-group analysis to test the moderating effects of the configurations of MN on the relationship between SCRM and operational performance. The results indicate that the configurations of

MN negatively moderate both the effect of SCRM on operational efficiency and flexibility with the p-values being 0.012 and 0.007 respectively. Thus, H3a and H3b are supported.

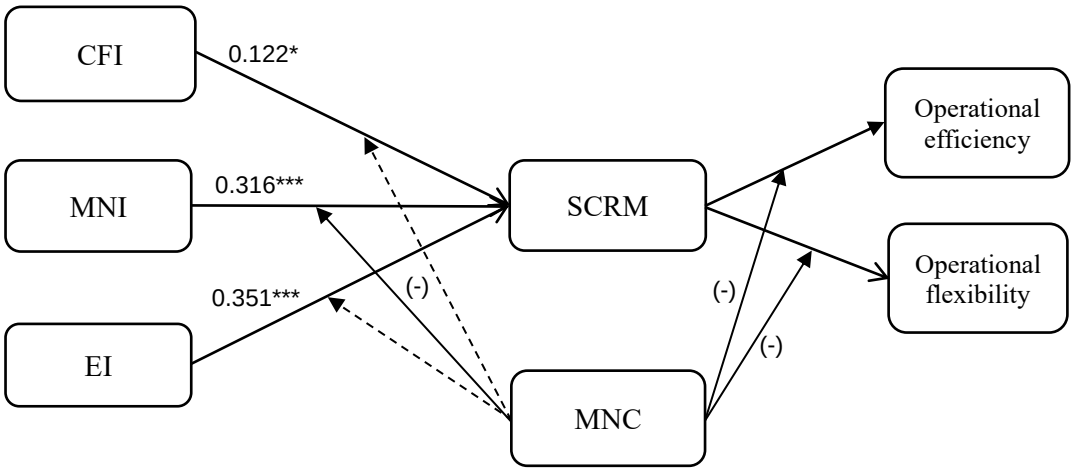

Figure 1 – The SEM model and moderating effects

We further conducted robustness check by deleting the firms that have multiple plants in one continent to test the robustness of our findings. The findings of the moderating effects of MNC do not change. Hence, our findings that based on the one country and one continent versus global plants manufacturing are robust and reliable.

Discussion

Theoretical contributions

Previous research on supply chain risk management has identified the important role of SCI in the monitor, assessment, and mitigation of risks. However, these studies are not comprehensive since they did not take into account the three dimensions of SCI (i.e. CFI, MNI and EI) simultaneously. Our study makes a contribution to the SCRM literature by examining the enabling role of three dimensions of SCI in the execution of SCRM practices.

Our study addresses the moderating effects of the configurations of MN on the SCI-SCRM relationship. Specifically, the broader the geographic scope of MN, the lower the efficiency of MNI on SCRM. This can be explained that a relatively narrow geographic scope of MN, which indicates more geographical concentrated dispersion and more similar country environments, allows for easier and more efficient information sharing and processing. The results support the moderating role of the configurations of MN in the relationship between MNI and SCRM whereas show no significant moderating effects on CFI-SCRM and EI-SCRM relationship. This may be due to the structural differences of the organizations (single plant, multiple plants, and supply chains) under different types of integration. Compared to a single plant and a supply chain, a manufacturing network (multiple plants) is a hybrid organization form which is characterized with both hierarchical structures (because multiple plants belong to a headquarter) as well as the organizational boundaries (because multiple plants are different organizations and located in different sites) at the same time (Aldrich and Herker, 1977; Grant, 1996; Hult et al., 2004). Hence, the integration of MNs experiences higher administration burden and production information processing inefficiency and thus are more sensitive to the level of geographic scope of MN (Goerzen and Beamish, 2003;

Zaheer and Hernandez, 2011). By contrast, a single plant is a pure hierarchical organization who achieves integration and cross-functional information sharing mainly through administrative command. A supply chain is a pure market form whose integration requires mainly for cross-boundary information sharing among the firms.

Our study also examines the moderating effect of the configurations of MN on the SCRM-operational performance relationship. Specifically, the broader the geographic scope of MN, the lower the efficiency of SCRM on both operational efficiency and operational flexibility. The results are intuitive because with the geographic scope of MN broadening, the administrative and operations information is more likely to be delayed and inaccurate, which creates barriers to achieve both operational efficiency and flexibility. Based on the results for H2 and H3, this paper contributes to the MN literature in the supply chain management field by linking the geographic scope of MN to SCI and SCRM from the perspective of IPT.

Managerial implications

Our study provides some managerial implications. First, our results suggest the positive impacts of three dimensions of SCI on SCRM. Thus, firms that want to better implement SCRM should spare more effort to develop SCI, including CFI, MNI and EI. Second, for multinational enterprises with broader geographic scope of MN, "extra" emphasis should be put on MNI to ensure SCRM since MNI is more sensitive to the geographical dispersion and country environment diversity than CFI and EI. Third, CFI and EI should be executed by firms with a broader geographic scope of MN because CFI and EI are less likely to be influenced by the configurations of MN and can enable the implementation of SCRM. Therefore, firms with a broader geographic scope of MN can leverage the CFI and EI to facilitate the SCRM.

Conclusion

SCRM is widely applied to deal with the supply chain risks induced by increasingly complex environments and sophisticated operations practices. Our study on SCI and SCRM suggests that the implementations of three dimensions of SCI (i.e., CFI, MNI, and EI) promote SCRM.

Further, research on MNs has become increasingly popular with the trend of globalization and the development of global manufacturing and supply chain networks. However, research that links the geographic scope of MN to SCI and SCRM is rare. Our study closes this research gap by empirically testing the role of the configurations of MN in the effectiveness of SCI on SCRM. Our results suggest that the configurations of MN negatively moderate the relationship between MNI and SCRM. In addition, the configurations of MN negatively moderate the SCRM-operational performance relationship.

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