Investigating the relationship between supply chain innovation, risk management capabilities and competitive advantage in global supply chains

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Structured Abstract:

Purpose- This study aims to propose and validate a theoretical model to investigate whether supply chain innovation positively affects risk management capabilities, such as robustness and resilience in global supply chain operations, and to examine how these capabilities may improve competitive advantage.

Design/methodology/approach- A theoretical model was developed from extant studies and assessed through the development of a large-scale questionnaire survey conducted with South Korean manufacturers and logistics intermediaries involved in global supply chain operations. The data were analysed using confirmatory factor analysis (CFA) and structural equation modelling (SEM) to validate the suggested model.

Findings- It was found that innovative supply chains have a discernible positive influence on all dimensions of risk management capability, which in turn has a significant impact on enhancing competitive advantage. Therefore, this work provides evidence for the importance

of supply chain innovation and risk management capability in supporting competitive advantage.

Research limitations/implications- This study contributes to providing an empirical understanding of the strategic retention of supply chain innovation and risk management capabilities in the supply chain management (SCM) discipline. Further, it confirms and expands existing theories about innovation and competitive advantage.

Practical implications- The finding provides firm grounds for managerial decisions on investment in technology innovation and process innovation.

Originality/value- This research is the first of its kind to empirically validate the relationships between supply chain innovation, risk management capabilities and competitive advantage.

1. Introduction

Effective supply chain (SC) risk management has become a major strategic requisite of global SCs (Ritchie and Brindley, 2007). This tendency emanates from the fact that risks and uncertainties have been generated by contemporary strategies for SC efficiency, such as the exploitation of globalisation, inventory reduction, centralised distribution and production, supply base reduction, lean operation, and outsourcing (Revilla and Saenz, 2017; Rotaru *et al.*, 2014; Blackhurst *et al.,* 2011; Jüttner *et al.,* 2003). For instance, although the proliferation of global offshore manufacturing has given cost advantage and access to the rapidly growing markets for multinational corporations, greater risks and uncertainties are encountered along global SCs, such as transportation risks, exchange rate risks and cultural risks, due to the inherently more complex nature of global sourcing and international logistics (Prater *et al.*, 2001). Hence, the development of SC risk management has been a natural response in recognition of these increasing risks (Christopher and Lee, 2004).

It has been debated whether innovation is an enhancer or a reducer of business risks (Klein-Schmeink and Peisl, 2013). SC innovation is a complex process to generate information processing and new logistics services by utilising technology innovation and process innovation in order to offer solutions for customer requirements and identify new ways to better processes (Lee *et al.*, 2011). As such, it can not only improve operational capability, but also augment risk management capability by acting as a catalyst to facilitate numerous activities such as enhanced planning, monitoring, forecasting and purchasing in complex SC practices. Leading firms, such as Microsoft, Samsung and Apple, have strived to embed SC innovation into their practices and operations along the global SC. Also, global logistics firms, such as DHL, FedEx and UPS are trying to make innovative improvement in logistics related capabilities (Golgeci and Ponomarov, 2013) as is Panalpina. This is attributed to the fact that the firms or SCs that have a higher level of innovation are considered, as early

adopters, to be more technically sophisticated, better at risk-taking and more integrated with SC partners. This means that they can more successfully reduce risks, disruptions and uncertainties by having more of a focus on developing risk management capability than later adopters (Tidd, 2010).

SC risk management has been rigorously studied by researchers, particularly over the last two decades, and some studies have attempted to examine the antecedents and consequences of robust and resilient SCs (Ambulkar *et al.*, 2015; Durach *et al.*, 2015; Hohenstein *et al.*, 2015; Golgeci and Ponomarov, 2013; Colicchia and Strozzi, 2012; Thun and Hoenig, 2011; Christopher and Peck, 2004). Despite the importance and intuitive association of both risk management capability and competitive advantage as competitive traits, this relationship has not been empirically addressed by existing studies. In addition, the relationships between SC innovation, risk management capability and competitive advantage have not been revealed in an integrative manner. Notably, the examination of this link would provide worthwhile insights that can uncover the Klein-Schmeink and Peisl (2013)'s conceptual proposition that SC innovation might cause risks but also bring about opportunities. Besides, although Ageron *et al.* (2013) presented innovative SC practices with an exploratory study, they called for further research of SC innovation consequences through the production of a more comprehensive framework.

To bridge this research gap, therefore, this study proposes a theoretical model to investigate how SC innovation may affect risk management capabilities and in turn how risk management capability may improve competitive advantage. Accordingly, this study attempts to answer two research questions: "Does SC innovation generate a positive impact on risk management capabilities?" and "Do risk management capabilities affect competitive advantage?" The research aims to contribute to providing new insights for managers in the

above associations, through a large-scale survey based study which provides empirical evidence that has been scarce in SC risk management field.

The next section reviews relevant literature, and proposes four research hypotheses. The third section outlines the research methodology applied in this research. The results of data analysis are shown in section four. Section five discusses theoretical and managerial implications before the final section displays limitations and suggests future research.

2. Theoretical background and hypotheses

This study aims to validate whether SC innovation has a positive influence on building risk management capabilities, and in turn on a firm's competitive advantage. The hypothesis model of this research was developed based on Grant's model (1991), considering the influences of resources (SC innovation) on capabilities (SC risk management capabilities) and, in turn, the impacts of capabilities on competitive advantage. This resource-based theory emphasises the useful resources and competencies of a firm as a main driver of competitive advantage (Barney, 1991). Firms' resources here do not just include tangible physical, monetary and human resources (Ansoff, 1965), but also encompass intangible organisational skills and knowledge as well as technical know-how (Hofer and Schendel, 1978). However, Grant (1991) underlined the distinction between resources and capabilities, arguing that resources build up firms' capabilities whilst capabilities are the direct sources of competitive advantage. The concept of capabilities has evolved to dynamic capabilities that can be defined as the ability to adapt to rapidly changing environments by integrating and re-designing internal and external competencies (Teece *et al.*, 1997), which share great similarities with robustness and resilience capabilities in SC research.

The research builds on a range of extant studies that have also empirically scrutinised the antecedents and consequences of risk management (Table I), although with a different focus

from this study. As for the antecedents, Bode *et al.* (2011) argued that SC disruption orientation, impact of SC disruption, dependence, trust and prior experience can affect the level of organisational responses to disruptions. More recently, Ambulkar *et al.* (2015) examined factors that affect development of firm resilience to supply chain disruptions. They assumed that various factors such as SC disruption orientation and resource reconfiguration are the key antecedents of firm resilience. When it comes to the consequences, researchers have used performance as the key variable, although measurement items were not consistent (Wieland and Wallenburg, 2012; Thun and Hoenig, 2011).

<insert Table I around here>

Despite the considerable number of studies which have examined the antecedents and consequences of SC risk management, its relationships with SC innovation and competitive advantage have not captured researchers' interests. In addition, although some studies such as Colicchia and Strozzi (2012) and Sheffi and Rice (2005) examined the link between risk management and competitive advantage, this link has not been empirically tested. Given this research gap, this section reviews the literature related to SC innovation, risk management capabilities and competitive advantage, and then develops a hypothesis model which can encapsulate the relationships between these constructs.

2.1 Supply chain innovation

Innovation is necessary for firms to respond to rapid changes in products and services as well as customer's demand and problems (Kim *et al.*, 2015; Christopher, 2005). Generally, innovation occurs within processes, technologies, services, strategies and organisational structures (Rogers, 2003). Specifically, SC innovation involves technology-improved

processes and procedures in the outbound SC as well as changes in product, process or service that either enhances efficiency or improves final customer's satisfaction (Seo *et al.*, 2014; Roy *et al.*, 2004). For instance, the competitiveness of logistics firms increasingly relies on their ability to adopt innovations that add value to the shippers' bottom line (Wagner, 2008). SC innovation emphasises the demands of the marketplace which can lead to an enhancement of value propositions for downstream customers (Flint *et al.*, 2009). Panayides and So (2005, p. 192-193) noted that "as supply chain parties become more innovative in terms of adopting new processes, operational routines and investing in new technological systems, supply chain effectiveness in terms of ability to fulfil what was promised, meet standards and solve problems will improve".

SC innovation is a multi-dimensional construct, which can be categorised into technology innovation and process innovation (Hazen *et al.*, 2012; Flint *et al.*, 2009; Paton and McLaughlin, 2008). The ability to manage technology and process innovation is becoming a critical capability for both the logistics department of manufacturers and logistics intermediaries (Lin, 2008).

Technology innovation aims to enhance the integrated information system, real-time tracking technology and innovative logistics equipment across global SCs. Technology innovation helps firms to heighten labour and capital productivity and offer real-time visibility regarding the flow of cargoes, information and sales data so that they can enhance inventory management and enlarge their value proposition for final customers (Christopher, 2005). For this reason, researchers have anticipated that the application of contemporary technologies, such as GPS, RFID and ERP, can effectively support risk management of SC (Ghadge *et al.*, 2012; Rao and Goldsby, 2009). Technology innovation also plays an important role in exploiting economies of scale in purchasing, logistics and central distribution centres

(Christopher, 2005), which can be a key means of differentiation in logistics services (Lin, 2008).

Although there are numerous technology innovations derived from technological advances, the greater efforts aimed at improving customer value result from process (service) innovation, such as developing more agile and responsive processes in the global SCs (Flint *et al.*, 2009; Paton and McLaughlin, 2008). Wagner (2008, p. 222) noted that "a process innovation is the implementation of new improved techniques, methods and procedures with the goal to continually improve the quality of a service or reduce the cost of providing a service". Process innovation is concerned with the effective re-design and re-engineering of the SC. By understanding how the SC transfers innovation as well as knowledge, meaningful process innovations and ultimate value for better services can be stimulated (Paton and McLaughlin, 2008). It focuses on operational issues and processes that enhance management practices, networking, distribution, procurement and so on (Chapman *et al.*, 2003).

2.2 Risk management capabilities (Robustness and Resilience)

A robust and resilient SC or logistics network is the ultimate goal of SC risk management (Colicchia and Strozzi, 2012) because it enables a firm to be sustainable even in the face of severe disruptions. Both robustness and resilience are thus often referred to as the capabilities to effectively deal with SC risks, but they have distinctive connotations (Spiegler *et al.*, 2012; Christopher and Peck, 2004). According to the distinctions by Asbjørnslett (2008), in essence, robustness is the capability to resist and sustain while resilience is the capability to adapt and retain.

Robustness in the SC setting is the ability to remain effective for all plausible future scenarios (Klibi *et al.*, 2010). Physical strength can best describe robustness (Christopher and Peck, 2004), which implies its capability to cope with errors and variability in SC management. SC

risk management studies emphasise solution robustness, which is the possession of the flexibility to leave many options to be decided under all plausible future scenarios (Klibi *et al.*, 2010). As robustness is closely related to standard SC design decisions, it is considered to be more suitable for reasonable variations (Christopher and Rutherford, 2004), regular fluctuations (Tang, 2006) or recurrent low-impact events (Klibi *et al.*, 2010) to sustain ordinary SC operations.

Resilience, on the other hand, is defined as "the ability of a system to return to its original state, or move to a new, more desirable state after being disturbed" (Christopher and Peck 2004, p. 2). In the SC context, it is an adaptive capability to prepare for, respond to and recover from unexpected events with connectedness and control (Ponomarov and Holcomb 2009). Researchers agree that resilience can be achieved by redundancy, flexibility, agility, responsiveness, visibility and collaboration (Ponomarov and Holcomb, 2009; Sheffi and Rice, 2005; Christopher and Peck, 2004). Contrary to robustness, resilient SCs are able to deal with unforeseeable events which can be characterised as low-probability but high-consequence (Pettit *et al.*, 2010).

According to Sheffi and Rice (2005), disruptions consist of, at one extreme, the mild initial impact stage to the other extreme of the severe full impact stage. To evaluate the magnitude of risk impacts within these stages, their approach considered both performance level and duration of disruptions. Robustness plays a pivotal role in the initial stage of a disruption because well-prepared logistics networks with risk awareness can minimise or even eliminate the regular risk occurrence (Tang, 2006). The variation from the normal performance level is also constrained because a robust SC can withstand and control disruptions at a tolerable level. Flexibility, anticipation with visibility, outsourcing quality control and collaborative risk preparation (Klibi *et al.*, 2010) all reduce the risk occurrence and risk impact, which in turn contribute to the robustness capability of a SC. In addition, robustness can buy time for a

firm to identify and implement the most effective risk mitigating measure by controlling the speed of the performance deterioration.

On the contrary, resilience is critical to the second stage because of its reactive nature to mitigate unexpected or subsequent risk events. As adaptability is the key in resilience (Ponomarov and Holcomb, 2009), this enables firms to re-engineer the processes (Christopher and Peck, 2004) by adequately responding to the new environment. Responsiveness also constitutes an important part of resilience because the speed of re-engineering is directly linked to the speed of recovery. As a consequence of adaptability and responsiveness, a resilient SC can quickly recover from disruptions to the normal performance level, or even to a more desirable level. In addition, resilience can reduce the magnitude of risk impacts by shrinking the duration of disruptions.

From this perspective on the distinctions between robustness and resilience, the former addresses the capability to proactively build a structure or a design, whereas the latter indicates the capability to survive, adapt, react and grow when facing disruptions, though reactively. Having these capabilities will change the capacity of the firm to operate successfully in international logistics over time and consequently the level of competitive advantage (Sheffi and Rice, 2005).

2.3 Competitive advantage

Competitive advantage refers to the extent to which a firm can generate a defensible position over its rivals (Porter, 1985). Porter (1985) put forward that firms are at two extremes, presented with a choice of pursuing either a cost leadership or a differentiation strategy to achieve competitive advantage. A differentiation strategy aims at gaining superior quality and image (even at considerable cost), whilst a low-cost strategy is concerned with lowering cost wherever possible (Yamin *et al.*, 1999).

There are many thrusts to improve competitive advantage such as cost, growth, reliability, quality, time-to-market, new production introduction, product line breadth, order fill rate, order/shipment information, increased customer service, efficient capital deployment, delivery dependability and flexibility (Li *et al.,* 2006; Tracey *et al.*, 1999). Stalk (1988) considered that accelerating the launch of new products or services and decreasing the time-to-market as a source of securing competitive advantage, and first-to-market products or services also obviously gain a competitive advantage. Oliva and Kallenberg (2003) argued that computer manufacturers such as IBM, GE and HP viewed service as a source of competitive advantage.

2.4 Hypotheses development

SC innovation, it would appear, should help the focal firm and SC partners to heighten risk management capabilities for more effective customer value creation. For example, innovative applications of integrated communication systems along the global SC can facilitate enhanced resilience and robustness capacity in terms of risk management (Waters, 2007), since they can offer opportunities for planning, monitoring, forecasting and replenishment, resulting in accurate, concrete and fast decision-making for emergent or important situations. As innovation often materialises in the form of technologically advanced infrastructure and equipment investments (Wagner, 2008), it may help to reshape effective risk management infrastructure or to reconfigure resource, improving resilience (Ambulkar *et al.*, 2015).

Of course, it should be noted that SC innovation can be a double-edged sword for the organisation's success. Having an innovative SC brings opportunities but it also contains the risk of creating uncertain practices. Innovative SCs using such applications might amplify the degree of accompanied complexity in the business and SC processes, causing uncertainties and difficulties in managing business and SC operations (Pettit *et al.*, 2010). Also, such a

higher level of innovative and complex processes makes it more difficult to recognise numerous types of risks that jeopardise the businesses and global SCs (Elahi, 2013). In this regard, the risk is often the price of innovation. Although SC innovation provides the firm with a foundation for better business performance, the very new adoption of SC innovation makes demand unpredictable, which results in unexpected fluctuation in logistics operations (Fisher, 1997). Therefore, it is imperative for managers to take a balanced approach to consider both the risks and opportunities of SC innovation. Taplin and Schymyck (2005) contended that risk managers should understand and grasp major risk scenarios from innovations and new technologies. In addition, because SC innovation needs changes of processes and rules in the SC, it takes a long time to implement and communicate along SC partners. The longer this takes the more riskiness increases which might hold back innovation endeavours (Cui *et al.*, 2012).

Nevertheless, a significant body of research contended that SC innovation plays a very important role in providing opportunities for fortifying the capabilities of the firm's risk management. The Aberdeen Group found through a survey of 180 global firms that using technology innovation and innovative processes such as information systems can augment risk management (Minahan, 2005). Haimowitz and Keyes (2002) claimed that a firm that has a risk management capability enhances its understanding of risk through innovation. Implementation of an innovative process can create an awareness of vulnerabilities and knowledge sharing with SC entities, which in turn enables a continuous process innovation to effectively reduce risk occurrence (Matook *et al.*, 2009). Therefore, the adoption of new technologies and innovative SC practices support more complex business processes in global SCs. In turn, the appropriate level of risk management capability helps firms to identify and mitigate the inherent risks of the complex processes.

SC innovation additionally plays a great role to enhance information channels and increase the breadth and speed of information sharing in order to improve service quality and risk management. Also, higher-accuracy and error-proofing SCs can be facilitated by innovation. As Klibi *et al.* (2010) argued, it is important for a firm to manage recurrent low-impact risk events as well as high-impact low-likelihood disruptions; this research suggested the robustness capability for the former and the resilience capability for the latter. When SC innovation is fully integrated as a resource, SC networks will be able to identify recurrent risk events and to effectively prepare for them, which fosters the robustness capability to minimise occurrence and impacts of risks. Likewise, the higher velocity and enhanced accuracy of information processing through SC innovation will lead SC networks to build the resilience capability based on adaptability, responsiveness and fast recovery.

Often, some firms develop risk management capability because their major suppliers and customers, as their SC partners, force them to adopt a certain level of formulaic risk management. It is well acknowledged that the strength of the SC is equivalent to its weakest point, so they would like to ensure that their SC is stronger than other competing SCs by maintaining a certain level of risk management capability. Therefore, if the level of SC innovation is very high by not only developing and diffusing knowledge, but also by closely collaborating amongst SC partners, they may advise and encourage each other to be involved in risk management capabilities development in order to prevent even one firm's disruption, which might have negatively affected the whole SC. With the aforementioned argument, it would be plausible that the level of risk management capability will be affected by the level of SC innovation. This leads to the first two hypotheses:

H1. Supply chain innovation has a positive influence on robustness capability.

H2. Supply chain innovation has a positive influence on resilience capability.

High level of environmental, technological and demand uncertainties have a substantial influence on the competitive position of firms, so different levels of risk management capacity pertaining to those uncertainties may confer different levels of competitive advantage. In other words, risk management in the SC forms a crucial capability which can lead to both cost reduction and differentiation to better compete in the volatile business environment (Colicchia and Strozzi, 2012). Therefore, senior managers have put more priority on setting their firms' strategies to secure adequate risk management capabilities. Proactive management of risks has become a competitive advantage through promoting a more strategic consideration of risk and its implementation to avoid unexpected SC disruptions (Henke, 2009).

Risk management capability might not yield an instant effect of competitive advantage in the short run, but it may emerge in the long run. Some firms still do not utilise their capability to manage risks as a source of competitive advantage, since they view risk management as a source of unnecessary costs (Elahi, 2013). Nonetheless, in practice, managers recognise that risk management is beneficial to reduce disruptions, lower costs, enhance added value and provide more reliable operations, enabling them to gain competitive advantage by controlling risk costs (Waters, 2007). The risk management capability encourages flexible operations that react quickly to changing conditions, so the firm that has the highest flexibility is likely to achieve and protect their competitive advantage.

Another viable explanation regarding the association of risk management capabilities and competitive advantage stems from competitive heterogeneity (Elahi, 2013), which is defined as the enduring and systematic performance differences amongst relatively close competitors (Hoopes *et al.*, 2003). Elahi (2013) argued that the different level of heterogeneity in access to risk management capabilities (resources) can serve as a source of competitive

heterogeneity. As we assume that the firm in this study is linked with multiple suppliers and customers in global SCs, by attempting to increase the level of SC innovation, their SC partners can notify the focal firm with a warning in regard to an evolving disruptive risk in advance of its occurring. This generates preparedness as a differentiation from its competitors (Elahi, 2013). Hence, the firm that deals well with disruptions by proper risk management capabilities can not only minimise both disruption costs and risk transfer costs (e.g. minimising safety inventory costs, delay-related costs and insurance costs), but also create opportunities for differentiating services (e.g. minimising the time of disruption and risk occurrence for reliable logistics operations) and reputation (e.g. attracting more potential customers and having more negotiating power due to an enhanced reputation). Ultimately, the firm can occupy an enlarged market share as a result of its competitive advantage.

H3. Robustness capability has a positive influence on competitive advantage.

H4. Resilience capability has a positive influence on competitive advantage.

3. Methodology

This study aims to validate a positive influence of SC innovation on risk management capabilities, and in turn on competitive advantage, by empirically analysing large-scale survey data by structural equation modelling. South Korea was selected for the survey due to its characteristics of rapid growth and success in the global market where it has notably benefitted from developing an expertise in modern technologies and processes (Lee *et al.*, 2016). According to Bloomberg (2016), Korea has the highest innovation index which aggregates various dimensions of innovative activities in 2015. This section explains how the constructs in the questionnaire were measured and how the survey data were collected.

3.1. Construct development

Measurement scales were developed for operationalising the constructs, as suggested by Churchill (1979). Most measures were derived from prior research that had validated the instruments, which provided confidence that they were reliable. Each construct was measured by adopting multiple items. All items were adapted to make them suitable for ensuring content validity based on in-depth interviews with senior managers in South Korea. This is because most items are employed from extant measurements that are used for developed countries such as from Europe or North America. Detailed items and references can be found in Appendix A. Since the items adopted from the extant studies were in English, three bilingual academics from the SC field reviewed the initial items and translated them into Korean so as to ensure conceptual equivalence.

The Q-sort method was employed to evaluate the appropriateness of construct validity. Three academics (who were not involved in the item translation noted above) and three practitioners were invited to undertake item placement ratios. All placement ratios of instruments within each target construct exceeded the suggested threshold of 70% (Hair *et al.*, 2009) (i.e. technology innovation=100%, process innovation=100%, robustness capability=95%, resilience capability=95%, and competitive advantage=100%). This ensured the adequacy of the constructs in capturing the pre-specified factor components of the constructs (Hair *et al.*, 2009). In addition, a pre-test was undertaken to examine the extent of applicability of the constructs five academics and nine senior managers from the logistics sector were asked to provide comments on the contents and wording of the survey. No further analysis was deemed to be required for item refinement, since the above multiple processes certified content validity.

The model incorporates industry types and firm size (number of employees) as control variables that possibly affect competitive advantage. Industry types were categorised into: (1)

finished goods manufacturers, (2) half-finished goods manufacturers, (3) raw material exporters/importers, (4) trading companies, (5) third-party logistics provider, (6) international freight forwarder, and (7) others as a dummy variable. It was assumed that different industry types may have varied impacts on competitive advantage. In addition, ceteris paribus, the larger firms may be likely to better combine internal resources for higher competitive advantage. Therefore, industry types and firm size were included in the model as control variables when the main SEM analysis was conducted.

The survey questionnaires employed a seven-point Likert scales to measure the perceptions of respondents, instead of a five-point scale, to reduce attenuation problems caused by range restriction (Oh and Rhee, 2008). The end points were labelled 'strongly disagree' to 'strongly agree' while the mid-point was labelled 'neither agree nor disagree'.

3.2. Data collection

Data were collected from 174 manufacturers and logistics intermediaries in South Korea which were actively engaged in global SC management. Questionnaires were distributed to global logistics or supply chain management (SCM) experts in the companies, who were expected to possess the best knowledge regarding the overall operations and management of the SC and performance of their firm. Higher levels of managers were selected as key respondents. Mailing lists were obtained from five sources: KILA (Korea Integrated Logistics Association), KOIMA (Korea Importers Association), KORCHAM (Korea Chamber of Commerce), KIFFA (Korea International Freight Forwarder Association) and the Korea Shipping Gazette.

The final online version (web-based) of the questionnaire was administrated to 1224 target respondents in two waves accompanied by a cover letter and statement of study purpose. The 174 complete responses received have yielded a response rate of 14.2%. In order to check for non-response bias, this study adopted two approaches (Sanders and Premus, 2005; Lambert

and Harrington, 1990; Armstrong and Overton, 1977). Firstly, non-response bias was checked by reviewing if there was a significant difference between the early (41) and late (40) responses as suggested by Armstrong and Overton (1977). The result of the t-test showed no significant difference at a p<0.05 along the six demographic variables and 18 measurement items, implying that non-response bias was unlikely in this study. Secondly, the difference between respondents and non-respondents was calculated for demographic variables such as the number of employees and annual sales. T-test showed no statistical differences in the sample and population at 99% confidence interval. Hence, the above results suggested that non-response bias was unlikely to have occurred in this study (Sanders and Premus, 2005; Lambert and Harrington, 1990; Armstrong and Overton 1977). The profile of respondents is summarised in Table II.

In addition, the common method variance test was undertaken, since just one response per organisation on self-reporting was collected (Podsakoff *et al.*, 2003). Firstly, Harman's single factor model was applied by employing confirmatory factor analysis (CFA). The model fit indices of χ^2=1203.386, df=135, normed χ^2=8.914, TLI=0.646, CFI=0.688, IFI=0.689, PNFI=0.585, SRMR=0.106, RMSEA=0.214 were unsatisfactory compared to the measurement model. Secondly, we compared the measurement model with the theoretically derived factor structures for measurement items that include four latent variables. The chi-square difference ($\Delta\chi^2$=947.433) between the four factor model and null model (single factor) was significant at 99.9% level. Thus, the common method variance test did not detect any issues of concern in this research.

<insert Table II around here>

3.3. Data analysis methods

Prior to the structural path model, CFA using AMOS 21.00 was undertaken to verify the measurement model by a two-step approach, as suggested by Anderson and Gerbing (1988). CFA aims to demonstrate an acceptable fit to the data collected. The goodness-of-fit-indices are assessed by normed χ^2<5 (Marsh and Hocevar, 1985), SRMR<0.01 (Hair *et al.*, 2009), TLI, CFI, IFI>0.9 (Hair *et al.*, 2009), and PNFI>0.5 (Finger *et al.*, 2014). RMSEA values range from 0 to 1, with smaller values indicating better models; values below 0.05 signify a good fit (Hair *et al.*, 2009). Reliability is evaluated by Cronbach's alpha and composite reliability (CR). All measures exceeded the minimum values of 0.6 (Hair *et al.*, 2009), whilst all composite reliability (CR) of constructs were greater than threshold of 0.6 (Hair *et al.*, 2009). Content validity was ensured through rigorous literature review, in-depth interviews, Q-sort and the pre-test. Additionally, convergent and discriminant validity were evaluated by using various stringent methods through CFA detailed in the next reported section.

4. Results and analyses

4.1. Measurement models

Reliability refers to the degree to which a measure scale is free from error and therefore yields consistent results (Hair *et al.*, 2009). Reliability was well certified because Cronbach's alpha and CR of the constructs exceeded 0.6. Validity is defined as the degree to which a measurement scale truly measures the construct that it was supposed to measure (Hair *et al.*, 2009). The fit-of indices of χ^2(315.802)/df (129)=2.448, TLI=0.935, CFI=0.945, IFI=0.946, PNFI=0.754, SRMR=0.041, RMSEA=0.091 suggested that the measurement model was satisfactory with good unidimensionality. Although the p-value of chi-square omnibus test was less than 0.05, it may be attributed to the relatively small sample size, which causes statistical difficulties with the inflation of some fit indices (Hair *et al.*, 2009). All these values were satisfactory based on the threshold in section 3.3.

All standardised factor loadings to corresponding constructs were over 0.5 (t-value>2.0), which were statistically significant at p<0.001 (Hair *et al.*, 2009). Moreover, each coefficient of all items was greater than twice of its standard error (Anderson and Gerbing, 1988), whilst all constructs of average variance extracted (AVE) exceeded 0.5 (Fornell and Larcker, 1981). All R^2 also were greater than 0.3 (Hair *et al.*, 2009). These results provide evidence of strong convergent validity.

<insert Table III around here>

Table IV shows that the squared root of AVEs were greater than each possible pairwise correlation between constructs (Fornell and Larcker, 1981). Further, all AVEs of constructs exceeded 0.5 (Fornell and Larcker, 1981). Finally, all correlations between constructs were less than 0.90 (Fornell and Larcker, 1981). These results added credence to evidence of discriminant validity.

<insert Table IV around here>

4.2. Structural model

Figure 1 displays a structural path. Overall, the proposed model generally has a satisfactory fit with χ^2(484.820)/df(163)=2.975, CFI=0.908, IFI=0.908, PNFI=0.745, SRMR=0.099, except for TLI=0.892 and RMSEA=0.107 which marginally exceeded the threshold. It should be noted that the p-value associated with the null hypothesis of a close fit was less than 0.05. However, this does not seriously harm the model fit, because it may have been derived from the small sample size (Hair *et al.*, 2009). The two control variables: industry type (p-

value=0.475, γ=0.038) and firm size in terms of number of employees (p-value=0.235, γ=0.059) had no significant effects on the competitive advantage.

The results supported H1, which argues that the level of SC innovation has a positive impact on robustness capability, showing a significant standardised coefficient (γ=0.773, p<0.001). H2 was also supported, indicating that SC innovation has a direct influence on resilience capability. The standardised coefficient was 0.644, which is statistically significant at a 0.001 level. The result also showed that higher degrees of robustness capability may result in enhanced competitive advantage, which accepts H3 (γ=0.289, p<0.001). Finally, H4 was also accepted by indicating the significant standardised coefficient (γ=0.586, p<0.001), which implied that the level of competitive advantage is directly determined by the level of resilience capability.

<insert Figure 1 around here>

5. Discussion and conclusion

This study contributes to providing an understanding of the potential for the strategic retention of SC innovation and risk management capabilities in the global logistics and SCM fields, because scant empirical research has examined the role of SC innovation and risk management capabilities as a strategic source and capability in the global logistics context. As such, this study may reply to Hazen *et al.* (2012) and Ageron *et al* (2013)'s echoes that how adopted SC innovation provides organisations with benefits is rather empirically unknown.

Further, this work contributes to the efficacy in augmenting competitive advantage through SC innovation and risk management capability so that it expands a theoretical foundation and existing body of knowledge for SCM and global logistics. Therefore, this work provides

compelling evidence for the importance of SC innovation and risk management capability in supporting competitive advantage. This finding is consistent with the resource-based theory (as well as Grant's model) as the possession of the capability relates well to competitive advantage (Teece *et al.*, 1997; Grant, 1991). Organisations occupying positions of competitive advantage can sustain such positions by being proactively involved in SC innovation to make sure that their resources are comparatively better than those of rivals (Grawe, 2009). In turn, risk management capabilities can built up by SC innovation, resulting in higher level of competitive advantage, as Grant (1991) put forward.

The most significant implication of this research is that SC innovation has a discernible influence on all dimensions of risk management capability. Innovation may be considered as a driver of risks, particularly when innovation is viewed as a 'revolutionary' intervention to SCs, because it may generate uncertainties and a temporary drop of performance. However, it is known that organisations gradually adapt themselves to the innovation by incorporating their internal resource responses, and eventually perform or even outperform the previous level of achievement by building risk management capabilities. The null hypothesis of this study was that SC innovation has no or a negative influence on risk management capabilities, but this was rejected by the SEM result. This finding is in line with Kern *et al.* (2012), which showed continuous improvement process has positive impacts on a firm's risk management comprising of risk identification, risk assessment and risk mitigation. This implies SC innovation, from an evolutionary perspective, cannot just increase the level of performance but that it also enhances risk management capabilities.

Another theoretical contribution of this study is to address the question, "to what extent does SC innovation lead to robustness and resilience capabilities?" Examining SC innovation in the context of SC risk management has received little attention. To some extent, the dominant role of SC innovation on risk management capability is surprising, given that few empirical

studies have examined this relationship. In this sense, the study moves beyond the conceptual framework of Roy *et al.* (2004), who focused chiefly on innovation generation in the SC. Although they viewed SC innovation as a consequence of interactions between SC partners, they overlooked the consequences of SC innovation. Moreover, although Golgeci and Ponomarov (2013) investigated the impact of innovativeness at the firm level on SC resilience, this research expands their model by examining the influence of innovation along the SC on risk management capabilities with more of an emphasis on global logistics operations. This research finds that an organisation that has stronger SC innovation has a higher level of risk management capability. The finding is consistent with prior studies (Haimowitz and Keyes, 2002) that argued that risk management capability can be enriched by the adoption of new technologies and innovative SC practices along the global SC. This finding is also in support of Grant's model, which argues that building competitive advantage is determined by the capabilities to secure risk management (Christopher and Peck, 2004; Grant, 1991).

Most prior research on SC innovation and SC risk management was conducted in developed countries such as Europe and North America, whereas this work would be one of the first attempts to explore them in South Korea, the earliest technology and innovation adopter in the world (Bloomberg, 2016). South Korea has experienced a rapid economic growth with a fast follower strategy since 1970s, which often led to massive volume of international trade without concerns about capability building for robust and resilient SCs. In this circumstance, process innovation plays a role to eliminate unclear procedures and to devise an agile and responsive system which integrates information from global SCs. In a similar vein, technology innovation can increase the volume and speed of information processing, which enables firms to analyse disruptions and adequately respond to them.

There will be several managerial implications to be derived from our findings. The results imply that innovative logistics operations along the global SC are an enhancer of risk management capability, which can justify the investment into SC innovation for continuous improvement. The logistics department of manufacturers and logistics intermediaries should, therefore, focus more on developing innovative ways to develop global SC practice (e.g. the deployment of the latest information system, RFID, PDA, continuous innovation and agile and responsive logistics processes) to improve risk management capability. This is consistent with Chapman *et al.*'s (2003) suggestion that innovation in logistics can be improved through the adoption of the latest technology and ICT developments. To boost SC innovation, logistics managers should not only cultivate an innovative working atmosphere, but also offer proper resources to support efficient logistics operations with the greatest level of efficiency. Additionally, managers tend to acknowledge that employees who just have past experience and knowledge are no longer suitable, given that dependence on SC innovation arises from the incredible changes in global logistics practices in the SC. Therefore, they should strive to deploy employees with the latest innovative knowledge or provide them with a proper training to bring existing employees up to date with new developments in practice. As the value of SC innovation can be enriched from being a learning organisations, managers should encourage employees and employee's teams to study and absorb new and innovative ways of operations. Also, firms should try to seek and acquire adequate information and knowledge through effective diffusion along the global SC. Although it is almost impossible for firms that are involved in global logistics to escape SC risks, deploying appropriate innovative SC strategies may be an effective solution to SC risk and disruptions.

The model in this research suggests that SC innovation is a fundamental source of a firm's robustness capability. With a high level of SC innovation, the senior managers may legitimise their efforts in maintaining robustness capability. The empirical result also found that a firm

and SC partners that have SC innovation are more likely to concern themselves with forming a proper degree of resilience capability, which is consistent with Christopher's (2005) claim. Therefore, logistics or SC managers should be consciously aware of the importance of a high degree of SC innovation and develop it so as to remain resilient in case of the disruptive SC occurrence. Additionally, they should strive to quickly become aware of any possible disruption and rapidly and accurately deploy pre-prepared emergency manuals during these periods. An ultimate goal of SC strategies is, therefore, to foster the robustness and resilience capabilities within the logistics network. The implication of the findings is that firms are required to put more effort into building robustness capability in managing SC uncertainties.

The finding indicated that competitive advantage is not only determined by robustness capability ($\gamma=0.289$), but also by the effort of building resilience capability ($\gamma=0.586$). In other words, both the risk management capabilities are strong determinants of competitive advantage. This link between SC risk management and competitive advantage has not been empirically addressed at this level of granularity previously, although many academics have argued that risk management can be a new source of competitive advantage (Elahi, 2013; Colicchia and Strozzi, 2012; Waters, 2007). It advocates that when both robustness and resilience capabilities are embedded in an integrated way in the global logistics operational processes these are effective in augmenting competitive advantage. Recent trends show that global logistics service providers view risk management capability as something that can be managed to enhance customer values and to diminish the cost of unexpected logistics disruptions. In particular, Panalpina and Expeditors explicitly advertise their cargo security solution and risk management capacity as being among their core service provision capabilities. Hence, global logistics managers should differentiate their firms from rivals by retaining both stronger robustness and resilience capabilities so that they are able to provide more customer values and grow faster in more complex global logistics markets. As Elahi

(2013) pointed out, if a firm takes a better defensive position towards disruption or risks, the defence automatically turns into an offence (differentiator) to the competitors. Additionally, they should develop, establish and internalise some qualities including flexibility, agility, responsiveness, visibility and collaboration in their operations, structure and culture, which may positively influence the level of robustness and resilience capabilities in more sustainable ways (Sheffi and Rice, 2005). By enhancing robustness and resilience capacities, the logistics intermediaries not only reap greater reputation and negotiation power, but also lessen risk transfer costs as a source of competitive advantage. These results are in line with previous studies' arguments that undertaking proactive risk management capability has become a vital means of enhancing competitive advantage (Elahi, 2013; Colicchia and Strozzi, 2012; Henke, 2009; Waters, 2007).

6. Limitations and future research

Although this work contributes to insights for academics and practitioners, there are limitations that can be addressed in future research. This work did not use objective data to measure a firm's competitive advantage, but employed the respondents' perceptions of their competitive advantage. Although these two sources may be highly correlated, it would be an option to blend in objective data for future studies. In addition, cross-sectional data was relied upon to test the theoretical model. However, the impact of risk management capability on competitive advantage might take a long time, in reality, to become apparent. Hence, future research may consider testing this model by adopting a longitudinal study. Data were collected from a single country, South Korea, so future studies could compare multiple countries to increase the generalisation of this finding.

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Figure 1. Structural model results
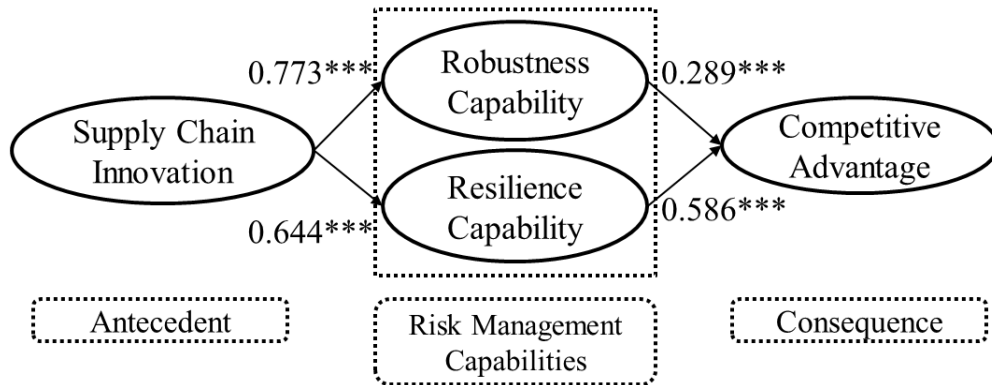
***p<0.001.

Table I. Antecedents and consequences of SC risk management

Categories	Research	Constructs
Antecedents	Manuj and Mentzer (2008)	Temporal focus, SC flexibility, SC environment, SC complexity
	Braunscheidel and Suresh (2009)	Market orientation, Learning orientation Internal integration, External integration, External flexibility
	Skipper and Hanna (2009)	Top management support, Resource alignment, Information technology usage
	Bode et al. (2011)	SC disruption orientation, Impact of SC disruption, Dependence, Trust, Prior Experience
	Ambulkar et al. (2015)	SC disruption orientation, Resource reconfiguration
Consequences	Zsidisin and Wagner (2010)	Resiliency practice, Disruption occurrence
	Thun and Hoenig (2011)	Preventive/Reactive SCRM, Performance
	Cheng et al. (2012)	Relationship development, Performance improvement
	Wieland and Wallenburg (2012)	Customer value, Business performance

Table II. The profile of respondents (N=174)

Sales in 2013	Frequency	%	Number of staff	Frequency	%
Less than $100M	57	32.8%	Less than 25	41	23.6%
$100M - $499M	45	25.9%	25 – 100	56	32.2%
$500M - $999M	58	33.3%	101 – 300	27	15.5%
More than $1B	14	8.0%	301 – 1000	24	13.8%
			1001 – 5000	15	8.6%
			More than 5000	11	6.3%
Total	174	100%	Total	174	100%
Position	Frequency	%	Logistics Career	Frequency	%
CEO/President	16	9.2%	More than 20 years	21	12.1%
Executive/Director	13	7.5%	16 – 19 years	13	7.5%
Senior Manager	44	25.3%	12 – 15 years	24	13.8%
Manager	79	45.4%	8 – 11 years	39	22.4%
Operator	22	12.6%	4 – 7 years	49	28.1%
			Less than 4 years	28	16.1%
Total	174	100%	Total	174	100%

Table III. Reliability and Validity

Variables	Items	Standardised loading	Mean	Reliability and validity
Supply	SCI1	0.801***	4.098	α=0.924
Chain	SCI2	0.685***	3.724	CR=0.924
Innovation	SCI3	0.716***	3.891	AVE=0.672
(SCI)	SCI4	0.913***	4.236	
	SCI5	0.906***	4.241	
	SCI6	0.868[1]	4.155	
Robustness	RB1	0.861***	4.954	α=0.920
Capability	RB2	0.904***	4.632	CR=0.921
(RB)	RB3	0.852[1]	4.937	AVE=0.745
	RB4	0.834***	4.713	
Resilience	RS1	0.880***	4.799	α=0.943
Capability	RS2	0.938[1]	5.000	CR=0.944
(RS)	RS3	0.896***	4.874	AVE=0.809
	RS4	0.882***	4.971	
Competitive	CA1	0.954***	4.943	α=0.962
Advantage	CA2	0.972[1]	4.874	CR=0.963
(CA)	CA3	0.897***	4.747	AVE=0.866
	CA4	0.898***	4.776	

Note: ***$p<0.001$; [1]Initially fixed at 1.0

Table IV. Mean, standard deviation, squared root of AVEs and correlations of constructs

	Mean	Standard Deviation	SCI	RB	RS	CA
SCI	4.06	1.44	0.820			
RB	4.80	1.24	0.739***	0.863		
RS	4.91	1.23	0.595***	0.849***	0.899	
CA	4.83	1.32	0.672***	0.793***	0.744***	0.931

Note: ***p<0.001, Squared root of AVE is on the diagonal; SCI: supply chain innovation; RB: robustness capability; RS: resilience capability; CA: competitive advantage

Appendix A. Variables and measurement items

Variables	Measurement Items	References
Supply Chain Innovation (SCI)	*We pursue…* (SCI1) a cutting-edge system that can integrate information. (SCI2) technology for the real-time tracking. (SCI3) innovative vehicles, packages or other physical assets. (SCI4) continuous innovation in core global supply chain processes. (SCI5) agile and responsive processes against changes. (SCI6) creative methods and/or service.	Seo *et al.*, 2014; Lee *et al.*, 2011; Wagner, 2008; Flint *et al.*, 2008; Paton and McLaughlin, 2008; Bello *at al.*, 2004; Roger, 2003
Robustness Capability (RB)	*Our logistics network is able to …* (RB1) remain effective and sustain even when internal/external disruptions occur. (RB2) avoid or minimize risk occurrence by anticipating and preparing for them. (RB3) absorb a significant level of negative impacts from recurrent risks. (RB4) have sufficient time to consider most effective reactions.	Wieland and Wallenburg, 2012; Colicchia and Strozzi, 2012; Klibi *et al.*, 2010; Asbjørnslett, 2008, Christopher and Peck, 2004;
Resilience Capability (RS)	*Our logistics network is able to …* (RS1) adapt to the disruptive situations by quickly re-engineering logistics processes. (RS2) promptly and adequately respond to logistics disruptions. (RS3) quickly recover to the previous performance level or to a more desirable level. (RS4) reduce the extent of negative impacts by quick responses.	Golgeci and Ponomarov, 2013; Petit *et al.*, 2010; Ponomarov and Holcomb, 2009; Sheffi and Rice, 2005; Christopher and Peck, 2004;
Competitive Advantage (CA)	*Our logistics network has …* (CA1) competitive advantage in the efficient logistics operations. (CA2) competitive advantage in the effective logistics operations. (CA3) competitive advantage in differentiating our logistics operations. (CA4) competitive advantage in the reputation of our excellent logistics operations.	Li *et al.*, 2006; Yamin *et al.*, 1999; Tracey *et al.*, 1999; Stalk, 1988