ESSAYS ON SAFETY AND SECURITY ISSUES IN SHIPPING AND TRANSPORT LOGISTICS

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Essays on Safety and Security Issues in Shipping and Transport Logistics

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CERTIFICATE OF ORIGINALITY

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_____(Signed)

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Abstract

Managing safety and security is critical for socially responsible operations in a globalized supply chain. Stakeholders have become increasingly concerned about safety and security issues in shipping and transport logistics operations. Faced with safety and security risks inherent in global supply chain management, organizations must understand the effectiveness of logistics security practices and their performance contingencies that may influence the effectiveness of such practices. Also, organizations need to take a multi-level approach to examine whether their internal and national contexts would affect accident performance in global operations.

The major goal of this thesis is two-fold: To understand (1) the impacts of logistics security certification on adopter firm's operational performance and the contingency factors in affecting such impacts, and (2) the role of external context in the relationship between organization's internal context and safety accident likelihood. To this end, I conduct this research grounded in related organizational theories to empirically address the above issues through three independent but interrelated essays. Specifically, the first study (Essay 1) helps identify the research gaps in the existing literature on supply chain security. The second study (Essay 2) fills one of the research gaps identified in study 1 by exploring the performance impact of a well-recognized logistics security certification (i.e., Customs-Trade Partnership Against Terrorism) and incorporating supply chain contingencies. The third study (Essay 3) investigates the role of national context in the relationship between organization's internal context and safety accident performance.

Publications Arising from the Thesis

1) Xun Tong*, Kevin Linderman, Kee-hung Lai, Chris K.Y. Lo, and T.C.E Cheng. Managing safety in global operations: The effect of national culture, 2017. Plan to submit to *Transportation Research: Part E*.

2) Xun Tong*, Kee-hung Lai, Chris K.Y. Lo, and T.C.E Cheng., 2017. Signaling benefits of C-TPAT certification: Operational performance and upstream supply chain complexity. Plan to submit to *Journal of Supply Chain Management*.

3) Xun Tong*, Chris K.Y. Lo, Kee-hung Lai, and T.C.E Cheng. Security issues in supply chain management: A citation network analysis, 2017. Under the second round review at *Computer & Operations Research*.

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Chapter 1. Introduction

1.1. Research Background and Motivation

> "*The bombings of two shipping and transportation hubs in Brussels are evidence that securing global supply chains is still integral to safeguarding the lives of people around the world and maintaining the stability of the global economy*." - "Heightened Supply Chain Security in the Shadow of Risk", *Sourcing Journal*. (2016)

> "*…just one container that is overloaded, poorly packed, with its contents unevenly distributed or badly secured, or improperly declared, can have serious repercussions. This may include loss or damage of cargo, injury or even death to members of the public or workers in the supply chain (who have had no control in the packing process), and even damage and loss of ships at sea or in port*."- *International Maritime Organization* (IMO), Speech by IMO Secretary-General Kitack Lim (2017)

The two news articles cited above highlight the importance and urgency of managing security and safety in shipping and transport logistics operations. In the past decades, numerous security and safety incidents occurred worldwide to cause financial losses to firms and threaten public safety and human health. For example, according to the *CargoNet*, there were 1,614 cargo thefts in U.S. and Canada alone, resulting in approximately 172.9 million USD. In promoting a responsible supply chain, regulatory agencies and supply chain partners should take corporate social responsibility (CSR) practices into account in managing shipping and transport logistics operations (Park-Poaps and Rees 2010). CSR is defined as "*context-specific organizational actions and policies that take into account stakeholders' expectations and the triple bottom line of economic, social, and environmental performance*."

(Aguinis 2011, p 855). From a broader perspective, managing safety and security issues is an essential element of CSR commitment because supply chain partners are expected to mitigate risks arising from potential safety incidents due to the mindlessness of organizational members or deliberate attacks by external agents such as terrorists. Similarly, security management is also a critical part of supply chain responsibility. For instance, the Worldwide Responsible Accredited Production (WRAP) which emphasizes "legal compliance including import/export and customs compliance and security standards" (*WRAP's 12 Principles*), has attracted attention for buyers and suppliers firms in the apparel, footwear, and sewn products sectors. As a result, managing safety and security issues in supply chains fall into an essential part of promoting CSR in supply chains.

Supply chain risk management concerns about risk identification, assessment, reduction, and prevention in supply chain operations (Wilding et al. 2012) while security and safety are two major components of managing the risks in shipping and transport logistics. "*Safety*" and "*security*" are sometimes used interchangeably in the literature (Marucheck et al. 2011, Speier et al. 2011). According to *Merriam-Webster* dictionary, *safety* and *security* have very similar but nuanced definitions. That is, *safety* is defined as "*the condition of being free from harm or risk*", while *security* refers to "*the quality or state of being free from danger*". However, an additional definition of *security* meaning "*measures taken to guard against espionage or sabotage, crime, attack, or escape*" is more generally used when referred to supply chain security (Control, Mar 25, 2010). To better contextualize the use of the two terminologies in this thesis, they are distinguished as follows. *Safety* management is more concerned about reducing the potential risks of accidents in operations, while *security*

management emphasizes the protection against deliberate attacks in logistics flows. This distinction is in line with recent studies (e.g., Closs 2008, Pagell et al. 2005).

In recent years, supply chain partners implement various initiatives to improve the security performance within and across their extended supply chains under the threats of possible attacks by external agents. For example, the U.S. Customs and Boarder Protection (CBP) developed a logistics security program called Customs-Trade Partnership Against Terrorism (C-TPAT) to help supply chain partners (e.g., importers, transport carriers, etc.) enhance security performance within organizations and across supply chains.

Safety accidents frequently occurred in industry sectors, causing significant damages to firm's reputation and adverse effects to the entire supply chain. For example, in 2013, the garment buildings in Bangladesh collapsed, resulting in more than 1,000 deaths. Post investigation revealed that this tragic accident was attributable to the weak safety awareness among managers and building constructers. That is, some buildings were illegally conversed from commercial use to industry use, additional floors were constructed above the original permit, etc.

Among various risks inherent in different parts of global supply chains, this thesis focuses on the shipping and logistics operations in supply chains to study security and safety issues. Figure 1-1 illustrates the research scope, context, and contributions of this thesis, showing that security and safety issues in logistics and

shipping operations is a sub-area of corporate social responsibility study in supply chain management.

The three independent but interrelated studies (essays) are connected as follows. Essay 1 provides an objective clustering of existing supply chain security research, which helps grasp recent research trends and identify research gaps in this area. Accordingly, Essay 2 targets several research gaps identified in Essay 1 (e.g., data collection in previous studies are subject to selection bias, and the underlying mechanism that facilitates security practice adopters to improve effectiveness is largely under-explored) to further examine the effectiveness of C-TPAT certification and how supply chain complexity affects such effectiveness from a signaling theory perspective. In parallel with Essay 2, Essay 3 investigates another critical issue in shipping and transport logistics: safety and organization's internal and national contexts. Collectively, the three essays provide a holistic perspective on the most critical issues in shipping and transport logistics with a socially responsible concern.

The context of the thesis is the *global* shipping and transport logistics operations and therefore this thesis intends to make contributions to the broader supply chain and operations management disciplines. The relevance and importance of this research topic pertain to that shipping and transport logistics operations play a critical role in ensuring a smooth cargo flow where security and safety risks can be effectively mitigated. More importantly, shipping and transport logistics operations involve multiple critical players in a globalized supply chain. As a result, the impact of security practice implementation and safety accident can offer important theoretical and

managerial implications to scholars and practitioners in international shipping and transport logistics.

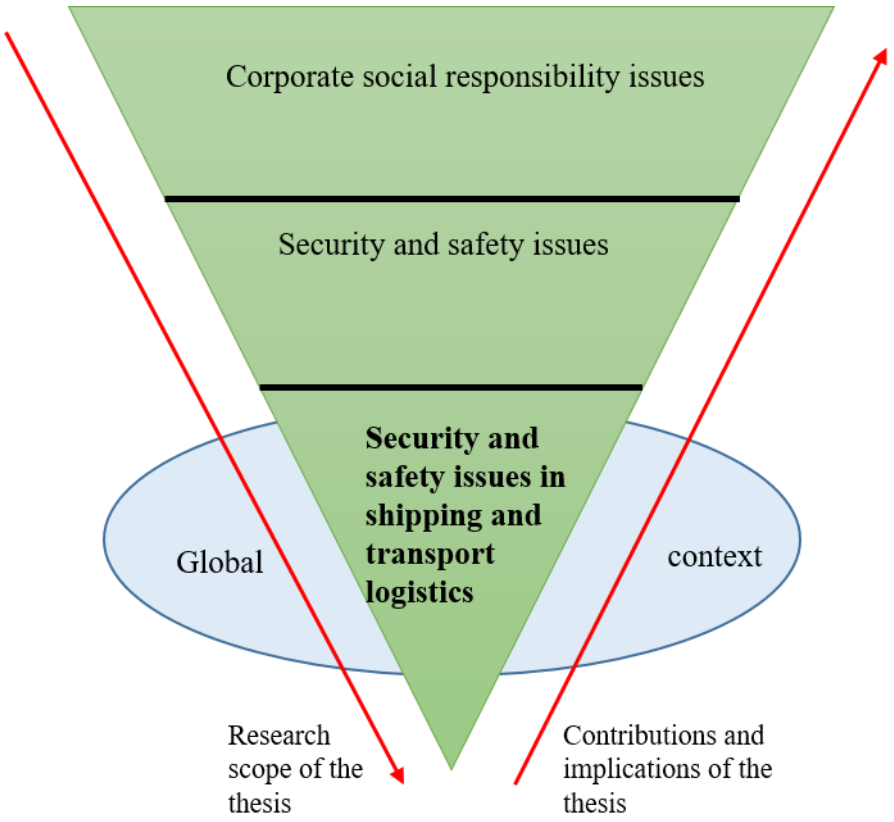

Figure 1-1. The Scope, Context, and Contribution of the Thesis

1.2. Research Objective

The objective of this thesis is to better understand the logistics security certification implementation and safety incidents on the operational and accident performance in the context of shipping and transport logistics. To achieve this objective, it is important to first acknowledge the study trends and gaps in the related

literature. As a result, in Essay 1, I use an objective clustering algorithm, namely Citation Network Analysis (CNA) to identify research clusters under a specific research theme and further employ Main Path Analysis (MPA) to identify critical articles in each research cluster.

The results of CNA and MPA help identify research gaps in SCS studies, motivating the research questions in Essay 2. That is, increasingly, supply chain partners adopt C-TPAT certification to secure legitimacy and convey their commitments to SCS management to stakeholders. However, the operational impact of adopting C-TPAT certification is inconclusive in the literature. To articulate the effects of C-TPAT certification on adopter firms' operational performance and how importer firms' upstream supply chain complexity influences the benefits of C-TAPT adoption, I focus on the U.S. publicly-traded importer adopters and investigate the operational performance of adopter firms from a signaling theory perspective. The contingency factors (upstream supply chain complexity) are considered because the C-TPAT certification focuses on streamlining cargo flow in firms' upstream supply chain (e.g., importing activities)

Maritime shipping is an international industry which has a long history of tracking ship incidents. Ship incidents can cause financial losses to stakeholders (e.g., ship collision) or threaten worker safety (e.g., fire on ship). Prior research suggests that organization's internal context can impact safety performance (see Tinsley et al. 2011, Vaughn 1996). In addition, as organizations need to manage safety across different contextual settings in the global economy, I study how national context may influence

the internal context and accident. Accordingly, in Essay 3, I investigate how ships' internal safety context affects accident likelihood and how national context would moderate such relationship based on a multi-level analysis.

Collectively, my thesis focuses on the safety and security issues in shipping and logistics operations by exploring the following central research query.

Central Research Question: *What are the impacts of security certification adoption and the internal safety context on the operational and accident performance in shipping and logistics transport operations? How do supply chain complexity and national context (and other contingency factors) moderate such impact?*

The above central research query is addressed by investigating the following individual research questions in each essay. That is, three specific research objectives are listed below (in Section 1.3.) to guide the three individual essays.

1.3. Research Design

To adequately answer the above central research query, I divide it into several small research questions formulated within each research context of this thesis. Specifically, I examine three questions (listed below) by arranging my thesis in three individual essays.

1.3.1. Chapter 2-Essay 1

In Chapter 1, I use a CNA and a MPA to study the research trends and knowledge structures in SCS literature. Because the global supply chain encounters various

security risks such as importation of illegal drugs and terroristic attacks to transportation hubs. Scholars and practitioners have begun to pay attention to security issues within organization's operations and across their extended supply chains. In particular, since the 9/11 incident, the international trade communities and national security regulatory agencies have tightened up the standards for security scrutiny. Scholars have conducted various studies in this area. To better grasp the trends and research gaps in SCS literature, which is a relatively new research area in operations and supply chain management, I use CNA to achieve the intended research goals by answering the following research question.

What is the knowledge structure and content of existing SCS studies?

I collect data (sample research articles) from the *Web of Science* (WOS) database by searching for relevant keywords and use software to conduct CNA and MPA on the 143 sample SCS articles. Based on the *Louvain* algorithm, I identify four research clusters (research domains) in SCS literature and they show knowledge transformation in SCS chronically. The four research clusters are (1) *SCS Conceptualization and Application*, (2) *Security Management Systems*, (3) *Transportation Security*, and (4) *Terrorism*. I then sketch the knowledge structure in each research cluster and identify the critical articles by the traversal weight values (De Nooy et al. 2011) through MPA. Articles in the main path of each research cluster help summarize critical research findings and knowledge structures. Moreover, based on the main path in each cluster, I identify research gaps and recommend future research directions in each research cluster (research area).

In addition, I provide a systematic framework comprising antecedent for SCS practice adoption, the mechanisms for managing SCS, and performance outcomes of SCS adoption. The suggested framework integrates the identified research clusters and main path articles to facilitate knowledge development in SCS management. As I find that numerous conceptual work in SCS management used organizational theory to explain phenomena observed in managing SCS, I also review the organizational theories that have been applied to study SCS issues and suggest possible organizational theories that can be used in future SCS studies.

1.3.2. Chapter 3-Essay 2

In Chapter 3, I draw upon signaling theory to investigate the financial impact of a specific logistics security certification (Customs-Trade Partnership Against Terrorism, C-TPAT) adoption, which intends to fulfill a research gap identified in Essay 1. That is, few prior study used secondary longitudinal data to quantify the possible benefits from transport logistics certification adoption. I collect news announcement of C-TPAT adoption from Factiva online newspaper and periodicals database. Importing data of the sample firms are collected from the U.S. CBP and firms' financial data is from the Standard & Poor' COMPUSTAT database in Wharton Research Data Services (WRDS). I focus on U.S. publicly-traded importer firms because the C-TPAT emphasizes importing security in U.S. boarders and public firms can provide reliable financial data, which can be used to construct various variables for testing the hypotheses. This Chapter addresses the following research question.

Does C-TPAT certification adoption improve importer firms' operational performance? If so, how would the level of upstream complexity (detail, dynamic, and spatial complexity) influence the singling benefit from C-TPAT certification?

To address the above research question, I use signaling theory perspective to predict that adopter firms could create competitive advantages through signaling commitment-to-SCS to their stakeholders (e.g., customers and regulatory agency). I then argue that firms that have a greater level of upstream complexity (*detail*, *dynamic*, or *spatial*) can better utilize C-TPAT certification as a commitment-to-SCS signal when compared to firms that have a lower level of complexity (*detail*, *dynamic*, or *spatial*) in their upstream supply chains, thus enabling the former to generate greater competitive advantage than the latter.

To infer causal relationship between C-TPAT adoption and operational performance, I match each sample adopter firm to a non-adopter control firm that has very similar pre-event characteristics with the sample firm. I use Coarsened Exact Matching approach, which has superior advantages over other existing sample-quasi pair matching algorithms such as propensity score matching to match sample firms with properly selected control firms. Using a standard econometric analysis, which is a Difference-in-Difference regression, I examine whether C-TPAT certification adoption leads to improved financial performance in adopter firms vis-à-vis the control firms. To further test how supply chain related performance contingencies affect the benefits of C-TPAT certification, I investigate whether upstream supply chain complexity influences the financial performance due to C-TPAT certification adoption. The results suggest that C-TPAT certification leads to an increase in return on assets

and sales growth while a higher level of *detail*, *dynamic*, and *spatial* complexity in upstream supply chain significantly strengthens such performance outcomes.

1.3.3. Chapter 4-Essay 3

In Chapter 4, I contextualize my research in the international maritime shipping industry by examining how internal safety context of an organization (i.e. ship) affects its future accident likelihood and how a higher-level context (i.e., national culture context) moderates such relationship. Unlike prior research use a single level analysis to study organization's safety performance, I investigate how a lower level context (i.e., internal context) can be moderate by a higher level context (i.e., national context) in managing safety. The maritime shipping industry thus provides the best context for us to conduct this research, because the crews on ship are often multinational that have diversified national cultures. In addition, the safety accidents in the shipping industry are also well documented and publically available from the Lloyd's database.

Data in this research are collected from a commercial database recording historical ship incidents in the global maritime shipping industry. The unit of the analysis in this study is the ship. I construct internal safety context variable by using the ship-level data and I draw upon Hofstede's national culture measures to construct national context variables. I address the following research question in this essay.

What is the role of the internal safety context of a ship and national culture on the ship's safety accidents?

The results of this research suggest that 1) a ship's internal safety context (*attentiveness to safety*) significantly affects the likelihood of future safety accident; 2) national context (national culture) significantly moderates the effect of a ship's internal safety context on the likelihood of a safety accident. Specifically, I find that a low internal safety context (low *attentiveness to safety*) results in even higher likelihood of serious accidents in countries with high Power Distance, high Individualism, and low Uncertainty Avoidance. Furthermore, I find that ships learn from past serious accidents but this effect tends to be less dependent on national culture. Collectively, the results show that an organization's internal safety context (*attentiveness to safety*) depends more on the national context than its ability to learn from serious accidents. The importance of theses study results to the broader implications for managing safety in international shipping and transport logistics operations are also discussed.

1.4. Research Methods

Table 1-1 summarized the research methods used in the thesis. The second row briefly describes the underlying algorithm or mechanism of each methodology. The third row gives the purpose of the methodology applied in a specific research context. I also list the robustness checks (if any), references (scholarly articles) introducing the research method, and sample research articles using the specific research method that have been published in management journal outlets.

Table 1-1. Research Methods Used in the Thesis

	Essay 1		**Essay 2**		**Essay 3**	
Research methods	*Citation network analysis*	*Main path analysis*	*Coarsened exact matching*	*Econometric modeling*	*Multi-level analysis*	*Econometric modeling*
Algorithm/mechanism	Louvain algorithm	Traversal weight of an arc or vertex	Exact match on 1:1 basis between a sample and a control firm	Difference-in-difference analysis of sample and control pairs	Cross-level interaction effect	Random-effect Poisson regression on count data
Purpose	Determine the optimal number of research clusters	Remove the arcs below a certain level of the traversal weight and include those above in the main path	Perform balancing *ex ante* between sample and control firms by "coarsening" a set of observed covariates	Remove all stable sources of between-firm variability, leaving only variability within firms over time to detect if *ex-post* difference is statistically greater than *ex-ante* difference	Test whether the strength of the relationship between two lower-level constructs changes due to a higher-level construct	Investigate whether hypothesized variables are significant predictors of future accident
Robustness check	NO	NO	Other matching algorithms (e.g., propensity score matching) are considered	Longitudinal event study is considered	Multilevel mixed-effects Poisson regression	Random-effect negative binominal regression on count data
References	Girvan and Newman (2002)	De Nooy et al. (2011)	King et al. (2010), Lacus et al. (2012)	Wooldridge (2009)	Aguinis et al. (2013)	Hox and Kreft (1994)
Sample articles	Wilding et al. (2012)	Fan et al. (2014)	Gray et al. (2014)	Aggarwal and Hsu (2014)	Hirst et al. (2011)	Rothaermel and Hess (2007)

1.5. Contributions of the Thesis

The contribution of each essay is summarized at the end of each essay while an overall summary of research contributions is detailed in Chapter 5. The key contributions of my research work are (1) to reveal the signaling mechanisms that enable the improvements in transport logistics security certification adopters firms' operational performance and (2) the role of national context (national culture) on ship's internal safety context and accident performance. Prior survey-type research in security and safety are subjected to selection bias issues. Moreover, most of the extant research focused on single level (i.e., firm-level) analysis, failing to explore cross-level variables that may influence the outcome variables. This thesis, however, addresses the above limitations to contribute to the literature of safety and security studies in the shipping and transport logistics context. Moreover, as stakeholders in shipping and transport logistics industries increasingly emphasize security and safety in operations, the findings in this thesis should offer important managerial implications for practitioners and policy-making strategies for regulatory agencies.

1.6. Organization of the Dissertation

Table 1-2 illustrates the organization of the dissertation which outlines the structure of the thesis and research activities in each chapter.

Table 1-2. Thesis Structure and Research Activities

Organization	Contents	Research activities
Chapter 1	Introduction	Research overview
Chapter 2	Security Issues in Supply Chain Management: A Citation Network Analysis	Citation network analysis and main path analysis on 143 sample SCS articles
Chapter 3	C-TPAT Certification and Operational Performance	News announcements, importing data, and financial data of 101 publicly-traded U.S. importer firms
Chapter 4	Managing Maritime Safety in Global Operations: The Effect of National Culture	61,342 historical ship incident data from global shipping industry
Chapter 5	Conclusions	Contributions and implications of the research outcomes

While novel and important implications are discussed in this thesis, the research conducted during my current study is only a beginning. I believe there is much work to do in security and safety research in shipping and transport logistics operations.

Chapter 2. Essay 1: Security Issues in Supply Chain Management: A Citation Network Analysis

2.1. Introduction

Lewis (2003) defined operational risk as "the potential for an operation to generate negative consequences for various external and internal stakeholders". Operational risks are caused by variations/disruptions that affect the material, product, and information flows in the supply chain (Jüttner et al., 2003). Operations managers continuously seek management innovations to mitigate such risks along with other types of the risk occurring in global supply chain management, such as uncertainty in currency exchange rate and political instability (Meixell and Gargeya, 2005). Supply chain risk exists everywhere including ports, factories, warehouses, etc. (e.g., Fang et al., 2013, Wagner et al., 2009, Yip, 2008) across the global supply chain. Supply chain risk management includes various aspects, such as problems of coordination between supply and demand, labor strikes, natural disasters, etc. For example, prior studies propose the emergency logistics distribution approach to counter the risks of disasters in a limited time frame (Sheu, 2007) and provide possible solutions to disaster relief operations in the context of humanitarian logistics (Ahmadi et al., 2015). Mathematical models have been used to find optimal solutions for managing the risks of outsourcing by considering time, quality, and costs (e.g., Zhu, 2015), as well as the risks of hub disruption in a biomass supply chain (e.g., Marufuzzaman et al., 2014). The risks mentioned above could be a result of randomized events, such as earthquakes, and it does not matter whether there is an agent (e.g., smugglers and terrorists) actively intervening the operations.

Supply chain security (SCS) management, as defined by Closs (2008), concerns "*the application of policies, procedures, and technology to protect supply chain assets (product, facilities, equipment, information, and personnel) from theft, damage, or terrorism, and to prevent the introduction of unauthorized contraband, people, or weapons of mass destruction (WMD) into the supply chain*." In general, security management emphasizes formulating strategies to prevent or mitigate the adverse consequences caused by security breaches. SCS management, compared with supply chain risk management, places an extra emphasis on the active disruptions caused by unknown agents, who might harbor illegitimate motives for their actions. To develop a secure supply chain, operations managers must evaluate the vulnerability of each operations process in order to minimize the exposure of their operations procedures to unknown third-party agents. For example, since the terrorist attack on the New York World Trade Centre in 2001, global logistics security has been tightened up (e.g., the imposition of additional inspections and deployment of advanced security technologies).

Both academic researchers and practitioners are aware of the negative impact of SCS incidents, e.g., shipment delay caused by pirates hijacking container ships, on the performance of organizations. Securing cargo movements and their conditions across the physical boundaries between organizations, as well as in-house security issues within an organization, are the key research areas. Piracy not only causes huge losses in cargoes but also diminishes the quality logistics services because ships need to be re-routed to avoid further losses.

Cargoes may contain WMD, illegal drugs, and prohibited chemicals. Moreover, logistics and inventory facilities are liable for damages, which render raw materials and products in inventory or in transit unavailable. The risks associated with such incidents will compromise the performance of the supply chain and undermine customer satisfaction. Security issues in supply chains are relatively under-explored, leaving plentiful opportunities for future research. Marucheck et al. (2011) addressed security issues with a focus on product security (e.g., intentional contamination). Considering the impacts of global supply chain operations characterized by complex and interactive coordination among various partners, they highlighted that a product security problem could escalate into a supply chain security problem if there is no immediate remedy. They also suggested researching SCS issues from the operations management (OM) perspective.

Recently, to promote better management of SCS issues, governments and trading organizations have initiated various SCS management programs, such as Customs-Trade Partnership Against Terrorism (C-TPAT), Authorized Economic Operator (AEO), and the International Ship and Port Facility Security (ISPS) code for all the organizations in a supply chain. Supply chain partners (e.g., overseas suppliers and transport carriers) voluntarily or are mandated to implement security practices to showcase their commitment to security management (Autry and Bobbitt, 2008; Sarathy, 2006). The adopter organizations use these security standards to guard themselves against loss caused by undesirable security incidents. In view of the growing importance of security management in OM, we review the published security management studies in the OM literature with the following objectives:

1) *visualize and analyze the knowledge structure and content of existing SCS studies and*

2) *propose possible future research opportunities on SCS issues based on the analysis of the existing literature.*

We use the citation network analysis (CNA) to conduct the review. CNA has the advantage of providing an objective identification of the research domains (see Pilkington and Meredith 2009) which are the clusters in the citation network. The number of clusters is determined by the optimized *modularity index* (Fan et al., 2014; Colicchia and Strozzi, 2012).

Researchers had paid scant attention to SCS issues before the terrorist attack in the U.S. on 11 September 2001. For example, before the attack, homeland security management had attracted small interest in SCM research. The tightened security control across borders after the attack has prompted researchers and practitioners to tinker how security management could help improve the security and performance of global supply chains that are vulnerable to increasing and widespread risks of disruption. Roughly, research studies on security issues in SCM include 1) empirical investigations of the impact of the implementation of security practices (e.g., Chang et al., 2014; Lu and Koufteros, 2014), 2) mathematical modeling to optimize management systems incorporating security considerations (e.g., Bakshi and Gans, 2010), and 3) theoretical exposition of pertinent issues such as security enhancement and security breach prevention/recovery (e.g., Melnyk et al., 2013).

However, the rough classification above is inadequate in covering all the security-related issues in SCM. For example, it does not cover studies on technological adoption for SCS, which has emerged as a popular management approach for mitigating security breaches. Moreover, given the continuing growth in globalized production and outsourcing activities, firms emphasize coordination among supply chain partners for managing SCS. Hence, the perspective of traditional security management that mainly focuses on facility, personnel, or warehouse security is inadequate to embrace the contemporary view of security with a global supply chain focus. Also, a review of security management highlights the risks associated with active agents with illegitimate motives to cause disruptions, which has evolved as a major concern in contemporary supply chain management.

2.2. Methodology

The conventional systematic literature review approach is largely objective but inevitably some decisions are subjective. Decisions on sample papers classification may be biased (Lewis et al., 2007; Wilding et al., 2012). Researchers determine the major research domains, based on their knowledge, and thus the quality of the domain classification is largely dependent on their capability. Moreover, the conventional method cannot accurately capture the dynamics of the research trend. To address these concerns, recent OM researchers have adopted the CNA approach to objectively classify the pertinent literature into specific research domains (e.g., Fahimnia et al., 2015; Fan et al., 2014).

To obtain an initial sample set of SCS-related research papers, we first identified relevant keywords for the literature search in the *Web of Science* (*WOS*) database. We used the following keywords: "supply chain", "security", "secured", "management", "terrorism", "operation", "accident", and "risk". We also used reasonable combinations of these keywords: "supply chain AND security", "secured AND supply chain", "security AND management", "operation AND security", "accident AND management", "risk AND management", as well as the single words "terrorism" and "accident". Given that SCS is a relatively new topic, we set a twenty-year review period from 1995 to 2015. We limited *Document Types* to "*article*" and refined the results under *WOS*' categories function by restricting them only to *Operations Research*, *Management Science*, and *Business*. We identified 257 articles for further reading. We carefully read each paper and eliminated articles that are outside the research scope (i.e., articles that only contain the above keywords but are irrelevant to SCS studies). Eventually, we collected 143 papers as the sample for further analysis.

We used the statistical software packages *HistCite* and *Gephi* to conduct the citation network analysis. We first performed a descriptive statistical analysis of the journals downloaded from *WOS* by using *HistCite*. Tables 2-1 and 2-2 and Figures 2-1 to 2-4 present the sample articles' top author ranking, contributing organization/country ranking, distribution by journal, by publication year, by articles' research methodology, and data collection/analysis method, respectively. We used *Gephi*, a powerful tool for providing visualized and interpretative clusters figures, to generate the cluster figures (see Figure 2-2 to 2-5).

Table 2-1 reports the five most productive researchers, and their total local citation scores (LCSs) and global citation scores (GCSs). LCS refers to the attention received by other authors within the same research domain. GCS indicates that how a selected paper has received citations from other research disciplines (e.g., policy research). For example, some sample papers have frequently been cited by administrative policymaking or homeland security research works (e.g., Mueller and Stewart, 2012). Our database shows that the rankings of LCS and GCS are not necessarily consistent. Table 2-2 shows the top five contributing organizations/countries with respect to LCS and GCS. Michigan State University (organization) and the U.S.A (country) provide the most contribution to the SCS literature. Figure 2-1 displays the distribution of publications by the journal. SCS management articles frequently appear in the *International Journal of Shipping and Transport Logistics* and *Supply Chain Management - An International Journal*, while only a few articles appear in the broader OM and SCM outlets. Figure 2-2 shows the trend of the SCS related publications, which has a dramatic growth since 2005. This trend implies that the academia is paying attention to security management issues. Figure 2-3 shows the number of papers in terms of the type of article, data collection method, and data analysis method. 78 (54.55%) sample articles adopt the empirical approach, and 10 (6.70%) articles use mathematical modeling, 14 (9.79%) articles use meta-analysis, 25 (17.48%) articles are conceptual works, and 16 (11.19%) articles are literature reviews. Figure 2-4 shows the data collection methods used: among the 78 empirical papers, 19 (24.36%) use case studies, 31 (39.74%) are survey studies, 20 (25.64%) are interview-based, two (2.56%) use secondary data, and 6 (7.69%) use multiple sources of evidence.

Table 2-1. The Top Five Researchers and Their Articles' Total Local Citation Scores (LCSs) and Global Citation Scores (GCSs)

Rank	Author	No. of articles published	Total LCSs/GCSs
1	MD Voss	5	18/57
2	DJ Closs	4	18/57
3	Z Williams	4	13/44
4	TCE Cheng	3	5/126
5	SA Melnyk	3	1/21

Table 2-2. The Top Five Contributing Organizations/Countries and Their Total LCSs and GCSs

Rank	Organization	No. of articles	Total LCSs/GCSs	Country	No. of articles	Total LCSs/GCSs
1	Michigan State University	8	19/100	USA	88	173/2540
2	SUNY Buffalo	6	4/363	China	21	10/290
3	Central Michigan University	5	17/62	UK	15	7/107
4	The Hong Kong Polytechnic University	5	5/153	Canada	7	11/85
5	Purdue University	5	1/36	Australia	4	3/63

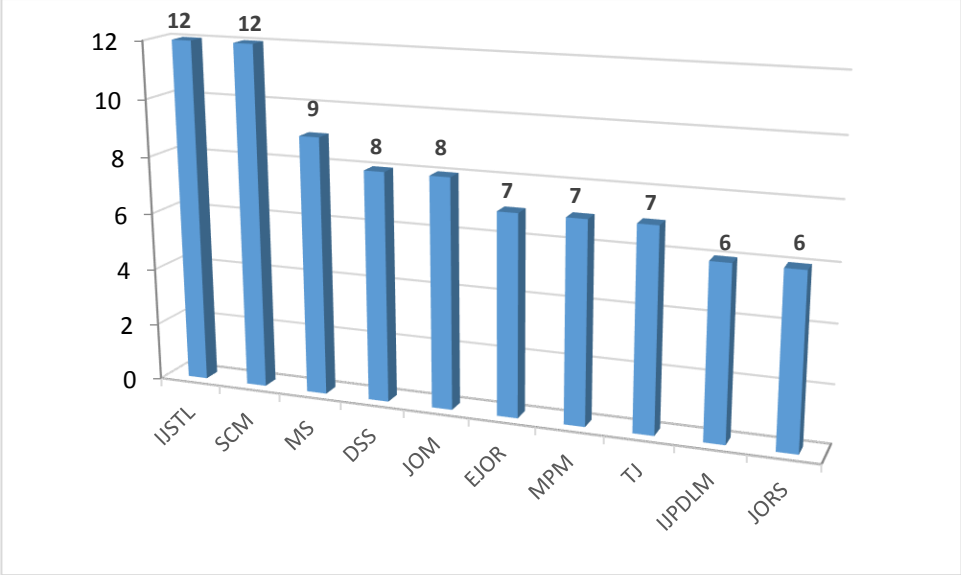

Figure 2-1. Distribution of Number of Articles Published in Journals (excluding journals with fewer than six sample articles)[1]

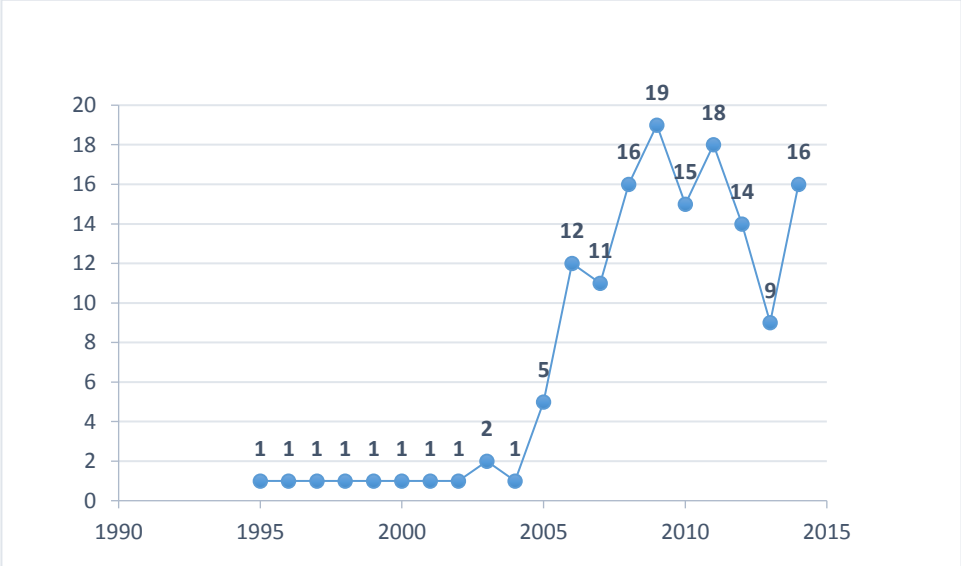

Figure 2-2. Distribution of Number of Articles by Year

[1] IJSTL= *International Journal of Shipping and Transport Logistics*, SCM = *Supply Chain Management-An International Journal*, MS = *Management Science*, DSS = *Decision Support Systems*, JOM = *Journal of Operations Management*. EJOR = *European Journal of Operations Management*, MPM = *Maritime Policy & Management*, TJ = *Transportation Journal*, IJPDLM = *International Journal of Physical Distribution & Logistics Management*, JORS = *Journal of the Operational Research Society*

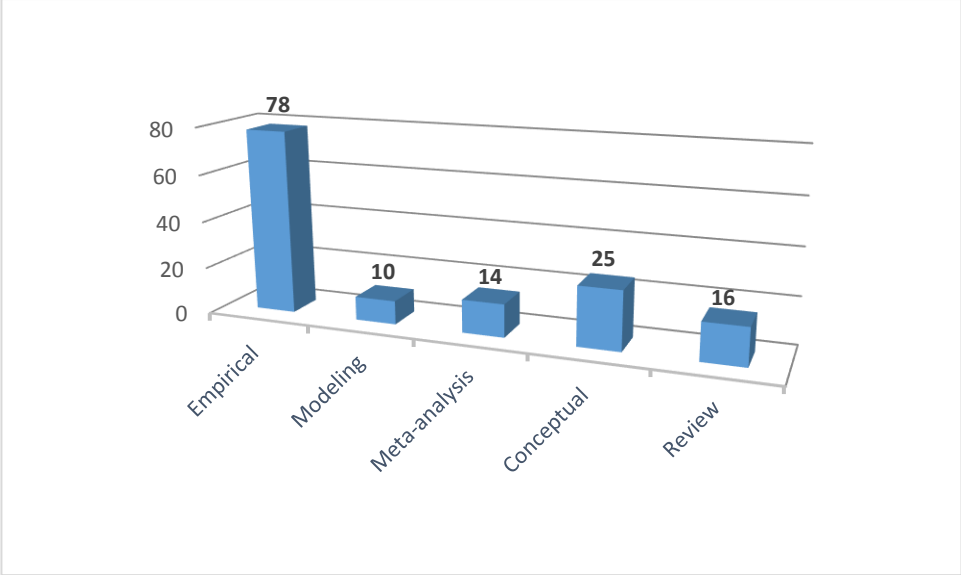

Figure 2-3. Distribution of Article Types

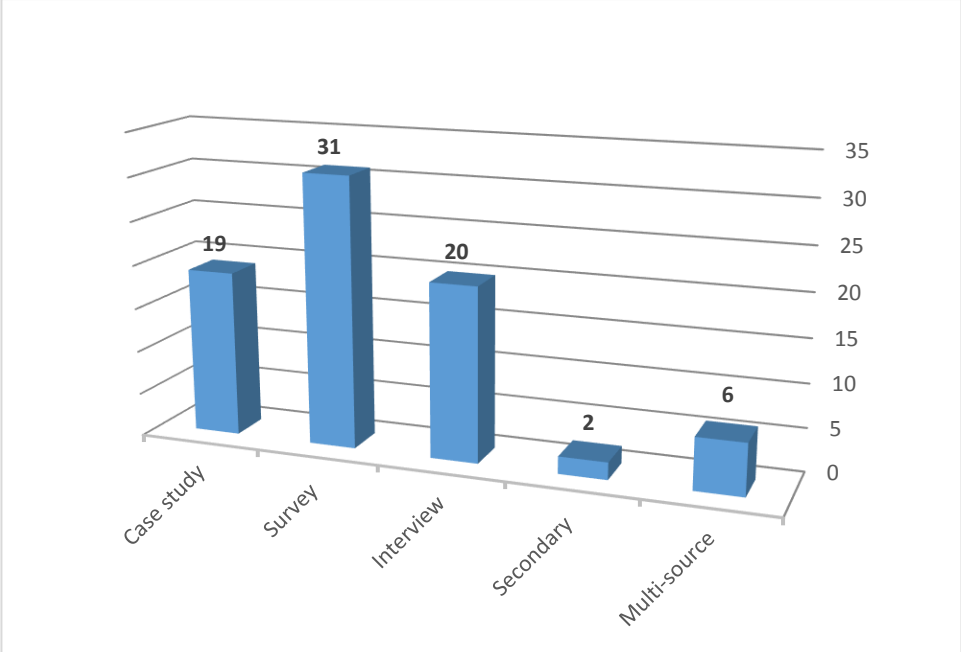

Figure 2-4. Distribution of Data Collection Method

2.3. Citation Network Analysis: Major Research Clusters

We use CNA to identify clusters of our sample articles. In any network, a cluster can be identified by maximizing the density within a cluster while minimizing the

connections of nodes between different clusters (Clauset et al., 2004; Radicchi et al., 2004). CNA is based on the concept of "edge-betweenness" (EB). Instead of searching for edges that are central to communities, EB focuses on edges that are "between" communities (less central). This algorithm aims at progressively removing loosely connected edges from a quasi-constructed graph such that a solid community structure (clustered communities) can be finally outlined, see Girvan and Newman (2002). Specifically, we can view a cluster in a citation network as a group of articles that are potentially under the same research topic.

We use the *Gephi* clustering package to determine the number of clusters and classify each node (i.e., article) into its corresponding cluster. A modularity index is needed for optimizing the "modularity" of a network by measuring the within-cluster and between-cluster densities. De Meo et al. (2011) proposed the formula below to calculate a network's modularity *Q*:

$$Q = \sum_{s=1}^{m} \left[\frac{l_s}{|E|} - \left(\frac{d_s}{2|E|} \right)^2 \right],$$

where *m* refers to the number of clusters, *s* is a cluster, *E* stands for the total number of edges in a network, l_s is the number of edges between the nodes of a particular cluster *s*, and d_s represents the sum of degrees of the nodes in the s^{th} cluster. The above formula reflects that in order to maximize the network modularity *Q*, i.e., to create clusters with high densities within themselves but loosely coupled between one another. Each given cluster should involve the highest possible number of edges, while

the network should be divided into several clusters with a total degree as small as possible. Based on the above approach, we obtain four major clusters. The optimal number of clusters is 19 (the *Q* value is 0.440). However, we find that 15 of the 19 clusters contain only one to three nodes (articles). Given that the numbers of articles in the 15 clusters are very small, we should confirm the creation of the 15 clusters. Labeling these clusters as "scattered clusters", we review the relationships between the nodes in the scattered clusters to avoid omitting any major article that belongs to other major clusters. Figure 2-5 shows the final four major research domains identified by CNA. We provide a list of the articles under each of the clusters in the Appendix. Table 2-3 shows that, among the 143 sample articles, 26 papers (18.18%) are related to SCS conceptualization and application, 19 papers (13.29%) discuss security management systems, 15 papers (10.49%) examine maritime security, and six papers (4.20%) deal with terrorism and other external risk issues. The results also show that 77 papers in our sample do not belong to any cluster. This is attributable to the limitation of CNA as the number of citations from a paper is usually inversely proportional to its year of publication. Recently published papers may have fewer citations, leading to weak connections with papers that may actually contain similar research topics in nature, hence failing to be classified.

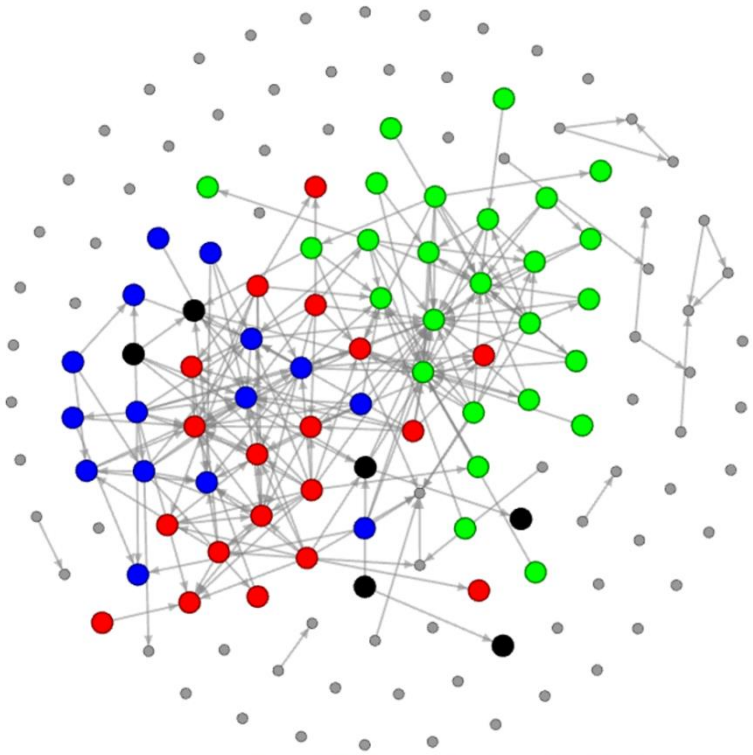

Figure 2-5. Identifying Clusters by Using CNA

Notes: 1) We used the *Gephi* software (*Louvain algorithm*) to determine the optimal number of research clusters. The *Q* value (modularity index) equals 0.440, and the suggested number of cluster is 19. Small nodes (in gray) represent scattered clusters; 2) Different colors of nodes refers to different clusters (as indicated in the legend).

2.4. Main Path Analysis: The Knowledge Structure

Clustering a network provides an overview of the literature. However, it cannot chronically capture the incremental development of the knowledge and the transformation of research paradigms. We need to know how an article integrates prior knowledge and leads to new research avenue. It should be noted that the fundamental objective of main path analysis is not to review the details of the contents in a specific

research domain, but to capture the knowledge transformation process and provide possible research opportunities that can be perceived according to the overall research paradigm. Resolving the above problem, the main path analysis (MPA) measures the connectivity of articles by searching the nodes (articles) with the highest centrality degree. Articles in the main path are considered critical and pioneering in its research domain. The main path analysis first calculates the "traversal weight" of each article within a research domain. The traversal weight of an arc or vertex is "the proportion of all paths between the *source* (earliest cited article) and *sink* (latest and never being cited) vertices that contain this arc or vertex" (De Nooy et al., 2011). The main path articles are obtained by removing the arcs below a certain level of the traversal weight and eventually articles with greater traversal weights will be included in the main path. Following Fan et al. (2014), we calculate the traversal weight as follows:

$$W_{ij} = TP_{ij}/TBS_j,$$

where TP_{ij} represents the total number of citation paths from a particular article i to *sinks* in the network while TBS_j denotes the total number of citation paths between all the articles and *sinks*. We conduct the main path analysis using the *Pajek 2.05* software.

2.4.1. Main Path Analysis for All the Sample Structure

Figure 2-6 shows the overall main path analysis for all the sample articles. Lee and Whang (2005) emphasized the importance of SCS research and introduced how fundamental quality management approaches can address SCS issues. Kleindorfer and Saad (2005)'s security assessment framework suggested how SCS can be prevented by employing mindful strategies in a firm's supply chain management. Inspired by the

above two works, Sarathy (2006) provided a comprehensive review of the relationship between security management and the global supply chain. This conceptual paper provides a holistic view of security management issues in SCM, the impact of security risks, the importance of collaborative between supply chain partners, and the potential research directions.

Based on the conceptual guidance from Sarathy (2006)'s work, Voss et al. (2009) conducted an empirical study on supplier selection with a security concern in the food supply chain (e.g., under what circumstances do firms compromise production and delivery efficiency for supplier security). Their study revealed that firms with international exposure have stronger security awareness and the awareness improves the firm's operating performance.

Yang (2011) conducted an in-depth investigation of maritime security issues in view of insufficient attention being paid to maritime security regulations in the literature. Yang (2011) developed maritime security strategies to strengthen cargo security in Taiwan and discussed maritime security initiatives (e.g., 24-hours Rule and Container Security Initiative) with respect to their applications in Taiwan. Furthermore, Yang (2011) employed a bowtie analysis to model accident scenarios by synthesizing the causes and impacts of accidents.

Yang and Wei (2013) discussed other security management dimensions, such as facility and cargo management, accident prevention and processing, information management, and partner relationship management, for firm's and customs' security

performance. Similarly, Chang et al. (2014) estimated the likelihood of security accidents, relevant consequences, and accident scale by the stochastic dominance method and risk-mapping technique. They provided useful guidance for the customs to identify response strategies to prevent accidents.

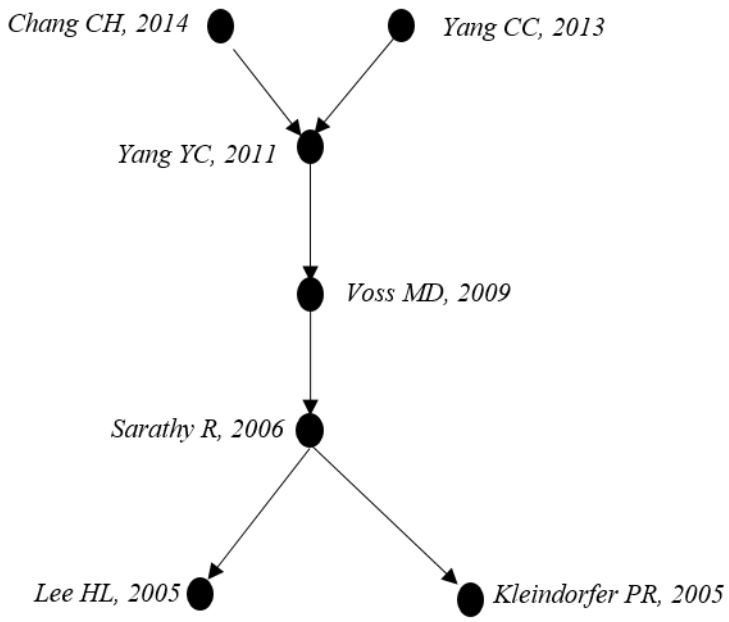

Figure 2-6. The Overall Main Path for All the Sample Papers

2.4.2. Cluster 1: SCS Conceptualization and Application

SCS conceptualization and application is the largest research area among the clusters. Figure 2-7 chronically depicts the knowledge transformation and accumulation in this research area.

Three key research works (i.e., Chopra and Sodhi 2004, Tomlin 2006, and Kleindorfer and Saad 2005) constitute the foundation of this cluster. Chopra and Sodhi

(2004) discussed various factors that may cause security problems and thereby threaten supply chain efficiency. They provided management guidelines to ensure a firm's security performance by minimizing the firm's and the firm's partners' potential security accidents. Kleindorfer and Saad's (2005) security framework points out that the emerging supply chain security concern may arise from "acts of purposeful agents", e.g., terrorists. The framework consists of self-assessment tools to prevent potential security problems. Kleindorfer and Saad (2005) empirically tested and enriched the proposed framework in their study.

Tomlin (2006) studied the sourcing problem-related supplier reliability. It was a pioneering work on supplier selection under logistics security and cost restrictions. Tomlin (2006) studied how various supplier characteristics (in particular supplier reliability) and the nature of security breaches affect a firm's strategic decisions on supply chain security. Based on the three foundation works discussed above, Trkman and McCormack (2009) explored how endogenous uncertainty (market turbulence and technological turbulence) and exogenous uncertainty (continuous risk and discrete events) will affect the likelihood of security disruptions.

Wilding et al. (2012) conducted a literature review of supply chain risk, while SCS was recognized as a key domain for further research. The review also helps practitioners to identify and apply security strategies in their SCM. Marley et al. (2014) proposed a theoretical model to study SCS based on the normal accident theory perspective. Normal accident theory implies that accidents are inevitable (normal) when the environment is highly complex or tightly coupled. Accordingly, the authors

suggested strategies to prevent SCS accidents by reducing the complexity and decoupling of systems.

Given that security research in OM is relatively recent compared with other research realms, e.g., occupational safety, research on SCS is mainly derived from a broader concept of risk management and supply chain disruption research. Therefore, this stream of research mainly focuses on general concepts/frameworks of SCS topics and suffers from the following drawbacks. Given growing global outsourcing and off-shore manufacturing activities, the above studies provide limited implications because their analyses are restricted to supplier selection with security concerns. Therefore, for future studies on this cluster, a deeper understanding of broader security coordination among various supply chain partners (e.g., suppliers, manufacturers, transport carriers, and end customers) is needed. Also, the security of outsourcing from upstream partners is of great importance to manufacturing firms because if a security problem occurs, manufacturing firms may fail to arrange substitutes, resulting in a loss of productivity. Eventually, it will affect downstream service performance (e.g., on-time delivery). Hence, future studies may investigate how the upstream security management efforts will affect downstream service performance.

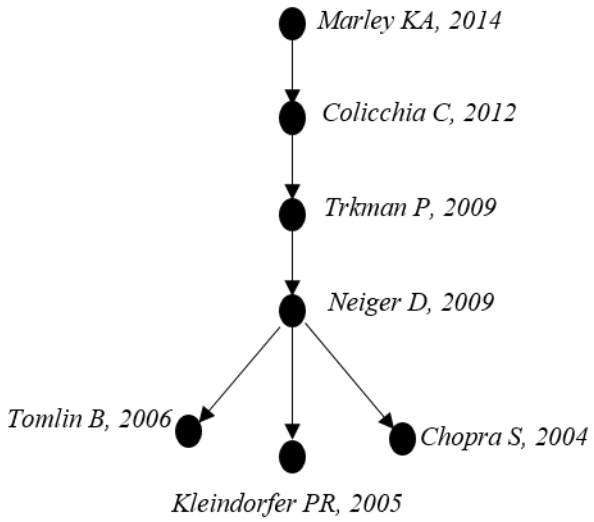

Figure 2-7. The Main Path for Cluster 1 (SCS Conceptualization and Application)

2.4.3. Cluster 2: Security Management Systems

Articles in this cluster are specific on the security management system. This cluster provides practical insights on the management and implementation of security management systems.

Russell and Saldanha (2003) developed five principles for logistics security management by considering the cost of managing terrorist attacks, complying with government regulations, or adopting a widely accepted standard security certification. Based on a case study, Sheu et al. (2006) confirmed the positive effect of adopting C-TAPT, a popular standard logistics security certification, on the improvement of international supply chain collaboration.

Autry and Bobbitt (2008) conceptualized SCS orientation, which is "a firm-level orientation representing the firm's collective attention to supply chain security management". SCS orientation of an organization helps distinguish the concept of supply chain security from general supply chain risk. They showed the importance and timeliness of considering security management as an independent and critical research area that should not be restricted to the realm of supply chain risks or supply chain disruptions.

Williams et al. (2008) classified the security management literature concerning security risk mitigation and security performance enhancement into four categories, namely intra-organizational, inter-organizational, a combination of the two, and ignoring both. They clarified the terminologies used in SCS research and comprehensively reviewed the strategies and practices that organizations adopt in managing SCS.

Whipple et al. (2009) empirically investigated the security performance differences between global and local food companies. The results indicate that global food firms and local firms differ significantly in security performance outcomes because a more complex operational environment (i.e., the global market) can strengthen firms' security awareness. The authors also call for an integrated security management system, e.g., communication strategies for sharing information to mitigate SCS risks, emphasizing that a collaborative security system with supply chain partners can help individual firms to achieve SCS goals better.

Voss and Williams (2013), and Lu and Koufteros (2014) studied specific supply chain security initiatives (e.g., C-TPAT as a third-party SCS management system and Interactional Ship and Port Facility Security Code as shipping security system) and their performance effects on adopting parties. The former study introduced a concept called relational security to account for private-public partnership in security management, and they emphasized the importance and effectiveness of such partnership in maintaining a secure global supply chain. The second study identified five major sources of pressure to adopt security practice, which are the government, customers, peer firms, norms, and performance, based on the institutional theory perspective.

The articles in this main path provide insightful discussion on the effectiveness of various security management systems. However, only a few of the above studies investigated why organizations decide to implement security practices. The moderating effects of adoption incentives and other antecedents to adoption have not been discussed. Whether the firm's operational capability affects the effectiveness of SCS management practice and how external contingencies affect the likelihood of SCS practice implementation are important research questions not yet addressed. Security management systems are primarily designed to prevent security accidents. Future research in this cluster can examine the effectiveness of SCS management systems with a more objective approach. For example, researchers can examine the abnormal change of security performance (regarding security accident rate) or financial performance (in terms of stock return) after adopting security management systems.

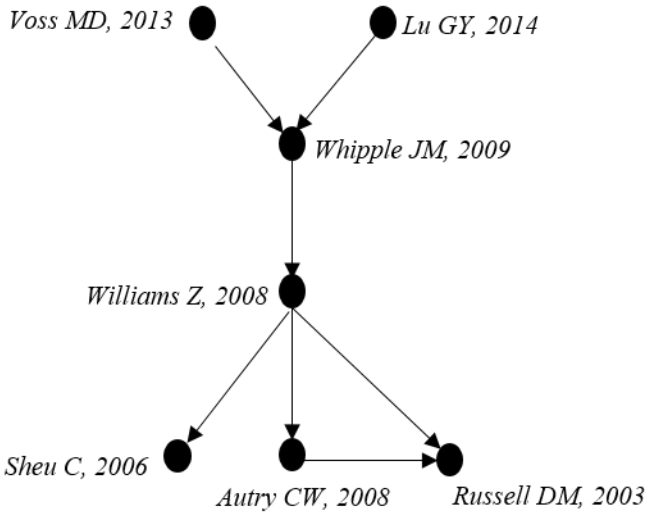

Figure 2-8. The Main Path for Cluster 2 (Security Management Systems)

2.4.4. Cluster 3: Transportation Security

This cluster discusses security issues in the transportation and shipping industries. Lee and Whang (2005) proposed a model to minimize the cost of achieving security targets and the model is based on quality cost analysis. Similar to the quality manager that reduces the quality cost by quality management**,** the operations manager can also reduce the security cost by properly applying SCS practices. Therefore, they analyzed various security initiatives and compared and contrasted with quality management practices, bringing insights to transportation security from quality management research.

Thibault et al. (2006) reported findings on how logistics and maritime firms respond to the trend of security management. Based on interviews with senior container line executives, port officials, and marine terminal security officers, they highlighted the importance of maritime security in international cargo flows. For firms

that are actively involved in cross-border logistics security initiatives and provide feedback to the government, their chances of successful security management are much higher.

Considering that both cargo and information flows are critical to container transport chain management, Lun et al. (2008) adopted the institutional theory perspective to analyze various isomorphic pressures in the transportation industry that lead organizations to adopt security management information systems. Security management technologies (e.g., radio-frequency identification (RFID) technology, container non-intrusive inspection (NII) technology, and smart box initiative) were investigated. Their study sheds light on the effect of each institutional isomorphism, i.e., *coercion*, *mimesis*, and *norms*, on the adoption of container security technology.

Yang (2011) focused on Taiwan's maritime SCS and identified the security factors that may adversely influence container security. Moreover, they suggested considering efficiency, competition, and cost to strike a balance between security improvement and cost reduction.

Chang et al. (2014) and Yang et al. (2013) enriched safety and security management research on container shipping by conducting a case study and a survey study. The former employs a combination of qualitative and quantitative methods to identify and rank the risk factors. The latter provides a comprehensive study of the impact of security management on the performance of container shipping operations.

However, the above studies have an insufficient emphasis on the unique characteristics of the transportation industry, such as the location and connectivity of a seaport. The current literature only investigates how popular security programs have been generically applied in the transportation industry. It is notable that maritime transportation has been playing the most active role in global cargo movement in terms of container/dry bulk/tanker volumes. Accordingly, we should pay additional attention to security issues in the maritime transportation industry. Research questions such as 1) how to help long-distance cargo movement to have fewer service variations and security breaches during transit and storage, and 2) how to incorporate security concerns into maritime transport system design (e.g., port and route planning) at the early stage, should be investigated in the future study. Placing security issues as a priority at the system designing stage could reduce the cost of system reconfiguration when a security breach occurs.

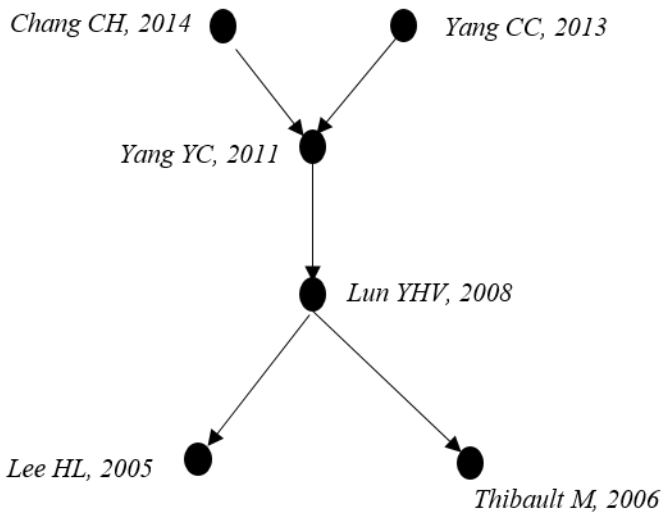

Figure 2-9. The Main Path for Cluster 3 (Transportation Security)

2.4.5. Cluster 4: Terrorism

This cluster contains six articles. The traversal weights for the articles in this cluster are highly similar, implying that all the articles are equally important. Unlike the other clusters, no main path knowledge structure can be established. Considering the small sample size in this cluster, we think terrorism research with an OM focus should be further developed.

This cluster covers the public policy of preventing terrorist attacks. The optimal solutions of cost saving, efficiency enhancement, and prevention of terrorism disruption are discussed. For example, Pinker (2007) developed mathematical models for assessing a defensive mechanism comprising private and public warnings of security breaches. Other studies seek to resolve the conflicts that governments' anti-terrorism departments often encountered. Governments' anti-terrorism related departments need to ensure adequate inspections of suspicious cargoes at the customs, while simultaneously minimizing the congestion caused by intensive inspections (Bakshi and Gans, 2010).

Given the growing terrorism concerns, we suggest the following directions to mitigate such threats in future research. 1) Examine the effectiveness of security regulations across countries and how they affect the trading activities globally, 2) investigate where the blind spots of the global logistics for terroristic activities are, and 3) how to balance the level of security and efficiency in international trade.

Research works in the above clusters not only contribute to specific security concerns in supply chain management but also provide additional insights to the supply chain risk literature. Especially for Cluster 3 - Transportation Security and cluster 4–Terrorism, which are perceived as the primary and growing risks in the global supply chain in recent years, should receive greater attention from the academia to assess their potential impacts on firms' overall risk. How the research works in Cluster 2 – Security management system could help effectively reduce the risks exposed in Clusters 3 and 4 would be an important research avenue for future research.

2.5. Future Research Directions

We demonstrate topical clusters (citation network analysis) and incremental knowledge transformation (main path analysis) in the above discussion, which helps researchers identify future research opportunities in SCS studies by considering the current issues in the SCM context and the limitations of the methodology we employed. In addition to the future research directions suggested at the end of each main path analysis (see Section 4), we suggest avenues for future research.

First, we call for more research on security management in the downstream supply chain. It is because service defection caused by security accidents can lead to severe adverse consequences for manufacturers or transport carriers, eventually harming the entire supply chain. For instance, a previous study has investigated how an individual's regulatory focus, level of risk, and uncertainty of supply chain disruption affect supply chain employees' strategy to mitigate disruption (e.g., Cantor

et al., 2014). This study can be extended to investigate how employees (e.g., operations or security managers) in manufacturing firms or transport firms access the security risk levels from their upper suppliers and establish effective strategies to mitigate such security risk. In addition, the methodologies used in empirical studies are limited to case study and survey, either of which is subject to criticisms (e.g., sample selection basis, the reliability of respondents, etc.). To overcome this methodological deficiency, future research should consider using objective data to measure firm performance outcomes after the adoption of SCS practices or after a security breach.

Second, in the matrix for CNA, the algorithm does not distinguish the importance of each citation to a sample article. However, in reality, some references are cited only for simple utility and used for a small part of the paper while others may contribute to the major foundation of the research. We acknowledge that the CNA approach to clustering fails to consider this distinction. We can weigh the importance of each citation based on the application of each corresponding cited article in each sample article to strengthen the robustness of CNA.

Finally, as CNA is dependent on citation numbers and neutrality between citations, it may include "inappropriate citation", e.g., a citation used as a counter-example to provide evidence on the inappropriateness of the cited paper. The limitation of this study is that we cannot confirm the relationship between the citing paper and the cited paper. Future studies could identify the inappropriate citations to mitigate possible sample selection errors.

2.6. Proposed Theoretical Framework for Supply Chain Security Management

The above review outlines the extant knowledge structure of SCS studies, which can help academia and practitioners identify research opportunities to extend this research stream. However, there is a lack of a systematic framework to explain security management issues in practice or theorize the antecedents for adoption, the mechanisms for managing implementation, and performance outcomes of SCS practices adoption. A lack of knowledge development hinders the ability of scholars to explain why firms adopt (or not to adopt) SCS practices and how they perform in the implementation outcomes. We propose a framework to facilitate knowledge development of SCS management by integrating the above–discussed issues (see Figure 2-10).

We suggest a model account for the influence of external environment on firm's decision making (e.g., Lun et al. 2008) based on the organizational performance feedback theoretical perspective (e.g., Greve 1998). Successful implementation of SCS practices needs to follow three steps: Setting SCS goals, taking actions to implement, and reinforcing the practices (if the feedback is good) or refining the practices (if the feedback is not good) and adjusting the goals to a proper extent. Usually, firms set their SCS goals to achieve legitimacy (e.g., follow the industry norms to adopt a security management certification) or improve operational efficiency by security management. For SCM, firms take various actions to strengthen their SCS and the related practices can be broadly categorized as an internal control (e.g., employee security training and regular inspections) and cooperative strategies with partners (e.g., joint site inspections with the U.S. Customs and Border Protection).

Finally, firms need to assess the performance of these practices and take improvement actions where appropriate. Contingency theory suggests that the performance outcome of an organizational practice is contingent upon firm's internal and external environments (Grötsch et al. 2013). Therefore, firms operating under different environments may attain different security performance outcomes. Firms can repeat the established security routines to continuously address security problems if the current performance outcomes are considered satisfactory. In contrast, when their security goals set are not met, they may revisit the goals with proper adjustments and revamp the practices. This research framework pinpoints possible determinants of SCS practices adoption, the performance contingency, and the performance feedback mechanism (reinforce, revise, and revamp), facilitating future studies to extend this stream of research.

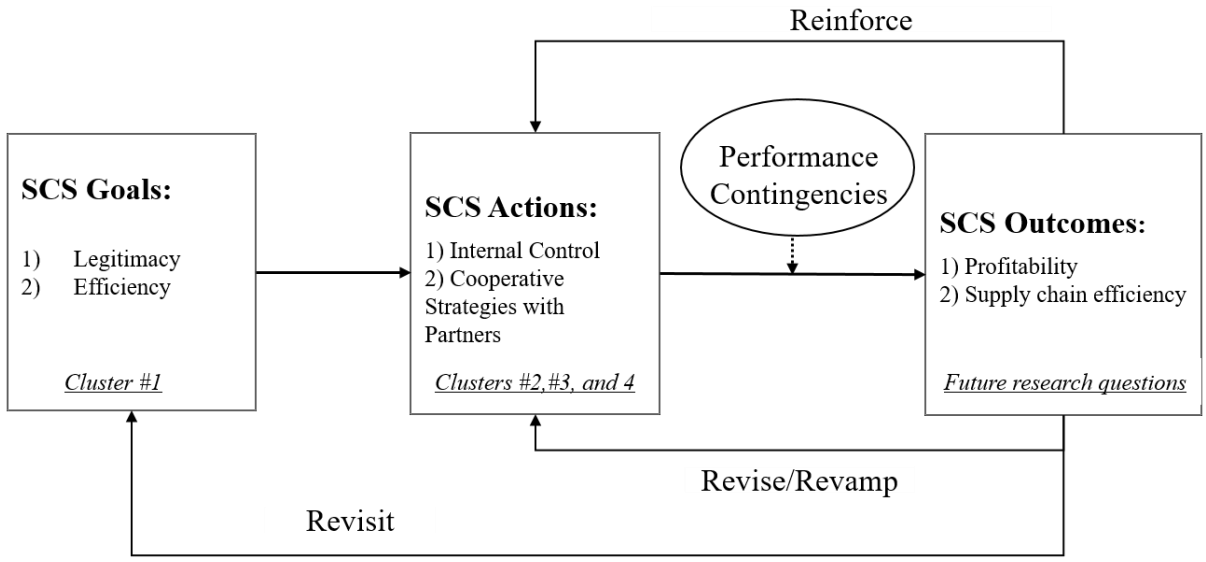

Figure 2-10. Proposed Framework

Note. Cluster #1: *SCS Conceptualization and Application*; Cluster #2: *Security Management System*; Cluster #3: *Transportation Security*; Cluster #4: *Terrorism*. Cluster #1 helps managers properly set their SCS goals while the insights in Cluster #2, #3, and #4 are good for managers to take references when implementing SCS practices. As mentioned in Section 5, the future research may use objective (archive) data to measure SCS performance outcome which would overcome the basis caused by perceptual constructs in previous survey studies.

2.7. A Review of Organizational Theory for Supply Chain Security Management

Although citation network analysis identified research domains and research gaps in SCS literature, the phenomena observed necessitates the application of pertinent theoretic frameworks. Connelly et al. (2011) and Sarkis et al. (2011) advocated that applying organizational theory to address OM issues can strengthen the theoretical underpinnings of the research questions. We review organizational theory because security management issues were often investigated at the organizational level, and there are a number of organizational theories had been used to explain the incentives and consequences of adopting such practices.

Despite the growing number of studies employing the theoretic framework to address SCS management issues, there is a lack of a systematic review of such applications. In the 143 sample articles, the researchers used institutional theory, high-reliability theory, normal accident theory, and game theory as the theoretical frameworks in their studies. Table 2-4 presents the organizational theories used in the SCS management literature.

From the perspective of institutional theory, the external environment presents a "taken-for-granted" context that pressurizes organizations to conform to legitimacy (e.g., security practice implementation). Researchers suggest three "isomorphism" mechanisms, namely *coercive* (e.g., legal enforcement), *mimetic* (e.g., following

successful examples when the effect of SCS practice is uncertain), and *normative* (i.e., professionally or socially accepted norms) to explain how the institutionalized environment leads individual organisations to make a decision (e.g., adopting a popular security management standard) (DiMaggio and Powell, 1983; Meyer and Rowan, 1977; Oliver, 1991). Security management practices diffuse through global supply chain by these institutional pressures.

High-reliability theory and normal accident theory take two contradictory views on the likelihood of a security accident. The high-reliability theory contends that accidents are preventable if abundant measures are taken to manage SCS. Supply chain partners can maintain a reliable supply chain by making efforts to develop employees' *mindfulness* of security. *Mindfulness* of security can be improved through personal training, SCS technology adoption, and SCS collaboration with partners, etc. On the other hand, normal accident theory emphasizes that accidents are normal (inevitable), especially given the complex nature of today's global supply chain. Specifically, when a firm operates in a highly complex or tightly coupled supply chain, despite that sufficient SCS practices have already been implemented, the firm cannot avoid accidents (Weick et al., 1999).

Researchers in economics, political science, and management use the game-theoretic method to study a wide range of strategy equilibria among multiple decision makers (in most cases there are two players). The focus is on finding the optimal solution under various conditions (e.g., perfect information versus imperfect information). Recently, SCM researchers have begun to employ game theory models

to address specific problems in security management. As discussed previously, the models focus on how to simultaneously achieve efficiency (e.g., investment returns on security management) and security enhancement.

Table 2-3. A Review on Organizational Theories used for SCS Studies

Theory	**Institutional theory**	**High-reliability theory**	**Normal accident theory**	**Game theory**
Content	External pressures (i.e., *coercive, normative, and mimetic*) are the major determinants of the organizational behaviors	Accidents are preventable when sufficient measures are taken and *mindful* strategies are properly implemented	Accidents are inevitable in organizations especially when operations are highly complex or tightly coupled	Behavioral relations of decision making between two players can be mathematically modeled
Application in the SCS management literature	Coercive pressure stemming from government agencies; since the first wave of adopting a certain security enhancement program, the adoption becomes a norm in industry; firms imitate successful adopter firms when the value of adopting SCS practice is uncertain	Regardless of hostile environment in which firms reside, firms can still get rid of SCS accident by implementing sufficient mindful security practices (e.g., standard third-party certification adoption)	The occurrence of SCS breach is normal (inevitable).The likelihood of SCS breaches is higher in more complex and tightly coupled system. Practitioners should endeavor to decrease the complexity or decouple the system.	To reduce cost while maintaining a certain level of security needs an optimal strategy satisfying cost reduction and security enhancement.
Sample article	Lu and Koufteros (2014)	Speier et al. (2011)	Marley et al. (2014)	Bakshi and Gans (2010)
Potential research questions	1) Is it possible that conformity can be a conscious and strategic endeavor	1) Are there any undiscovered factors within an organization that	1) How can the likelihood of an accident be determined by	The game theoretic approach can be complemented

	that may result in improved security performance outcomes as well? 2) Is there any performance distinction between early and late adopters? Unlike late adopters,early adopters are more likely to autonomously pursue underlying values.	helps create high-reliable organizations? 2) Can high reliability in security aspects be achieved by implementing SCS practice?	the characteristics of the firms? 2) What are the differences between high-reliability theory and normal accident perspectives in viewing the effectiveness of an SCS practice? 3) Are the two theories contradictory or can they be integrated?	by an empirical investigation to examine the behavioral relations between policy maker and business partners.

Apart from the theories discussed above, contingent theory, resource-based view, and social network theory are deemed as appropriate theories for underpinning studies that address various SCS management issues. Specifically, the contingent theory asserts that the outcome of a management practice is contingent upon the context of the organization in which it resides (Lai et al., 2013). Accordingly, when an organization adopts a security practice, operations managers should take specific conditions (e.g., security awareness of employees, firm size, organizational culture, etc.) into consideration in order to accurately predict the effects of the adoption. Future research may take the contingent theory perspective to develop research question such as: Is the security performance of a firm after adopting an SCS practice is contingent upon the organizational security culture embeddness in the firm? If so, do firms with higher levels of security culture embeddness outperform firms with lower levels of security culture embeddness in terms of security performance?

Because implementing SCS practices is context specific, costly, and time-consuming, an SCS practice or management system, once properly implemented, is

regarded as a “resource” to the adopter firm. Such a resource can be rare, especially in the early stage of its diffusion in the industry, and valuable because the practice is designed for enhancing security management. Therefore, the resource-based view might be an appropriate lens to view theoretical development in the SCS management context. In this respect, a firm can utilize an SCS practice as a resource to attain sustainable competitive advantage. Considering SCS management practices as resources for adopter firms, researchers can measure various performance outcomes associated with SCS practices (e.g., logistics efficiency, financial performance, the likelihood of security breaches, etc.). It is important to understand the underlying mechanism of how organizational resources affect firms’ performance outcomes in the SCS context.

Social network theory suggests that social relationships among organizations or individuals significantly affect organizational behavior, so affecting performance outcomes (Jones et al., 1997). Centrality and density are the two major elements in this theory, measuring the importance of a flow/transfer or involvement in a network and the proportion of the number of existing linkages relative to all the possible linkages within a network, respectively. The global supply chain network comprises relationships among various partners with regard to centrality and density, i.e., relationships among suppliers, manufacturers, transport carriers, and customers. A strategic location (centrality) in the supply chain may result in competitive advantage because of slow and selective diffusion of an innovative management practice (e.g., an SCS practice) from the center to the boundaries. Also, organizations with the dense relationships, e.g., frequent trading activities, are more likely to imitate SCS practice adoption of other organizations. By employing social network theory and considering

the early diffusion stage of an SCS innovation, we may develop propositions such as 1) firms with a strategic location (e.g., locating in the centre of a supply chain network) have higher likelihoods of adopting SCS innovations; and 2) firms sharing dense relationships with one another are more likely to adopt SCS innovations.

2.8. Conclusions

We review 143 sample research studies on SCS management, from which we identify four major research domains by CNA, which provides an objective approach to clustering research topics. Moreover, we apply MPA to outline the development of the knowledge structure of each research domain. This paper contributes to the literature on SCS research with an OM focus in the following aspects. We identify and analyze the research domains under SCS, and show the main path of studies within each domain. These findings help researchers identify fundamental studies in each research domain and enable them to position their studies in an appropriate research domain and research gaps. Moreover, we identify research gaps on the main path and suggest potential research directions for SCS management.

Chapter 3. Essay 2: C-TPAT Certification and Operational Performance

3.1. Introduction

Growing international production, sourcing, marketing, and trading activities have brought a variety of risks to supply chain security (SCS) management. Numerous SCS incidents such as terroristic attack, importation of prohibited weapons, and drug smuggling have occurred worldwide and consequently affected public safety, national security, and economic prosperity. The supply chain security accidents have caused both financial and productivity losses to supply chain partners (Tang 2006). The suicide bombings attack cited above caused over 30 deaths and seriously damaged the supply chain infrastructures (airport and highway station), resulting in subsequent delays of transportation. In addition to the catastrophic accidents, numerous SCS

incidents have occurred to cause financial losses and threaten human health and lives (Hintsa et al. 2009, Peleg-Gillai et al. 2006). For instance, the number of thefts at warehouses, container terminals, and in cargo transits has been continuously increasing (*Security Magazine*, April 1, 2016). In 2016, the cargo thefts occurred four times as much as that in 2012 at container terminals or in cargo transits (*FreightWatch International*). The goal of securing supply chain lies between promoting an efficient flow of legitimate business while mitigating SCS risks inherent in the contemporary complex and dynamic global business environment (Thibault et al. 2006). As a result, public and private sectors respond by implementing security management practices to enhance SCS within firms and across their supply chains.

The 9/11 incident has prompted the U.S. government to revamp security strategies for heightening the security level across international and domestic supply chains. The U.S. government has devoted special attention to *inbound* transportation through the seaport because it is the most favored channel by terrorists to import hazardous goods such as illegal weapons or drugs (the U.S. CBP). The seaports have become the most vulnerable spots because of the high volume and variety of import goods passing through them. The war on terrorism shall be fought by various stakeholders, such as the business community, which desires a secure environment to streamline business, and the government agencies, whose primary duties pertain to maintain economic prosperity by providing security to the society (Sheffi, 2001). Among various SCS initiatives, the Customs-Trade Partnership Against Terrorism (C-TPAT) certification is the most widely adopted SCS enhancement program among firms. This certification was developed by the U.S. CBP, to recognize the ability of adopter firms in managing SCS risks. C-TPAT focuses on security enhancement,

responsibility compliance, and building a cooperative bond between the CBP and C-TPAT certified firms, highlighting U.S. border security threatened by high-risk cargoes. To be C-TPAT certified, firms must demonstrate a continuous commitment to improving SCS. Certified firms can receive the "fast lanes" treatment in the customs clearance process, and less (or no) inspection at the customs. More importantly, C-TPAT certification represents firms' commitment-to-SCS and a clear signal that their operations within firms and across the supply chain boundaries are secured.

Signaling theory suggests that to reduce information asymmetry, one party (the signaler) can send a signal processing desirable information about itself to others (receivers) who cannot observe the information directly (Connelly et al. 2011). Signaling theory perspective explains how firms would benefit from signaling positive messages (e.g., commitment-to-SCS) to their stakeholders whereas receivers can use the signal to differentiate signalers from others, resulting in improvement of operational outcomes in the signaler (e.g., firm). Prior studies have argued that the adoption of standard certification is a valid signaling behavior (e.g., Terlaak and King 2006), which helps certified firms secure legitimacy and generate competitive advantages.

Firms increasingly recognize the importance of mitigating SCS risks in a complex supply chain environment. In particular, when firms compete internationally, they need to take complexity inherent in managing their global supply chains into account. For example, a news article on *Financial Times* (January 25, 2016) discussed how an increasingly complex supply chain affects firms' strategies in mitigating risks caused by the globalized economy, revealing that "companies blamed the complexity

of their supply chains and the inadequacy of supplier responses to their own enquiries."

Complexity can present in various ways in managing a global supply chain. Bozarthe et al. (2009) suggested that two types of complexity (i.e., detail and dynamic complexity) exist in upstream, internal manufacturing, and downstream supply chains. In the context of this study, since C-TPAT certification mainly concerns about the importing security across U.S borders which relates to the upstream importing activities in a firm, we confine our study to the *upstream* complexity of supply chains. Signaling theory suggests that because the signal (sent by the signaler) contains favorable information regarding the signaler, it can be beneficial for the signaler to reduce information asymmetry between itself (e.g. certified firm) and the receivers (e.g. stakeholders) (Connelly et al 2011, Hei and Robertson 1991, Porter 1980, Rindova and Fombrun 1999). Moreover, we demonstrate that the competitive advantage from signaling C-TPAT certification varies across the levels of upstream supply chain complexity. Because recent studies have highlighted upstream complexity as a critical contingency in influencing supply chain management (Bode and Wagner 2015, Bozarth et al. 2009). Operations managers need to take upstream complexity into account in managing importing security which relies on firms' smooth communications and coordination with suppliers in activities such as packaging, containerization, documentation, insurance, storage, and importing and exporting regulations. In the context of SCS management, we examine whether and how upstream supply chain complexity affects the effectiveness of C-TPAT certification as a signal to convey firms' commitment-to-SCS to stakeholders. Specifically, we seek to explore whether the complexity inherent in the interface between the firms' importing activities and their upstream supply chains influences the signaling effects of C-TPAT certification.

The remainder of the paper has the following organization. Section 2 reviews the literature and proposes research questions. Section 3 develops theoretical framework and hypotheses. Section 4 presents data, research methodology, and results. Section 5 discusses the implications for theory and practice, limitations, and future research directions.

3.2. Theoretical Background and Hypothesis Development

3.2.1 Conceptual Background

Existent studies on the performance effects of management standards such as ISO 9001 for quality management and ISO 14001 for environment management give mixed findings. For example, a large body of research has found significant and positive relationship between management standard adoption and firm (or plant) operational performance (e.g., Corbett et al. 2005, Lo et al. 2014, Prajogo et al. 2012) while some studies have found insignificant relationship (e.g., Heras et al. 2002, Martínez-Costa et al. 2009, Terziovski et al. 1997).

Although these studies provide fruitful insights on the values of management standards implementation, they may also be prone to the following limitations. (1) Some studies used a small sample of self-administered survey study based on

perceptual measures where the selection bias has not been satisfactorily addressed (e.g., Whipple et al. 2009). (2) A stream of research used second-order performance metrics (i.e., financial performance) instead of first-order metrics (i.e., process compliance) to account for the effects of *process* management standards. This seems problematic because "second-order performance improvements also may be attributed to other non-operational factors, such as 'signaling', in which the certified company is treated more favorably by its customers and by the stock market, regardless of any realized, process-level benefits of certification" (Gray et al. 2014, p.3). (3) The use of *the resource-based view (RBV) of the firm* in management standards research is debatable. A number of research in operations management has heavily drawn on the RBV to argue that management standards are resources to adopter firms which help them generate competitive advantages vis-à-vis their competitors (e.g., Nair and Prajogo 2009, Prajogo et al. 2012). A recent discussion on the appropriateness of using RBV in operations management research (Ketokivi 2016) introduces two counterpoints regarding whether management practices could be considered as *resources*. For example, in view of the definition of RBV in Barney (1991), Bromiley and Rau (2016) argue that "most practices are not rare or impossible to imitate. Indeed, operations management scholars generally want to identify practices that many firms can implement". Therefore, RBV may not be applicable in explaining how management practice as a resource can help firms generate competitive advantage. On the contrary, in response to Bromiley and Rau (2016), Hitt et al (2016) defend the relevance and value of using RBV in operations management research by arguing that although firms "commonly engage in a number of similar practices (e.g., TOM, Benchmarking, etc.) but even so, they may complete them differently, because of different capability". The

inconclusive discussion shows that at least, the use of RBV is management standards research is debatable in the operations management literature.

Given that C-TAPT certification improves the relationships between certified firms and stakeholders (e.g., U.S. CBP and customers) by providing direct and tangible advantages in U.S. customs and strengthening customers' confidence in adopter firms' SCS management, rather than focusing on how management practice (i.e., C-TPAT) can be utilized as a resource for competitive advantage, this study takes a signaling theory perspective which fits better in the C-TPAT context. That is, RBV emphasizes how management standards help develop "capabilities necessary to perform the practices selected that, in turn, are used to help implement the desired strategy in an effective manner", which is more in line with how resource facilitates internal *process* improvement. By contrast, C-TPAT which focuses on building trust between adopter firms and stakeholders, is more in line with signaling perspective that looks beyond the "process-level benefits of certification" (Gray et al. 2014). As a result, drawing upon a perspective of non-internal operational improvement mechanism enabled by signaling C-TAPT certification, we examine whether and how C-TAPT certification could lead to increase in operational performance.

In view of the widespread recognition of SCS management, researchers have investigated the possible motivations (e.g., institutional forces) for the adoption of C-TPAT certification (e.g., Lun et al. 2008), established conceptual models to analyze security initiatives (e.g., Russell and Saldanha 2003), or employed mathematical modelling approach to optimize the inspection level to minimize costs of SCS

implementation (e.g. Bakshi and Gans 2007). These streams of research provide guidelines for researchers and practitioners to realize the importance of SCS practices and successfully implement SCS measures. However, whether and how C-TPAT certification adoption helps firms improve operational performance is largely unknown. Some researchers employed survey studies to examine the effects of SCS practices, suggesting that SCS practices lead to positive operational outcomes. However, these studies used perceptual constructs and could not fully address the sample selection bias (e.g., Whipple et al. 2009).

In addition, C-TPAT has significant security and throughput implications for U.S customs and importer firms. The current SCS literature mainly focuses on a universal implication of SCS practices for all firms without differentiating the context for which these practices are originally designed. That is, C-TPAT provides direct benefits for importer firms in customs clearance process (e.g., less inspection, priority for inspection, or exemption from inspection). More importantly, unlike other existing *process* management standards (e.g., ISO 9001 and ISO 14001) (see Linderman et al. 2010, Schroeder et al. 2008), C-TPAT certification provides direct benefits (such as faster border crossing and fewer inspections) to adopter firms by the certification body, the U.S Custom Border Protection. Prior studies did not highlight such difference in their analysis of the impact on firm performance. To fill these research gaps, our first research question is: *Does C-TPAT certification adoption improve importer firms' operational performance?*

Porter (1980) suggests that "a signal is any action by a competitor that provides a direct or indirect indication of its intentions, motives, goals, or internal situation" (p. 75). Such signals inform market participants about a firm's (competitive) intentions (Hei and Robertson 1991). Thus, signals communicate to stakeholders the value that a firm is creating for them (Rindova and Fombrun 1999). A signal is useful for reducing "information asymmetry" between two parties such that the signaler can convey its latent and unobservable attributes to the receivers through signaling behavior. (Connelly et al. 2011). Signaling theory has been applied to a variety of management literature such as human resource management (e.g., Suazo et al 2009), operations/supply chain management (e.g., Sarkis et al 2011), strategic management (e.g., Reuer and Ragozzino 2012), entrepreneurship (e.g., Janney and Folta 2003), organization behavior (e.g., Terlaak and King 2006) etc. For example, Reuer and Ragozzino (2012) investigated how signals of initial public offering (IPO) affect other firms' choices of governance (joint venture vs. acquisition). Their study shows that asymmetric information plays a critical role in influencing firms' acquisition deals and mitigating adverse selection and the value of signals is heterogeneous depending upon the characteristics of exchange partners, suggesting that strategic alliance should take signaling effect and firm contingency into account. Also, Terlaak and King (2006)'s empirical investigation examined the effect of ISO 9000 certified facilities from a signaling perspective. They argue that ISO 9000 certification helps adopter facilities obtain a competitive advantage through signaling capabilities of producing high-quality products. However, the positive effect of signaling is moderated by how buyers encounter difficulties in acquiring information about suppliers. In other words, management standards would help firms convey unobservable attributes to their stakeholders. In particular, since C-TPAT certification offers direct operational

advantages (e.g., faster border crossing in U.S Customs) to adopters, the signaling effects from C-TPAT adoption is likely to be delivered to adopter importing firms.

Signaling effect is particularly important in a complex environment because the signal can reduce the search time and cost for a supplier or a business partner (Connelly et al. 2011, Terlaak and King 2006). Complexity is a broad area in management studies (Anderson 1999). Recent studies have begun to focus on the firms' supply chain network complexity and how it affects firms' operational performance (e.g., Choi and Hong 2002, Bozarth et al. 2009). Complex adaptive system (CAS) perspective is applied to supply chain management studies in understanding how individuals adapt to the complex environment (Choi et al. 2001, Schneider and Somers 2006). Several scholars have urgent the necessity to take complexity into account in supply chain and operations management research (Bode and Wagner 2015, Vachon and Klassen 2002).

There are many definitions of supply chain complexity. Vachon and Klassen (2002) suggested that supply chain complexity has two dimensions (a form of technology and nature of information processing), both of which affect delivery performance (delivery speed and reliability). Their findings suggest that lowering degree of complexity could improve delivery performance. Supply chain complexity can also be classified as: *upstream*, *internal manufacturing*, and *downstream* complexity (see Bozarth et al. 2009). Choi and Hong (2002) used *structural* complexity in the supply chain consisting of *horizontal* (the total number of individuals within the same level), *vertical* (the number of levels in the system), and

spatial (the degree of dispersion among individuals in the system) complexity. In addition, from a dynamic perspective, complexity is categorized as *detail* and *dynamic* complexity where the former refers to "distinct number of components or parts that make up a system" while the latter means "the unpredictability of a system's response to a given set of inputs" (Bozarth et al. 2009).

In the context of this study, C-TPAT certification mainly concerns about the importing security in importer firms' upstream logistics flows (e.g., customs clearance) and their extended supply chain operations. Prior studies also suggested that upstream supply chain complexity affects supply chain performance (e.g., Bode and Wagner 2015). As a result, we study the *upstream* complexity associated with the signaling benefits from C-TAPT certification adoption. Because the importing dynamics associated with supplier portfolios in upstream supply chains can introduce complexity. We follow the widely-adopted definition of supply chain complexity in Bozarthe et al. (2009), which is "the level of detail complexity and dynamic complexity exhibited by the products, processes, and relationships that make up a supply chain". Thus, we examine how *detail* and *dynamic* complexity in firms' upstream supply chains influence signaling benefits. Since the origins of import goods vary significantly which can influence the difficulties in interpreting C-TPAT signals by stakeholders. In addition to *detail* and *dynamic* complexity, we conceptualize the source diversity of per-unit import goods as the *spatial* complexity (see Section 4.3). This conceptualization of supply chain complexity is similar to Bode and Wagner (2015)'s spatial complexity of "geographical spread of an organization and/or a supply base". The second research question guiding this study is: *How would the level of*

upstream complexity (detail, dynamic, and spatial complexity) influence the operational performance from C-TPAT certification?

This study conceptually and empirically investigates the signaling effect of C-TPAT certification on adopter firms' operational performance by analyzing a longitudinal data of adopter and properly matched non-adopter importers. We collect data from multiple sources: publicly traded importer firms' C-TPAT certification data, importing data, and financial data. The levels of the upstream complexity (*detail*, *dynamic*, and *spatial complexity*) in sample firms vary significantly, which provides a favorable context for testing the hypothesized effect of upstream supply chain complexity on operational performance. This study offers important theoretical and practical implications on whether and how certified importer firms can obtain signaling benefits from C-TPAT, providing broader insights for potential benefits from a management certification. This paper departures from prior work assuming that internal *process* improvements due to management practice implementation can contribute to the increase in operational performance (e.g., *RBV of the firm*), which is debatable in the operations management literature. We answer the call in Gray et al. (2014) that non-process compliance-related performance outcomes (e.g., operational performance) from certification can be attributed to non-operational factors such as "signaling". That is, we contribute to the management standards certification literature to develop the argument that the second-order effects (i.e., operational performance; first-order performance is the process-related outcome such as process compliance) can be obtained from signaling benefits. Based on the Coarsened Exact Matching (CEM) method and difference-in-difference analysis, the results of this study tend to

be more robust in comparison with previous research which relied on perceptual constructs and/or other matching methods subject to several limitations (see Section 4.2). Moreover, we show that the signaling benefits from C-TPAT certification are contingent on the levels of upstream supply chain complexity in firms. Specifically, a high level of upstream supply chain complexity increases the signaling value of C-TPAT certification, in which it brings higher operational performance to adopter firms than those with a low level of supply chain complexity. We also discuss how managers and policymakers could acknowledge the signaling effects of C-TPAT certification in firms' SCS management.

3.2.2. The Impact of C-TPAT Certification

It is common for firms to have security routines before adopting C-TPAT. To obtain the certification, candidate firms need to implement and internalize a variety of security measures required by the certifying body (i.e., the CBP) and strive to integrate all these security routines into a coherent whole (C-TPAT official site). Stakeholders (supply chain partners or customers) can understand the candidate firms' efforts in implementing extensive security measures once the firm is C-TPAT certified. Because of the objective third-party audit, C-TPAT certification has the credibility and observability serving as an effective instrument to signal to the stakeholders that adopter firms are generally committed to SCS management. As a result, C-TPAT certification can differentiate certified and non-certified firms based on their potential capabilities of managing SCS management.

C-TPAT certification provides a clear signal to the market and the CBP that the certified firm is paying attention to the potential security risks in their supply chain management, particularly on safely importing and distributing goods. Some businesses trade valuable and high-tech products that are highly *security-sensitive.* These firms have high demands to partner with highly reliable firms that have lower security risks. For example, pharmaceutical companies and the Food and Drug Administration (FDA) urgent transport service providers to be security conscious because prescribed medicines may be hijacked in transit or warehouses, leading to the illegal drug dealing in gray markets. Stakeholders encounter difficulties in identifying reliable firms that are committed to SCS management standards because searching such partners is costly. As such, C-TPAT certified firms could be differentiated by stakeholders from non-certified firms on a better commitment-to-SCS management.

Under the pressure that stakeholders increasingly require that their business partners are commitment-to-SCS, firms may consider adopting C-TPAT certification in pursuit of a better corporate reputation and signal sound SCS management to stakeholders by communicating about their unobserved competences in SCS management. However, such certification requires considerable investments in implementing security standards into firms' daily routines. Specifically, C-TPAT certification costs incurred by importers are estimated on an average of 55,100 USD at the early stage for certification (Thomasnet.com. January 23, 2014) including implementation costs (e.g., IT system/database development) and C-TPAT maintaining costs (e.g., personnel hired for maintaining C-TPAT). Riskier firms would incur higher implementation costs because more works and changes are needed to be done to fulfill the audit requirements. Riley (2001) suggests that the cost of

implementing management standards is negatively related to the *ex-ante* management performance in the firm. That is, possibly it is more costly for firms with "below-average" SCS performance to adopt C-TPAT than firms with "above-average" SCS management. Consequently, certification is likely to be only beneficial for "above-average" firms, leading to "above-average" firms can and will go for certification while "below-average" firms tend not to go for certification. This logic echoes Terlaak and King (2006)'s "*certification must be advantageous only for the high-quality ones*". Therefore, certified firms could leverage the C-TPAT certification as an effective signal to convey their commitments-to-SCS to the stakeholders by reducing supply chain partners' *adverse selection* risk (Reuer and Ragozzino 2012) and increasing the confidence of supply chain partners in focal firms' security management. The C-TPAT certification can be rewarded by preferences (e.g., products or services) on certified firms by their stakeholders.

Accordingly, we argue that establishing a better-integrated security regime through adopting C-TPAT certification will benefit firms, enabling them to achieve a competitive advantage because it tends to be less costly for firms with "above-average" level of commitment-to-SCS to meet the stringent criteria for C-TPAT certification than firms with "below-average" commitment-to-SCS. Therefore, the expected competitive advantage from adopting C-TPAT certification can motivate "above-average" (i.e., high commitment-to-SCS) firms to go for the C-TPAT certification while "below-average" firms may by inhibited from adopting the certification. Moreover, importers can use C-TPAT certification as a signal of SCS commitment to U.S. CBP and receive "fast lane", less inspection, or exemption from inspection advantage in the customs clearance process. As evidenced by practitioners that "*The*

importer of record needs to identify if the reduction in shipping problems due to C-TPAT registration has a greater dollar value than the implementation costs. But organizations now registered in C-TPAT are, in fact, seeing positive results in their total landed costs" (Thomasnet.com. January 23, 2014), C-TPAT certification offers advantages to certified firms through signaling the commitment-to-SCS to their stakeholders, hence increasing orders from customers, and reducing supply chain disruption costs (e.g., delayed shipments). Taken together, C-TPAT certification adoption would help firms increase profitability and sales growth. Accordingly, this suggests the following two hypotheses.

H1: *C-TPAT certification adoption positively affects firm's profitability (i.e., ROA).*

H2: *C-TPAT certification adoption positively affects firm's sales growth.*

3.2.3. The Effect of Upstream Supply Chain Complexity on the Signaling Benefit

Although C-TPAT could bring signaling benefits to the adopting firms, the effectiveness of these signals can be contingent upon the varying levels of upstream supply chain complexity of the importer firms. Prior studies have demonstrated that the effectiveness of signals is apt to vary across supply chain characteristics (see, e.g., Narasimhan et al. 2015). Similarly, C-TPAT certification aims at streamlining the *upstream* supply chains for importer firms (i.e., faster lane priority, less inspection or exemption from inspection advantage for C-TPAT adopter at the U.S customs). Specifically, in customs clearance process, goods delivered to the notify or consignee

party (importer) that is C-TPAT certified can be subject to the above-mentioned advantages. As a result, the complexity embedded in upstream supply chains, specifically in the coordination between suppliers and importers in managing SCS is likely to affect the effectiveness of the signaling. Consider, for example, one importer experienced a significant increase in the number of overseas suppliers in a focal year (the country of origin may also vary), the importing procedures would be more complicated in customs clearance process.

In this study, we examine three types of complexity in the upstream supply chain, namely *detail*, *dynamic*, and *spatial* complexity, which are well-theorized in the literature (see, Choi and Hong 2002, Bozarth et al. 2009), in influencing the effectiveness of signaling SCS commitment through C-TPAT certification. Although there are many other dimensions of supply chain complexity in the literature, we argue that the three types of complexity in upstream supply chains fit better in the context of C-TPAT. Specifically, *detail* complexity means "distinct number of components or parts that make up a system" (Bozarth et al. 2009), *dynamic* complexity refers to "the unpredictability of a system's response to a given set of inputs, driven in part by the interconnectedness of the many parts that make up the system" (Bozarth et al. 2009), and *spatial* complexity is referred to as the "degree of dispersion among members within the system" (Choi and Hong 2002).

We argue that firms that have a high than the low level of complexity (*detail*, *dynamic*, or *spatial*) can better utilize C-TPAT certification as a commitment-to-SCS signal, thus enabling them to generate greater marginal revenues. The accorded

advantages from C-TPAT certification become strong incentives for importer firms with a high level of upstream supply chain complexity. Shorter custom clearance time can reduce variability and risk inherited from the complexities of firms' internal and external operations (Bowersox 2002, Lee and Whang 2005). That is, firms with a high rather than low level of complexity would adopt C-TPAT from a *rational* perspective (*rational* adoption). In other words, these firms are more motivated to pursue certification for operational benefits as it brings scale-economy advantage in cargo movement for trading, contributing to the increase in marginal revenues derived from faster cargo flows, priority in customs clearance, and a better relationship with the CBP, which can help effectively mitigate risks caused by a high level of complexity. *Rational* adoption may lead to *separating* equilibrium (see Gibbons 1992) where the signals regarding SCS management can be interpreted differently by stakeholders according to the level of supply chain complexity. In contrast, it appears that firms have a low rather than high level of upstream complexity may pursue C-TPAT certification due to *coercive* pressure or mimic adoption behavior (e.g., Jennings and Zandbergen 1995), in order to meet the minimal requirements in the institutional environment (*coercive* adoption). For example, buyer firms increasingly require transport carriers and suppliers to be C-TPAT certified, firms with a low level of upstream complexity are under pressure to adopt the certification. Accordingly, they may ambiguously signal C-TPAT certification to stakeholders through *coercive* certification without acknowledging the true value of the certification. That is, the *coercive* adoption may lead to *pooling* equilibrium (see Gibbons 1992) where stakeholders could not easily interpret the signals to discriminate between firms on their SCS management as all firms choose to adopt C-TPAT. Hence, *coercive* certification could not enable their stakeholders to discriminate their intended

commitment-to-SCS from others. Collectively, signaling benefits from *rational* adoption of C-TPAT certification (motivated by high complexity in the focal firm's upstream supply chains) can be more valued by stakeholders than *coercive* adoption of C-TPAT (due to the low level of complexity inherent in the focal firm's upstream supply chains), leading to greater competitive advantage for adopter firms having a high level of complexity.

Signal *observability* refers to how well the signal can be recognized by stakeholders. As noted by Connelly et al. (2011), "*observability* is a necessary but not sufficient characteristic of a signal". A high level of signal *observability* can result in the better differential ability for a stakeholder to discriminate between adopter firms on their commitment-to-SCS. The central role of effective signaling pertains to reduce information asymmetry (Connelly et al. 2011, Jiang et al. 2007). Therefore, the competitive advantage derived from C-TPAT certification would be contingent upon the extent to which stakeholders encounter difficulty in processing the information of commitment-to-SCS in adopter firms (*observability*). Consequently, successfully signaling commitment-to-SCS to stakeholders through C-TPAT certification can help adopter firms generate greater benefits when stakeholders encounter higher information asymmetry in processing such information (see, e.g., Folta and Janney 2004). In the context of importing security in the upstream supply chains, it is likely that a high level of complexity increases the signal *observability* to a greater extent such that stakeholders could value more on the signal of C-TAPT certification. As a result, C-TPAT certification can help generate greater competitive advantages for firms with a high degree of complexity in upstream supply chains. We separately

discuss how *detail*, *dynamic*, and *spatial* complexity would affect the signaling effectiveness as follows.

Detail complexity

Detail complexity in the upstream supply chains concerns the number of variables in the system (Bozarth et al. 2009). It can result in difficulty for stakeholders to acquire information about how and to what extent focal firms have committed to SCS, amplifying information asymmetries between the stakeholders and the focal firms. Such information asymmetries impose costs on stakeholders in verifying commitment-to-SCS in focal firms. Bozarth et al. (2009) find that the number of suppliers can be used to measure the upstream *detail* complexity. A great level of *detail* complexity in upstream refers to a large supply base comprising of a great number of suppliers for a buyer firm (e.g. Choi and Hong 2002).

It is possible that a high level of *detail* complexity (e.g., a high number of suppliers) in the upstream supply chain requires more efforts for stakeholders to articulate the underlying SCS management status in the adopter firms. Thus the signaling *observability* tends to be high. Choi et al. (2001) argued that the complexity of the supply base is associated with a buyer firm's extensive interconnectedness with numerous suppliers. Therefore, as the level of *detail* complexity increases, the interconnectedness among adopter firms and stakeholders will be diversified and difficult to manage due to the increased processes across cultures, regulatory requirements, technical standards, etc. (Yang and Yang 2010). However, C-TPAT certification can be used to differentiate high from low commitment-to-SCS firms.

Because a high *detail* complexity (e.g., a large supply base) can motivate importers to adopt C-TPAT from a *rational* perspective while a low *detail* complexity (e.g., a small supply base) can lead to the *coercive* adoption of C-TPAT. Therefore, *rational* adoption could help firms to clearly signal message about the commitment-to-SCS to stakeholders and stakeholders can react accordingly. As a result, the *detail* complexity inherent in the upstream supply chains could lead to greater signaling benefits from certification for firms having a high than the low level of *detail* upstream complexity. This suggests the following hypothesis.

H3: *C-TPAT certification adoption improves operational performance to a greater degree for importers that have a greater level of detail complexity than those have a lower level of detail complexity in their upstream supply chains.*

Dynamic complexity

Dynamic complexity is defined as "the unpredictability of a system's response to a given set of inputs, driven in part by the interconnectedness of the many parts that make up the system" (Bozarth et al. 2009). Similarly, a high level of *dynamic* complexity is associated with "situations where cause and effect are subtle, and where the effects over time of interventions are not obvious" (Senge 1990, p.71). Thus the *observability* of signaling C-TAPT tends to be high. Isik (2010) suggested that variability is associated with the variations of internal and external states (environment), thus if the types of the system elements change rapidly or unexpectedly, the *dynamic* complexity of the system increases. As a result, it is more difficult for stakeholders to overcome the uncertainty about how and to what extent that adopter

firms have dedicated to SCS management, due to high information asymmetries caused by the high level of the *dynamic* complexity in the upstream supply chain. *Dynamic* upstream supply chain complexity affects how stakeholders observe capabilities of focal firms in managing the turbulence and evolving interconnectedness of various factors in their upstream supply chains. For example, the change in the number of supply chain partners (suppliers) indicates how stable (unstable) the interconnectedness between the focal and partnering firms, affecting the ability of stakeholders to articulate the underlying commitment-to-SCS in focal firms. C-TPAT certification, on the other hand, can overcome the drawback of information asymmetry on firms' commitment-to-SCS where a high level of *dynamic* complexity could lead to *rational* adoption while a low level of *dynamic* complexity could result in *coercive* adoption. As a result, the signaling benefit (competitive advantage) is likely to be greater for firms having a high than the low level of *dynamic* upstream supply chain complexity. This suggests the following hypothesis.

H4: *C-TPAT certification adoption improves operational performance to a greater degree for importers that have a greater level of dynamic complexity than those have a lower level of dynamic complexity in their upstream supply chains.*

Spatial Complexity

Spatial complexity captures the degree to which geographical distances or sources of supplies disperse in the system (e.g., Choi and Hong 2002). The more dispersed the sources or distances in the focal firms' upstream supply chains, the higher the uncertainty that the stakeholders will encounter in processing information about the

underlying commitment-to-SCS in the focal firms. Dispersion of variables in the focal firms' upstream supply chains may influence the ways how focal firms interact with supply chain partners and how they could process information about their SCS management to stakeholders. C-TPAT certification may lead to higher signaling *observability* to firms with a high than the low level of spatial complexity in upstream supply chains by reducing information asymmetry to a greater extent. For example, the more diverse the sources of annual import goods per supplier, the more information processing, coordination, and monitoring costs may incur, due to the differing factors among different suppliers such as exchange rate fluctuations, trade restrictions, and cultural differences. As a result, a high level of *spatial* complexity can increase the *observability* of signaling C-TPAT certification to stakeholders.

Spatial complexity can manifest in various ways in a firm's upstream supply chain. Consider, for example, the more disperse (further away) the suppliers located from the focal firm, the more efforts that the focal firm may need to convey SCS dedication to its stakeholders because the *spatial* complexity inherent in the geographic distance hinders information processing regarding SCS management Importers having a high rather than low level of *spatial* complexity may adopt C-TPAT from a *rational* perspective instead of adopting it due to coercive pressure. *Rational* adoption can increase the value of C-TPAT signaling more than the *coercive* adoption. This suggests the following hypothesis.

H5: *C-TPAT certification adoption improves operational performance to a greater degree for importers that have a greater level of spatial complexity than those have a lower level of spatial complexity in their upstream supply chains.*

3.3. Method

3.3.1. Data

In this research setting, we collected data from multiple sources to test hypotheses. We focus on publicly listed companies in the U.S. because C-TPAT was developed and driven by the U.S. CBP and listed companies publicize reliable financial data which can be used for constructing variables of operational performance. There are indeed numerous initiatives regarding SCS management, (see, e.g., Table 1 of Hintsa et al. 2009). However, as motioned above, the C-TPAT program focuses particularly on U.S. border security, aiming at minimizing the risk of importing hazardous cargoes to the extended U.S supply chain (C-TPAT official website). The CBP provides the advantages of faster clearance and less inspection or exemption of inspection to the certified firms, which is likely to increase adoption of C-TPAT certification among importer firms if they consider efficiency in customs clearance as strategically important. Among many other SCS programs, the importing-focused SCS nature of the C-TPAT program allows us to investigate how upstream supply chain complexity could affect importer firms' operational outcomes after obtaining the C-TPAT certification.

We searched all the announcements pertinent to C-TPAT certification during 2006 to 2014 (a nine-year period). Because there is no publicly available database that

consolidates all the records of C-TPAT certified firms, to identify a preliminary list of certified firms, we thoroughly searched the Factiva/ProQuest/Lexis-Nexis online newspaper and periodicals database, corporate official websites, and corporate 10-K reports using the keywords "customs and trade partnership against terrorism" and "C-TPAT". Through the above steps, we found 194 C-TPAT certification adoption announcements. We read the full text of each announcement and excluded unsuitable announcements by taking the following steps: (1) We dropped 29 firms because they had not been listed on the U.S. stock exchange yet when they obtained C-TPAT certification. (2) Following practice in previous studies (e.g., Hendricks et al. 2014), for multiple announcements of C-TPAT certification adoption from the same certified firm, we only included the first announcement in our sample, thus eliminating another 13 announcements. The final sample comprises 152 announcements from 152 different publicly traded firms with the respective firm names and certification dates.

Relative to other SCS initiatives, the most distinctive benefits provided by the CBP for C-TPAT certified firms include faster lanes for customs clearance, inspection priority, or less/no-inspection privilege, etc. (C-TAPT official website). Due to these advantages grant to importers, we confine the research scope to U.S importers. The bill of lading records from the PIERS database contain comprehensive information about an importer and its importing records, including firm address, the name of oversea suppliers, import volumes, lading dates, etc. Once a U.S importer is engaged in foreign trade via ocean container transport, there should be manifest data captured by the CBP. We classify whether a C-TPAT certified firm is an importer or not by searching its name (in full and ticker symbol) in all the bills of lading records in *Import Bill of Lading Data* from the PIERS, IHS Markit database (from 2006 to 2014). Only

when a firm's name appears in any bill of lading records during this period, do we confirm that this firm is an importer. We double-check the credibility of the matching by looking at whether a firm's address (in the COMPUSTAT database) from our sample is consistent with that (consignee or notify party's address) in the bill of lading record. Among the 152 C-TPAT certified firms, we found that101 firms were involved foreign trade via ocean container transport, and we collected their import and supplier data from the bill of lading records accordingly. We then downloaded financial data of the 101 certified importers from the COMPUSTAT database for further analysis.

In the next step, we need to match a sample C-TPAT adopter to a C-TPAT non-adopter *importer* firm (control firm). We thus downloaded the company name and financial information of all the listed firms that have the same four-digit SIC codes with the sample firms during the study period from Standard & Poor's COMPUSTAT database. These firms are candidate control firms that have importing records in PIERS database from 2006 to 2014. We merged the three data sources, namely, online newspaper and periodicals database, lading record database, and COMPUSTAT financial database for testing our hypotheses. Table 3-1 reports the distribution of the sample importer firms.

Table 3-1. Distribution of Sample Firms

Categories	***N***	**%**	**Adoption year**	***N***	**%**
Food and kindred products	7	6.9	2006	4	4.0
Apparel & other textile products	1	1.0	2007	18	17.8
Lumber and wood products	2	2.0	2008	5	5.0
Paper and allied products	11	10.9	2009	8	7.9
Printing and publishing	4	4.0	2010	5	5.0
Chemicals and allied products	10	10.0	2011	14	13.9
Primary metal industries	5	5.0	2012	13	12.9
Fabricated metal products	3	3.0	2013	19	18.8
Industrial machinery & equipment	24	23.8	2014	15	14.9
Electronic & other electric equipment	23	23.0	Total sample firms	101	100
Transportation equipment	3	3.0			
Instruments & related products	1	1.0			
Misc. manufacturing industries	2	2.0			
Other industries	5	5.0			
Sum	101	100			

Note. 152 U.S. publicly listed firms are identified as C-TPAT adopters (with adoption dates and years) during 2006 to 2014, among which 101 are U.S. importers (confirmed with reference to the CBP's bills of lading records).

3.3.2. Matching

To answer the first research question, we examine whether C-TPAT certification adoption is associated with significant improvement in adopter firms' operational performance. We need to match each sample firm (i.e., a C-TPAT adopter importer) to a control firm (i.e., an importer firm that has not adopted C-TPAT) that has very similar *ex-ante* characteristics with the sample firm. Prior research regarding creating sample-quasi control pairs to compare performance outcome prior to and post an event has emphasized that only a robust matching can yield comparable sample-control pairs (e.g., Barber and Lyon, 1996, Corbett et al. 2005, Hendricks et al. 2014).

We adopt the Coarsened Exact Matching (CEM, see King et al. 2010, Lacus et al. 2012) method to select a control firm for each sample firm. CEM approach balance on pre-certification covariates between control and corresponding sample firm. The CEM method is similar to Barber and Lyon (1996) and Corbett et al. (2005) but has several superior advantages over other matching algorithms because it "generates matching solutions that are better balanced and estimates of the causal quantity of interest that have lower root mean square error than methods under the older existing class, such as based on propensity scores, Mahalanobis distance, nearest neighbors, and optimal matching", for the details, see Lacus et al 2011 (p.359).

Specifically, unlike other matching algorithms such as propensity score matching, CEM doesn't require "determining *ex ante* the size of the matched control sample, then ensuring balance *ex post* ". That is, CEM performs exact one-to-one matching by coarsening a set of covariates, ensuring that "strata have at least one treatment and one control unit, then running estimations using the original (but pruned) uncoarsened data" (Aggarwal and Hsu 2014). For instance, using the single nearest neighbor matching method from propensity score matching can lead to imbalanced covariates between sample and control firms. The common practice to achieve the balance is to minimize the *caliper* size which is the difference between sample and control firm's propensity scores, yet the number of pairs of sample-control firms used for the subsequent regression will be reduced accordingly (Lacus et al. 2012, Rosenbaum and Rubin 1985). Consequently, the attrition for sample and control observations may bias the results from the regression analysis. To overcome this, the CEM has been applied to numerous management studies as a more stringent matching method (see recent papers using the CEM, e.g., Agrawal and Hsu 2014, Overby and Forman 2015, Singh and Agrawal 2011). A recent example of CEM application in operations management research is Gray et al. (2014).

We obtained a set of candidate control importer firms from COMPUSTAT database (see Section 4.1). The CEM method requires matching on categorical dimensions on an 1:1 basis between a sample and a control firm. Following Abadie and Imbens (2006) and Gray et al. (2014), we match a sample C-TPAT certified importer firm to a non-certified importer firm with replacement (a non-certified firm can be matched to several sample firms once the criteria set met) based on the criteria below. (1) Four-digit SIC code; (2) public-traded firm; (3) importer firm; (4) employee

number category (six discrete buckets): < 300, 300-1,000, 1,001-2,500, 2,501-5,000, 5,001-8,000, and > 8,000; (5) Sales (in $ MM, four discrete buckets): < 10,000, 10,001-20,000, 20,001-30,000, and > 30,001). The selection of these criteria and buckets involves trade-offs between the fraction of the sample (whether a match can be found for a sample) and the stringency of the matching criteria (see Singh and Agrawal 2011, p. 138). "Public" and "importer" criteria are used for controlling firm type, "four-digit SIC code" ensures sample and control firms are comparable within the same industry, "employee number" and "sales" are the two metrics to account for the firm size and marketing capability. The five criteria have been considered comprehensive in matching (e.g., Gray et al. 2015, Lo et al. 2014, Singh and Agrawal 2011) to ensure highly comparable sample-control pairs. We matched a sample firm to a control firm meeting the above criteria by using data from the year when the sample firms implemented C-TPAT certification, which is consistent with recent studies (e.g., Gray et al. 2014). Finally, we matched 101 C-TPAT certified sample firms with 77 control firms. That is, some controls are matched to more than one sample firm. Table 3-2 gives the characteristics of the sample and matched control firms based on CEM method. A series of *t*-tests show that sample-control differences are not significant at 5% level, suggesting that the CEM matching has achieved balance (sample-control pairs are highly similar) without comprising any sample observations to ensure *ex-post* balance (propensity score matching could be subject to this methodological disadvantage).

Table 3-2. Matching Criteria and Results of CEM

	Certified	Matched

	Mean	S.D.	Mean	S.D.
Employee number	3,141	2,872	3,346	2,804
Sales	24,412	14,819	23,918	12,556
Four-digit SIC code same?	Yes			
Publicly traded firm?	Yes			
Importer firm?	Yes			
N	101		77	

Note. Some firms are matched with more than one certified firms (matching with replacement, see Section 4.

3.3.3. Measures

Dependent variable. We measure firm's operational performance using two metrics: return on assets (ROA) and sales growth. ROA is a widely adopted financial measure to account for the overall efficiency on how a firm's assets can generate profit (e.g., Hendricks and Singhal 2014, Su et al. 2015), which is calculated by taking the ratio between a firm's operating income (before depreciation) and total assets. We use this metric to examine whether and how adopter firms could experience an overall improvement in operational efficiency through C-TPAT signaling benefits. Sales growth is the annual growth in relative to previous year's sales (e.g., Covin et al. 2006, Lo et al. 2014), which is the ratio between the difference of sales (difference of two consecutive years) and the sales of the earlier year. Sales growth is used as a direct measure to capture how market and stakeholders react to the signaling of C-TPAT certification.

Independent variables. To test hypotheses 3 to 5, we construct *detail*, *dynamic*, and *spatial* complexity as follows. We use the number of suppliers to measure *detail* complexity in adopter firm's upstream supply chain. The greater the number of suppliers in importer firm's upstream supply chain, the greater the level of *detail*

complexity will be (Choi and Hong 2001). *Dynamic* complexity is measured by the change rate of the number of supplier between two consecutive years. This variable helps captures how the variability of complexity in upstream supply chain affects the signaling benefit of C-TPAT certification. In the context of this study, *spatial* complexity in upstream supply chain reflects how diverse (disperse) in terms of supplier per unit import goods. That is, the more diverse the supplier origins per unit import goods, the higher the level of upstream complexity. Consider, for example, firm A has only one supplier supplying 60 units of goods annually to A while firm B imports from three different suppliers with an equal annual import volume of 20 units from each supplier. Although the total annual import volumes are the same for both firms, the levels of complexity in dealing with SCS management with suppliers in two scenarios tend to be different. It can be assumed that the complexity of dealing with SCS issues in firm B will be higher than that of firm A because SCS decision making and coordination is more disperse in firm B than that in firm A. Hence, we use the well-established inverse of concentration index (*Herfindahl-Hirschman Index, HHI*, see, Derfus et al. 2008) to measure *spatial* complexity (the degree to which supplier per unit import goods disperses). In this study, HHI_k is defined as the concentration of supplier per unit import goods. $HHI_k = \sum_{s=1}^{n_s} r_{k_s}^2$, where r_{k_s} is the ratio between annual import volume from supplier *s* and the total annual import volume from all suppliers in firm *k*. n_s is the total number of suppliers of firm k. Accordingly, *spatial* complexity in firm k is the inverse of the concentration index, i.e., 1-HHI_k.

Control variables. We control for the following variables which may affect the importer firms' performance. *Firm size* is the natural logarithm value of the total

number of employees. *Market value* is measured by the Tobin's Q ratio (e.g., Chung and Pruitt 1994). Consistent with previous econometric analyses (e.g., Baum and Wally 2003 and Su et al. 2015), it is important for us to control for the potential effects of current firm performance (i.e., dependent variable of year *t*) in predicting future dependent variable (year *t*+1 and *t*+2). Hence, we use DV (*t*) to control for the possible portion of heterogeneity resulting from past performance (e.g., Greene 2002, Wooldridge 2009). The *import volume* (natural logarithm of annually imported container volume) and the *volume change rate* (the difference between two consecutive years' import volume over the early year's import volume) would affect firm performance as well. We control for the two variables in the regression models as well. ISO certification experience may have an impact on firm's operational performance. However, compared with C-TPAT certification, which was initiated right after the 9/11 terrorist attack in 2001, ISO series certifications such as ISO 9001 for quality management and ISO 4001 for environment management have been diffused in the industries for more than 30 years (since 1987). Consequently, many companies especially publicly-traded ones have already adopted ISO. We carefully checked the samples and found that the majority of them are manufacturing firms, suggesting that they are more urged to adopt quality and environment management standards due to institutional forces (e.g., customers and government agencies request manufacturing firms to showcase their efforts on quality and environment management). Therefore, it is highly possible that both the sample and its control firms in the regression analysis are ISO adopters such that there may be no differentiated effects if ISO indicator variables (ISO adopter = 1, non-adopter = 0) are included. To further provide evidence for this judgment, we randomly selected 20 sample companies and their corresponding control firms (20 control firms) in the analysis.

Among the 40 firms, we were able to confirm that 31 and seven firms are ISO adopters from their official websites and Factiva news database, respectively. The remaining two companies are subsidiaries of two parent companies. In practice, subsidiaries should adopt ISO certification if their parent companies are adopters. We confirmed that their parent companies are indeed adopters. It is not surprising that U.S. manufacturing firms (especially listed firms that have greater exposures to the public) are ISO adopters.

3.3.4. Econometric Modeling: Difference-in-Difference Analysis

Given that our data is longitudinal across multiple subjects (i.e., firms), we consider partitioning variance between- and within-subjects (see Fitzmaurice et al. 2011). To test H1 and H2, we use a Difference-in-Difference (DID) analysis (Wooldridge 2009) to address the potential variability existing between-subject differences (e.g., the persistent mean-level difference in ROA) and within-subject differences over repeated measurements (e.g., variation in a firm's yearly ROA from its mean ROA for the study horizon) (Fitzmaurice et al. 2011). The availability of both *ex-ante* and *ex-post* C-TPAT certification data allows us to remove all stable sources of between-firm variability, leaving the only variability within firms over time. It is important to remove the between-firm variability in the analysis because it can affect outcome variables (e.g., Jacobson 1990). The DID analysis has been widely used in the literature to examine the impact of an event on performance during *ex-ante* and *ex-post* periods (e.g., Aggarwal and Hsu 2014, Gray et al. 2014, Overby and Forman 2015).

To understand the hypothesized effects of C-TPAT certification on importer firm's operational performance, we use a DID analysis to detect whether there is a statistically significant difference between (i) the difference in outcome variables between certified importer firms and their matched control firms in pre-certified period (*ex-ante* difference) and (ii) the difference in outcome variables between certified importer firms and their matched control firms in post-certified period (*ex-post* difference). That is, the following OLS model specifies a DID regression.

$$Y=\alpha_0 + \gamma_0\, Post + \alpha_1\, Certified + \gamma_1\, Post \times Certified + e$$

where Y is ROA or Sales growth, *Certified* is a binary variable, taking a value of 1 for all certified importer firms and 0 for all control firms. Similarly, *Post* takes a value of 1if the outcome variable lies in post-certified period for both certified and non-certified control firms, 0 otherwise (*Post*=0 if the outcome variable lies in pre-certified period for both certified and non-certified firms). e is an error term. Intuitively, we expect a significant and positive γ_1 to indicate that the difference in the post-certified period between the certified firms (*Certified* = 1 and *Post* = 1) and their matched control firms (*Certified* = 0 and *Post* = 1) is greater than the difference in pre-certified period between the certified firms (*Certified* = 1 and *Post* = 0) and their matched control firms (*Certified* = 0, *Post* = 0). No control variables are included in this step because the "(sample firms) are matched" (Gray et al. 2014). Table 3-3 gives the results of the DID OLS regressions. As can be seen, in the ROA model of year *t*+1, the key variable of *Certified* × *Post* is statistically significant at 1% level, suggesting that C-TPAT certification positively affects importer firms' profitability (ROA). The result of ROA model in year *t*+2 also suggests that certification leads to significant

increase in ROA ($p < 0.01$). Moreover, the two key variables of *Certified* × *Post* in sales growth models of years t+1 and t+2 are also statistically significant at 1%. Collectively, the results show that C-TPAT certification helps importer firms improve profitability and sales growth vis-à-vis matched non-adopters. Therefore, H1 and H2 are supported.

Table 3-3. Difference-in-Difference Analysis

	Year (t +1)		Year (t +2)	
Variable	ROA	Sales growth	ROA	Sales growth
Certified	0.003 (0.004)	0.002 (0.004)	0.001 (0.005)	-0.001 (0.003)
Post	0.015*** (0.005)	0.006 (0.004)	0.011** (0.005)	0.020*** (0.004)
Post × *Certified*	0.051*** (0.007)	0.068*** (0.006)	0.082*** (0.007)	0.051*** (0.006)
Constant	0.106*** (0.003)	0.083*** (0.003)	0.105*** (0.003)	0.090*** (0.003)
R-squared	0.036	0.028	0.033	0.027

Number of observations = 356 firms (all are matched).

*** $p < 0.01$,
** $p < 0.05$

3.3.5. Upstream Supply Chain Complexity

To test H3 to H5, we examine the effect of upstream supply chain complexity on firms' post-certification operational performance. Specifically, we test how *detail*, *dynamic*, and *spatial* complexity, measured by the number of suppliers, the change rate of the number of suppliers, and the source diversity of per-unit import goods, respectively, affect the operational performance in C-TPAT certified importer firms. Here, because our analysis only involves certified firms, but no longer a matched sample, we include control variables (see Gray et al. 2014, p.8) to account for their potential effects on the operational performance.

We first use OLS regression with residual analysis to find out whether heteroscedasticity exists. Using a *Breusch-Pagan* and a *White* test (Kosowski et al. 2007, White 1989), we confirm that the models are subject to heteroscedasticity problem (p = 0.000). One approach to address this is the panel- fixed effects with robust standard errors approach (e.g., Stock and Watson 2008). However, in our study, the independent variables of *detail*, *dynamic*, and *spatial* complexity do not necessarily update in the study period such that panel-fixed effect models could reduce multiple observations. Following Su et al. (2015), we use panel generalized least squares (GLS) method to account for heteroscedasticity, which has been widely applied in management studies (e.g., Gedajlovic and Shapio 2002, Zhang and Rajagopalan 2010). We specify the following model to investigate the effect of supply chain complexity (*detail*, *dynamic*, and *spatial*) on firms' operating performance.

$$DV_{t+k}=\alpha_0+\alpha_i I_i + \alpha_i Y_i+ \alpha_1 \textit{ Market value}_k+\alpha_2 \textit{ Firm size}_k+\alpha_3 DV_{(t)}+ \alpha_4 \textit{ Import volume}_t +\alpha_5 \textit{ Volume change rate}_t + \alpha_6 \textit{ Supplier number}_t + \alpha_7 \textit{ Supplier change rate}_t +\alpha_8 \textit{ Diversity}_t + e$$

where I_i and Y_i are industry and year dummies, respectively, k = 1or 2 for the following two years' operational performance since certification adoption year (year t). $DV_{(t)}$ refers to the previous firm performance metric-ROA or sales growth and e is the random error term.

Table 3-4 gives the results of the control variables and independent variables of the *detail*, *dynamic*, and *spatial* complexity on operating performance of sample

firms. We check the variance inflation factor (VIF) in all models and find the maximum VIF is 3.37 (<10), suggesting that there is no multicollinearity problem (Cohen et al. 2013). The control variables of *import volume* are positive and significant in all models. It is intuitive that a higher level of import volume in a firm is associated with a higher operating performance after certification, which may be attributed to the tangible and direct advantages offered by the CBP in customs clearance process that help firms translate such advantages into monetary savings. *Detail* complexity, as measured by supplier number, is highly significant in all models. For instance, in model 1, $p < 0.01$, $\beta = 0.010$, suggesting that an increase in one unit of *detail* complexity is significantly associated with 0.01 increase in ROA across sample firms on average. Therefore, H3 is supported. *Dynamic* complexity, which is measured by the change rate of supplier number, is also a significant predictor of firms' operating performance. For example, on average, firms can expect 0.6% increase in sales in the first year after certificationn (in column 2, $p < 0.01$). This supports H4. Also, as measured by the source diversity of per-unit import goods (the inverse *HHI* of the volume of import goods from different suppliers), *spatial* complexity significantly increases the operating performance in C-TPAT certified firms. For example, in Model 4, on average, a unit increase in *spatial* complexity significantly leads to 0.079 increase of sales ($p < 0.05$). Thus, H5 is supported.

Table 3-4. The Effect of Upstream Supply Chain Complexity

	Model 1	Model 2	Model 3	Model 4
Variable	ROA (*t*+1)	Sales growth (*t*+1)	ROA (*t*+2)	Sales growth (*t*+2)
Firm size	-0.000	-0.002***	0.001	0.001
	(0.001)	(0.001)	(0.002)	(0.002)
Market value	0.000	-0.000	0.002**	0.002**
	(0.000)	(0.000)	(0.001)	(0.001)
DV (t)	0.109***	-0.0001	0.067	-0.004
	(0.014)	(0.002)	(0.043)	(0.003)
Import volume	0.003**	0.007***	0.015***	0.013***
	(0.002)	(0.002)	(0.004)	(0.004)
Volume change rate	0.001	0.000	-0.002	-0.002

	(0.001)	(0.002)	(0.003)	(0.003)
Supplier number (H3)	0.010***	0.018***	0.018***	0.022***
	(0.003)	(0.004)	(0.005)	(0.004)
Supplier change rate (H4)	0.004***	0.006***	0.010**	0.011***
	(0.002)	(0.002)	(0.005)	(0.005)
Diversity (H5)	0.195***	0.128***	0.080**	0.079**
	(0.044)	(0.041)	(0.032)	(0.034)
Constant	-0.062***	0.063***	0.064***	0.081***
	(0.017)	(0.012)	(0.018)	(0.019)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Wald's Chi2	20873.44***	11156.29***	2986.63***	2959.70***

Standard errors in parentheses. Heteroskedastic Panel structure is used. Observation number=101 firms.
*** $p < 0.01$,
** $p < 0.05$,
* $p < 0.1$

3.4. Discussion

The urgency to secure the global supply chain, in particular, to ensure the importing security in the upstream supply chains, has promoted government agency (e.g., U.S CBP) and supply chain partners (e.g., importing firms) to activity participate in security enhancement programs such as the C-TPAT. Although existent research has examined the SCS initiatives and firm performance (e.g., Whipple et al. 2009, Yang and Wei 2013), these studies used perceptual constructs on variables, did not fully address sample selection bias, and provided inconclusive findings on the benefits of C-TPAT certification. More importantly, prior studies did not differentiate C-TPAT certification from other *process* management standards where second-order performance outcomes may be attributed to non-operational factors such as signaling effectiveness. To this end, we investigate the benefits of C-TPAT certification from a signaling theory perspective. The data in this study come from multiple archive data sources (e.g., news announcements, importing records, and financial performance). We show that C-TPAT adoption can improve the *observability* and *credibility* of firms'

commitment-to-SCS to stakeholders, leading to increasing in firms' operational performance. Also, since information asymmetry can be affected by the levels of the upstream supply chain complexity, we examine whether and how the signaling benefits from C-TPAT certification are apt to vary across *detail*, *dynamic*, and *spatial* complexity in the importer firms' upstream supply chains. Collectively, the findings of this study complement to the stream of research on SCS and supply chain complexity by revealing that importer firms can use the signal of C-TPAT certification to convey commitment-to-SCS to stakeholders and the significant role of upstream supply chain complexity played in affecting operational performance.

3.4.1. Implication for Theory

This paper offers several important and novel contributions to theory in SCS management studies. Numerous studies have investigated management standard certifications such as ISO series certifications (e.g., ISO 9001 for quality management and ISO 14001 for environment management). These management standards are largely concerned about promoting improvements in adopter firms' internal process management (see Linderman et al. 2010, Schroeder et al. 2008), meaning "an organized group of related activities that work together to create a result of value to the customer" (Hammer 2002, p.26). An effective *process* management is expected to create knowledge (Linderman et al. 2010). However, direct or tangible benefits are not guaranteed from adopting such standards. Research has not studied whether or not adopter firms can obtain signaling benefits from certification which offers such benefits by the certifying body (i.e., CBP). This study uses a signaling theoretical perspective to examine the potential benefits that adopter firms can obtain from C-

TPAT certification, which is different in some ways from the conventional process management standards.

We use a robust method (i.e., CEM) to match sample firms with properly selected control firms and investigate the hypothesized signaling benefits from C-TPAT certification in adopter importer firms. We argue that C-TPAT severs as a signal by adopter importers to differentiate themselves from low commitment-to-SCS firms by reducing information asymmetry imposed to stakeholders. From a signaling-performance relationship view, we demonstrate that C-TPAT certification adoption is an effective signaling tool to convey commitment-to-SCS to stakeholders, leading to significant increase in operational performance (ROA and sales growth) in adopter firms.

The second research question in this study deals with the upstream supply chain contingencies that may affect the signaling benefits. Specifically, the signaling benefit of C-TPAT certification appears to be heterogeneous across importer firms varying in upstream supply chain complexities. We find that the benefit depends on the level of upstream supply chain complexity, which includes detail, dynamic, and spatial complexity. We first argue that C-TPAT certification is more advantageous for firms with a high level of upstream complexity because they tend to adopt C-TPAT from a rational perspective (they are motivated by the advantages of fast lane/less inspection or exemption from inspection in customs clearance process) while others may adopt certification only due to coercive reason to secure legitimacy. The distinct motivations of firms varying in levels of upstream complexity can lead to a higher

increase in marginal revenue for rational adoption (firms with high upstream complexity) than coercive adoption (firms with low upstream complexity). On the other hand, a high level of complexity may lead to the high signal observability of C-TPAT certification. That is, C-TPAT could strengthen the commitment-to-SCS in adopter firms perceived by stakeholders through C-TPAT certification when the upstream complexity in the focal firms is high than when it is low. Specifically, the level of detail, dynamic, and spatial complexity reflects the extent to which the upstream supply chain is complex in terms of the number of suppliers, the unpredictability of supplier change, and dispersion among sources of import goods splitting among suppliers, respectively, which provides a holistic view of upstream supply chain complexity in the context of importing firm's SCS management. As a result, our research contributes to the SCS management literature by bringing the attention to the effect of upstream supply chain contingencies on SCS management. In particular, signaling benefits from standard certification should not be considered "one size fits all", but taking supply chain contingencies into account could help firms better interpret and utilize the benefits.

This study also contributes to the broader management standards literature. Research on management standards (e.g., ISO 9001 or ISO 14001) give mixed results about the financial performance benefits generated from implementing these standards (see, e.g., Corbett et al. 2005, Singh et al. 2001). A school of research on standard management certification argues that such certifications could serve as resources to adopter firms in helping them generate competitive advantages from an RBV perspective (see, e.g., Nair and Prajogo 2009, Prajogo et al. 2012). That is, adopter firms could utilize management standards as heterogeneous and immobile resources

in facilitating them generate sustained competitive advantages vis-à-vis their revivals which are not able to access the resources (Barney 1991). However, the use of RBV of the firm in studying management practices is debatable in operations management literature (see Bromiley and Rau 2016, Hit et al. 2016, Ketokivi 2016). For example, the assumption that such resources (certifications) are difficult to imitate may be problematic (e.g., Su et al. 2015). In promoting these standard certifications, a certain degree of isomorphism (Deephouse 1996) across organizations is encouraged, leading to homogeneity (instead of heterogeneity) among organizations in the diffusion of management standards. In this study, the CBP claims that "from its inception in November 2001, C-TPAT continued to grow". That is, management standards may not follow the tenants of the RBV of the firm which argues that resources are rare, valuable, in-imitable, and non-substitutable in nature. As a result, RBV may not be appropriately used to argue that certification can create heterogeneity between firms, which is the source of competitive advantage and high performance. By contrast, we conceptually and empirically show that a competitive advantage could be generated from management standards through a signaling mechanism. Signaling theory does not assume that C-TAPT certification should be in-imitable and non-substitutable but argues that signaling effectiveness can enable adopter firms to generate competitive advantages. Specifically, C-TPAT certification creates a signaling-based competitive advantage where the source of the competitive advantage pertains to the signaling effectiveness of a firm's commitment-to-SCS relative to rival firms. Because information asymmetry exists between focal firms and stakeholders, management standard adoption helps reduce such information asymmetry and generate competitive advantages for focal firms. In particular, when tangible and direct benefits are offered by the certifying body, adopter firms can benefit from adopting certification by

signaling to their stakeholders that they could be accorded with such benefits, enabling them to obtain a competitive advantage. Therefore, it is noticeable that management standards like C-TPAT, differ from conventional process-based management standards with no direct operational advantages offered by the certifying body. Drawing upon a signaling function of such standard management certification, we demonstrate that market participants and a government agency can be informed by the high status of SCS management in adopter firms, leading to improvement in operational performance in adopter firms.

3.4.2. Implication for Practice

The results of this study also offer managerial implications for practitioners and policymakers. We use a rigorous matching and econometric analysis to study whether and how C-TPAT certification leads to improvement in operational performance in adopter firms, showing that adopter importer firms can expect improvement in operational performance compared with matched none-adopter firms. This alleviates the concern in the literature that C-TPAT may not be able to delivery positive return to investment but burden firms with a high cost for investment (e.g., Rice and Caniato 2003). As a result, potential adopters can expect an increase in profitability in particular for importer firms with high levels of upstream complexity. From a policy-making standpoint, the CBP may highlight the beneficial effects of C-TPAT certification on importer firms' profitability in promoting this program. The promotion targeting at importer firms with a greater level of complexity in supplier portfolio, (e.g., higher supplier number, greater change in supplier number, and greater source diversity of import goods) should be accorded a higher priority. The performance

value of C-TPAT certification should be cogently communicated to the target audience as well.

3.4.3. Limitation and Future Research Directions

This study is also subject to several limitations that future research could address. First, we study a sample of publicly traded U.S importer firms. The implications in this study may not be generalizable to other contexts such as private firms whose financial data is not publicly available, and operating environments differ significantly from public firms. A survey study can be conducted to understand the operational performance change due to certification in private firms. Second, the complexity of supply chain in this study is restricted to upstream supply chain because C-TPAT certification is mainly focused on importing activities where smooth communications and coordination with suppliers in packaging, containerization, documentation, insurance, storage, and importing and exporting regulations are needed. However, it would also be interesting to study how downstream complexity may affect the signaling benefits from C-TPAT certification. As noted by Bozarth et al. (2009) that downstream complexity can be constructed by "the number of customers, the heterogeneity of customer needs, the average length of the product lifecycle, and the variability of demand". Future research is encouraged to study how such variables may also influence how adopter firms convey commitment-to-SCS through signaling C-TPAT certification. In addition, other than security of cargo, firms may also consider how the safety of firms' internal processes could be improved and how such processes may be influenced by the broader external environment.

Chapter 4. Essay 3: Managing Maritime Safety in Global Operations: The Effect of National Culture

4.1. Introduction

Lower trade barriers and information technology over the past few decades have fueled globalization (Friedman 2005). As a result, firms increasingly operate across global boundaries to take advantage of sourcing opportunities and expand into new markets (Chung and Alcácer 2002, Ferdows et al. 2016, Fuchs and Kirchain 2010). However, as firms expand operations across national boundaries, they also face new challenges. In particular, managing safety in the global economy presents new challenges for operations managers. For example, in 2013 the Rana Plaza building in Bangladesh collapsed, which resulted in over 1,100 deaths. Organizations that sourced production from Bangladesh failed to fully account for safety issues. Managing safety across national boundaries may require understanding the role of national culture. For instance, the Asiana Airlines Flight 214 crash in 2013 illustrates the effect of national culture on safety. Reports on the safety incident noted that "what they were struggling with was a cultural legacy, that Korean culture is hierarchical. The strong Confucian culture led to deference to hierarchal authority in the cockpit which contributed to the safety problem" (*The Diplomat*, July 16, 2013). In discussing the resolution to the problem, the director of flight standards at the South Korean transportation ministry said: "It's true that authoritarianism existed in the cockpit until the late 1990s (of South Korean flights) but we have now a completely different culture" (*The Diplomat*, July 16, 2013). This suggests that they were able to develop an internal safety culture to

counterbalance the national culture. Operations managers need to understand the relationship between the organization's internal safety context and national culture when operating in the global economy.

In the global economy, firms face the challenge of managing operations across national boundaries, which includes understanding cultural differences. Several scholars have investigated the role of national culture in managing operations (e.g., Flynn and Saladin 2006, Gray and Massimino 2014, Pagell et al. 2005). Recently, Lu et al. (2012) investigated how seafarers' perception of national culture influences their work safety in shipping operations. To our best knowledge, none of these studies examine the relationship between an organization's internal safety context and their situated national culture. High profile safety incidents have increased the attention to safety in the global economy. Increasing pressure from international NGOs (e.g., Greenpeace) has caused multinational organizations to focus more attention on managing safety across their global operations. For example, after the catastrophic garment-factory building collapse in Bangladesh, the international community put pressure on multinational brands and retailers that source from factories in Bangladesh to improve safety. Over forty multinational brands and retailers (such as WalMart and VF corporation) signed the agreements *Accord on Fire and Building Safety in Bangladesh* and *Alliance for Bangladesh Worker Safety* within sixty days of the incident and promised to provide financial and technical assistance to improve factories' safety. The Asiana incident further highlights the importance of understanding national context. Managing safety across national boundaries requires an understanding of the role of national culture to effectively address safety issues (Casey et al. 2015, Mearns and Yule 2009). Given the importance of safety

management in the national culture context, this study investigates the following research question: *What is the role of an organization's internal safety context and national culture on safety accidents?*

This study examines the influence of national culture on safety in the context of the maritime shipping industry. Maritime shipping is one of the most international and dangerous industries in the world[2]. It involves carriers from many different countries servicing locations worldwide with a long history of tracking and monitoring safety-related accidents due to the need for regulatory compliance (e.g., International Convention for the Safety of Life at Sea by the International Maritime Organization). Maritime shipping firms come from diverse countries with distinct national culture differences. The physical movement of cargo across oceans and ports by ships expose the workers to various safety risks. Safety incidents frequently occur during operations and range from minor safety incidents to severe accidents. For example, over the last decade there has been around 1.5 safety incidents per ship year, and on average at least one severe accident for each ship per year (Llyod's List). These statistics highlight the importance of safety in the shipping industry.

[2] For example, according to the National Safety Council of the U.S., transportation is one of the most dangerous industries in terms of the total number of human injuries (*Most Dangerous Industries for Workplace Injuries and Deaths*). In particular, maritime shipping involves carriers from many different countries servicing locations worldwide, shipping operations are vulnerable to various risks on the sea where humanitarian actions take longer time than other industries. We divided the total number of safety incidents by the total number of registered merchant ships under the International Maritime Organization on a yearly basis. On average, every ship is subject to 1.5 safety incidents per year. This number seems not so high at first glance, but compared with other highly reliable industries such as nuclear power generation and aircraft manufacturing which are almost accident-free, it highlights the safety concerns in maritime shipping operations

This research uses longitudinal data to analyze the effects of national culture and ship's internal context (*attentiveness to safety*) on accidents. The results show that ship's *attentiveness to safety* affects accidents. However, national culture moderates the effect of *attentiveness to safety* on accidents. Drawing on the Hofstede's dimensions of national culture, we show that the dimensions of Power Distance and Individualism amplify the relationship between *attentiveness to safety* and accidents, whereas Uncertainty Avoidance mitigates this relationship. That is, a low *attentiveness to safety* results in even higher accidents in countries with high Power Distance, high Individualism, and low Uncertainty Avoidance. However, the analysis shows that ships with high levels of *attentiveness to safety* can overcome the influence of national culture.

This paper contributes to the literature as follows: First, it shows that an organization's internal safety context influences the likelihood of accidents. However, the national context (national culture) significantly moderates the effect of the organization's internal safety context on accidents. As safety becomes increasingly important to multinational firms, they need to recognize how national context influences their ability to manage safety. Organizations will need to place a greater emphasis on developing a strong internal *attentiveness to safety* when operating in environments characterized by high Power Distance, high Individualism, or low Uncertainty Avoidance. More broadly, organizations benefit from developing a strong internal context for safety when the national context does not support safety. This study also contributes to our understanding of how to manage across national boundaries, especially with rising pressure from NGOs to promote a safe workplace for employees.

The rest of the paper has the following organization: Section 2 provides the research background information. Section 3 develops the hypotheses. Sections 4, 5, and 6 present the methods, results, and additional analyses, respectively. Finally, Section 7 discusses the theoretical and managerial implications.

4.2. Conceptual Background

4.2.1. Safety

Over the past few decades, much the research on operational performance has focused on conventional constructs like cost, quality, flexibility, and delivery (Ward and Duray 2000). More recently, research in operations management has recognized the importance of safety. Brown (1996) provided one of the first calls for research on workplace safety in the operations management literature and included safety as a dimension of social responsibility. Since then research on safety has started to emerge in the operations management literature. For example, Das et al. (2008) linked employees' perceptions of a safe work environment to quality outcomes, that is, safety contributes to quality outcomes. Lo et al. (2014) found that getting a safety management certification improves operational and financial performance. Their empirical results show that adoption of standard safety management practices improves a firm's long-run operational performance. However, some scholars argue that there is a trade-off between safety and productivity. That is, increasing safety comes at the expense of productivity or vice versa. For instance, Haunschild et al. (2015) argued that organizational accidents shift focus from innovation to safety. Their findings suggested a trade-off between safety and innovation. However, some

empirical research found that safety and operational effectiveness can complement one another through a coordinated joint management system (e.g., Pagell et al. 2015). In particular, Pagell et al. (2014) conducted a case study and found that establishing the *Joint Management System for Operations and Safety* led to both a safe work environment and higher productivity. They argued that safety reinforces operational performance. Another stream of research investigates how leadership and behavioral issues influence safety. Koster et al. (2011) identified the critical antecedents to safety performance, which included hazard reducing system (HRS), safety-specific transformational leadership (SSTL), and safety consciousness (SC). Vries et al. (2016) extended this study to investigate the effect of SSTL on operational outcomes (other than safety outcomes). They found that SSTL positively influences safety. We extend and build upon these prior studies to investigate how the relationship between an organization's internal context (*attentiveness to safety*) and their situated national context (national culture) affects safety.

4.2.2. Internal Context: Attentiveness to Safety

An organization's internal context may have an impact on safety. In safety literature, the internal context refers to the organization's safety culture, climate or *mindfulness* towards safety. Organizational culture is the underlying shared values and assumptions held among organizational members (Schein 1992). Safety culture is organizational members' shared "assumptions and values as they relate specifically to safety practices" (Pagell et al. 2014, p. 1163). Zohar (2003) noted that a safety culture involves "shared perceptions with regard to safety policies, procedures, and practices." Scholars also note that safety culture tends to be a tacit or unarticulated shared

assumption among diverse organizational members (Dejoy et al. 2004, Pagell et al. 2014).

Scholars have begun to recognize the importance of a safety culture and safety performance. For instance, Dillon et al. (2016) conducted a study of near-misses at NASA and found an inverse relationship between safety culture and the frequency of near-miss events. Pagell et al. (2014) noted that an emphasis on "getting work done over doing work safely" results from safety practices that do not go beyond explicitly stated safety procedures and policies. That is, mindlessly following safety procedures and policies may not result in safety outcomes. This further suggests that safety culture may not be appropriately measured by observing if an organization simply follows the safety procedures and policies. As a result, safety culture differs from having safety procedures and policies in place. Safety culture is more about the values and commitment to safety than the policies and procedures alone. Emerging research supports the view that safety culture is more strongly related to safety performance than simply implementing policies and procedures (e.g., Dillon et al. 2016, Høivik et al. 2008, Naveh et al. 2005, Phipps and Ashcroft 2012).

Collective *Mindfulness* refers to organizational members' attention allocated to "unexpected deviation that needs to be corrected" (Weick et al. 2008). *Mindful* organizations pay careful attention to safety problems and have a safety culture (Lo et al., 2014) while less mindful organizations lack the capability to reduce distraction and cannot hold an intended safety object in mind (Weick and Sutcliffe 2006). Studies show that minor incidents are seldom interpreted as failures because organizational members tend to interpret minor incidents as "good fortune" and pay insufficient

attention to them (e.g., Tinsley et al. 2011, Dillon et al. 2016). As a result, a lack of *mindfulness* (or *mindlessness*) to safety indicates a weak "capability to detect and manage unexpected events" (Weick et al. 2008).

The safety culture and *mindfulness* literature suggest that organization's internal context can impact safety performance. Organizational members' attention on safety plays an important role in predicting how internal context affects safety. That is, the *attentiveness to safety* within an organization influences safety outcomes. The *attentiveness to safety* refers to a sustained consciousness or awareness of ongoing events or information that influences safety. With low levels of *attentiveness to safety*, organizational members will discount events or information that could influence safety. Vaughn (1996) described the concept of "normalized deviation" where organizational members started to treat small deviations in expected outcomes as normal, which over time increased the organization's exposure to risk. Vaughn (1996) investigated how the 1996 space shuttle challenger explosion was a result of the organization treating anomalies in the wear of o-rings as normal and almost expected overtime. As a result of treating small unexpected deviations in o-ring wear as expected, they did not detect the conditions that led to the 1986 space shuttle challenger explosion. The normalization of such minor safety events creates a risky internal safety climate and exposes the firm to severe safety incidents. In organization's daily operations, the frequency of minor safety incidents reflects their *attentiveness to safety*. If minor incidents frequently occur, organizational members typically have lower levels of *attentiveness to safety*. Organizations with low *attentiveness to safety* will discount warning signals that may lead to bigger problems in the future. Hence, the more frequent the number of minor incidents an organization has, the lower their

attentiveness to safety. In these situations, the organization doesn't pay enough attention to safety issues and takes more risks (Pagell et al. 2014, Tinsley et al. 2011). Taken together, the frequency of minor safety incidents indicates the level of *attentiveness to safety* within the organization.

4.2.3. National Context: National Culture

Johns (2006) defined *context* in terms of a "cross-level effect", whereby variables at one level may influence variables at another level. Hence, higher-level context variables may moderate relationships between lower-level variables and outcomes. In the global context, numerous studies have highlighted the importance of national culture on operations management (e.g., Flynn and Saladin 2006, Gray and Massimino 2014, Pagell et al. 2005). National culture relates to the "collective programming of mind among the members of one group" (Hofstede 1983). National culture has been well studied in the general management literature (see, e.g., Doney et al. 1998, Shane 1994). In the operations management, national culture studies have mainly focused on process compliance of global manufacturing firms (e.g., Gray and Massimino 2014), quality management (e.g., Flynn and Saladin 2006), service operations (e.g. Metters 2008), and supply chain integration (e.g., Zhao et al. 2008), etc. There has been limited research on national culture and safety, (e.g., Casey et al. 2015, Lu et al. 2012, Noort et al. 2016). Research has also not examined the effect of national culture on internal context and safety performance. This becomes increasingly important as organizations need to manage safety across different contextual settings in the global economy.

Several operations management scholars have used Hofstede's dimensions of national culture to understand the role of national context on operations (e.g., Flynn

and Saladin 2006, Gray and Massimino 2014). The Hofstede's (2001) dimensions of national culture include Power Distance, Individualism, Uncertainty Avoidance, Long-term Orientation, and Masculinity (more recently, Indulgence was added as an additional dimension). Studies have confirmed the validity of using Hofstede's national culture dimensions in different management disciplines (e.g., Casey et al. 2015, Doney et al. 1998, Flynn and Saladin 2006).

4.3. Hypothesis Development

4.3.1. Internal Context: Attentiveness to Safety and Accidents

Attentiveness to safety, as reflected by the frequency of minor safety incidents, indicates commitment and awareness of safety issues. In a high *attentiveness to safety* context, employees share the underlying assumptions and values about the importance of safety and are mindful of events and information that could influence safety. Consequently, organizations with a high *attentiveness to safety* will not discount events and information that could influence safety, will go beyond simply adhering to safety policies and procedures, and value the importance of safety (Pagell et al. 2014, Tinsley et al. 2011, Tinsley et al. 2012). When *attentiveness to safety* is low, employees may only follow through with policies and procedures and do not fully adhere to safety practices. Moreover, a high *attentiveness to safety* may discourage organizational members to quickly make tradeoffs for safety with productivity (Smith et al. 2003). Taken together, high levels of *attentiveness to safety* will discourage an overly optimistic view of the risks and hazards related to safety while low levels of *attentiveness to safety* will encourage an overly optimistic view of current safety

situation. As a result, organizations with high levels of *attentiveness to safety* will have few serious accidents in the future. This suggests the following hypothesis.

> ***Hypothesis 1 (H1):*** *The level of attentiveness to safety is negatively related to the likelihood of future accidents.*

4.3.2. National Context: The Effect of National Culture on Attentiveness to Safety and Accidents

Increasingly scholars recognize the importance of national culture in management. Research shows that national culture influences decision-making (Pagell et al. 2005), business strategies (Nakata and Sivakumar 1996), and managers' willingness to justify unethical behaviors (Cullen et al. 2004), to name a few. Studies have begun to show the importance of national culture in operations management (e.g., Flynn and Saladin 2006, Gray and Massimino 2014). As a result, national culture may also have implications for safety. We argue that national culture moderates the effect of *attentiveness to safety* on accidents. That is, the "collective programming" of the mind at the national level affects the mindfulness to safety within the organization.

We adopt Hofstede's et al. (1980, 2010) national culture[3] dimensions to study the effects of national culture on accidents. Previous studies in operations management

[3] Hofstede's national culture model was developed based on his research team's longitudinal study on national culture. He incorporated variabilities within a single country. In addition, the analysis in present study is not focused on the individual level, but a more aggregated organizational level. Therefore, once Hofstede's culture dimensions are applied, they are treated as a collective measure. There is indeed literature focusing on the individual level of national culture on safety performance. Hence, this concern may be mitigated by emphasizing the level of analysis. Studies also show that culture is relatively inert, which changes very slowly. As a result, the single culture measure of a country can still be valid for analysis. I admit that there still will be some variances due to varying culture within a country

have used Hofstede's dimensions of national culture and the associated measures (e.g., Doney 1998, Gray and Massimino 2014, Pagell et al. 2005). Hofstede (2001) has five dimensions of national culture: Power Distance, Individualism, Uncertainty Avoidance, Long-term Orientation, and Masculinity. More recently, they added a new dimension called Indulgence, but it has limited data (Hofstede et al. 2010). Gray and Massimino (2014) argued that Power Distance, Individualism, Uncertainty Avoidance, and Long-term Orientation apply to the operations management context. As a result, we only develop hypotheses around these dimensions, but we include the other dimensions as part of a *post hoc* analysis. The hypotheses for the moderating effect of the dimensions of national culture on *attentiveness to safety* follow.

4.3.2.1. Power Distance

Power distance (PDI) refers to the extent to which "the less powerful members of organizations and institutions (like the family) accept and expect that power is distributed unequally" (Hofstede 2001). In a high power distance culture, people in the lower position of the hierarchy tend to accept an unequal distribution of power and seldom question the authority or participate in decision-making that may affect them. In other words, people will more likely accept centralization of decision-making and allow autocratic and paternalistic power relations. Previous studies showed that in high power distance cultures, supervisors tend to make decisions without listening to employees' opinions. Similarly, employees in lower positions of the hierarchy may be less engaged in investigating safety risks. Also, in high power distance cultures, safety

not being captured. However, the robustness analysis presented in the thesis has mitigated the concern to some extent.

risk factors perceived by the employees are less likely to be reported to supervisors and discussed for follow-up actions (e.g., Håvold 2007, Lu et al. 2012). As a consequence, the level of power distance can influence the communication of safety concerns between high and low-level individuals. Power distance level can affect the effect of organization's internal context (*attentiveness to safety*) on accident. Specifically, high (low) power distance weakens (strengthens) the tendency that organizational members have a consciousness or awareness of ongoing events or information that influences safety. Therefore, power distance can moderate the relationship between *attentiveness to safety* and future accident likelihood by amplifying (mitigating) the tendency to be attentive to safety within an organization. This suggests the following hypothesis.

Hypothesis 2 (H2)*: Power distance level positively moderates the relationship between attentiveness to safety and future accidents, i.e., a high (low) power distance level amplifies (mitigate) the negative relationship between attentiveness to safety and the likelihood of future accidents.*

4.3.2.2. Individualism

Individualism (IDV) refers to the degree to which the national culture values the individual over group interests (Hofstede 2001). In a country with high individualism, the needs of the individual outweigh the needs of the many and people are motivated more by personal goals. The level of individualism in national culture is associated with allowing individuals to deviate from group norms (Flynn and Saladin 2006, Gray and Massimino 2014). That is, high (low) individualism tends to be more (less) tolerant to deviation from group norms. The internal context (*attentiveness to safety*)

involves group values related to safety practices. To maintain a safe working environment, employees need to collectively value safety. However, high levels of individualism allow for deviation from group norms, which may conflict with the values of maintaining a safe working environment. Therefore, the level of individualism moderates the influence of *attentiveness to safety* on accidents. That is, high (low) levels of individualism can amplify (mitigate) the negative relationship between the *attentiveness on safety* and the likelihood of an accident. Low levels of individualism, on the other hand, can motivate organizational members to work together to encounter safety problems such that the potential safety risks can be identified and fixed. As a result, a high (low) individualism level can strengthen (weaken) the negative relationship between organization's *attentiveness to safety* and accident likelihood. Accordingly, this suggests the following hypothesis.

Hypothesis 3 (H3)*: Individualism level positively moderates the relationship between attentiveness to safety and future accidents, i.e., a high (low) individualism level amplifies (mitigates) the negative relationship between attentiveness to safety and the likelihood of a future accident.*

4.3.2.3. Uncertainty Avoidance

Uncertainty is a state where the conditions and outcomes are unpredictable. Uncertainty avoidance (UAI) in national culture refers to the tendency to avoid or eliminate uncertainty (Hofstede 2001). In a high uncertainty avoidant culture, individuals feel uncomfortable with uncertain or ambiguous conditions, which in turn motivates people to reduce uncertainty (Hofstede 2001, Pagell et al. 2005). Numerous empirical studies have found an association between uncertainty avoidance and the

level of stability, conformity to rules and social norms, and risk aversion (e.g., Flynn and Saladin 2006, Lu et al. 2012, Pagell et al. 2005). An uncertainty avoidance (tolerant) culture would encourage employees to actively (less actively) seek solutions to potential safety risks. An organization with a strong *attentiveness to safety* values more certainty with respect to safety outcomes than an organization with a weak *attentiveness to safety*. Therefore, the level of uncertainty avoidance in the national culture moderates the effect of organization's *attentiveness to safety* on accident. Specifically, a high (low) level of uncertainty avoidance leads organizational members to be more (less) attentive to the underlying assumptions and values with regard to safety practices within the organization. As a result, high (low) in uncertainty avoidance level can weaken (strengthen) the negative relationship between organization's *attentiveness to safety* and accident likelihood. This suggests the following hypothesis.

Hypothesis 4 (H4)*: Uncertainty avoidance level negatively moderates the relationship between attentiveness to safety and future accidents, i.e., a high (low) in uncertainty avoidance level mitigates (amplifies) the negative relationship between attentiveness to safety and the likelihood of future accident.*

4.3.2.4. Long-term Orientation

Long-term Orientation (LTO) refers to "the fostering of virtues oriented towards future rewards, in particular perseverance and thrift" (Hofstede 2001, p 359). Safety policies and procedures are generally long-term oriented (Lo et al. 2014, Pagell and Johnston 2016), and the values related to safety take a long-term perspective. Long-term orientation motivates employees to comply with safety standards and policies in the

long run. In addition, in a long-term oriented culture, employees tend to recognize the long-term adverse impact of safety accidents. These tendencies lead employees to be more compliant with the standard safety procedures. In contrast, a short-term orientated culture shift employees' focus on immediate gratification. Thus safety goals may be compromised for other short-term gains. Consequently, a long-term orientation moderates the relationship between organization's *attentiveness to safety* and accidents. Specifically, a high (low) long-term orientation level may amplify (mitigate) the tendency of organizational members to be attentive to the underlying assumptions and values related to safety practices within the organization. Therefore, long-term orientation negatively moderates the association between *attentiveness to safety* and the likelihood of an accident. This suggests the following hypothesis.

> ***Hypothesis 5 (H5)****: Long-term orientation level negatively moderates the relationship between attentiveness to safety and future accidents, i.e., a high (low) long-term orientation level mitigates (amplifies) the negative relationship between attentiveness to safety and likelihood of future accident.*

4.4. Method

4.4.1. Sample and Data

We test the hypotheses in the context of the global maritime shipping industry. As previously stated, the global maritime shipping industry offers a favorable setting to investigate the role of national culture on the likelihood of accidents. The data comes from the Llyod's List Intelligence database, which consolidates all global merchant sea-going ships (over 100 tonnages) registered under the International Maritime

Organization (IMO) and their incident reports (from the year 1978 to 2015). The database contains rich details of incidents by ship, such as the incident date, severity of the incident, ship type, and ship's manager firm country, etc. Significant variations exist between ships and the national culture of the manager firms. The data for our analysis are less susceptible to selection bias since the database contains information about all merchant sea-going ships worldwide that have been registered with IMO. Moreover, the *United Nations Convention on the Law of the Sea* (*UNCLOS*) makes it mandatory that the flag state (the state under whose laws the vessel is registered or licensed) should conduct an inquiry into every marine incident (Audit Scheme, International Maritime Organization). Under this legal requirement, all maritime authorities have a legal obligation to make timely reports of maritime incidents, and failing to report is an offense with a fine up to tens of thousands of US dollars while reporting maritime incidents does not result in prosecution (e.g., Maritime New Zealand). This policy helps ensure a high accident reporting rate to the maritime authorities. These reports should help improve maritime safety. Lloyd's list has compiled all historical incident reports, and this secondary data is considered the most comprehensive among all commercial maritime accident database (*Marine Accident and Casualty Investigation Boards*). The database collects both minor safety incidents and severe safety accidents. Figure 4-1 gives the sea-going ship (over 100 tonnages) minor and severe accident frequency by ship year. This figure shows that the overall frequencies of both minor and severe accidents fluctuate but remain at relatively high levels. Table 4-1 reports the descriptive statistics of the variables used in the analyses.

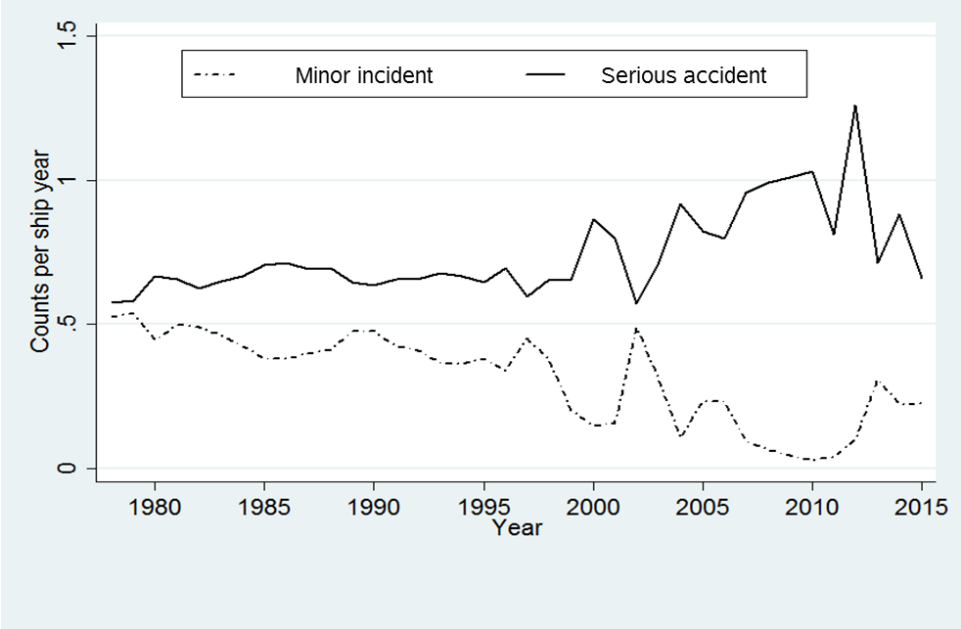

Figure 4-1. Frequency of Minor Incidents and Serious Accidents per Ship Year

Table 4-1. Descriptive Statistics

Variable	Mean	SD	Min.	Max.
Serious accident (*t*)	0.748	0.536	0	6
Ship age	16.951	11.453	3	112
Owner/manager firm same	0.501	0.500	0	1
Flag/manager country same	0.245	0.430	0	1
Bulk carrier	0.094	0.292	0	1
Container ship	0.038	0.191	0	1
Fishing	0.076	0.266	0	1
General cargo	0.293	0.455	0	1
Tanker	0.240	0.428	0	1
Minor incidents (*t*-1)	0.451	0.225	0	5
Minor incidents (*t*-2)	0.382	0.205	0	6
Minor incidents (*t*-3)	0.314	0.188	0	6
Individualism	46.032	24.903	14	91
Long-term orientation	48.839	24.872	13	100
Power distance	60.600	20.217	11	100
Unc,ertainty avoidance	64.375	26.222	13	100

Note: N = 61,342 for testing the main effect (H1);
N = 46,362 for testing the interaction effects (H2 to H5)

Dependent variable. We measure the dependent variable as the number of serious accidents for ship *i* in year *t*. The database defines a serious accident as an event that "results in personal injury, damage or loss" (Lloyd's list). Examples of serious accidents include: total loss of the ship (e.g., sank), seafarer death, or pollution (e.g., oil spill) to the environment. Some specific examples of serious accidents in the database follow (due to confidentiality, the IMO number and ship details are removed).

- "*Water entered No. 2 hold containing fishmeal cargo which subsequently fermented, giving off gases and causing the death of 1 crew*."

- "*Reported 13,500 tons of oil escaped and fouled beaches between plouescat & ST.Brieuc over a dozen vessels, 2,500 soldiers and volunteers employed to clean up*."

*Independent variables***.** We measure internal *attentiveness to safety* as the counts of minor incidents of ship *i* in each year (i.e., in years *t*-1, *t*-2, and *t*-3). The database defines a minor maritime incident as an "abnormal event occurring in the course of operations of sea-going ships" (Lloyd's list). According to professional maritime sources, the vast majority of maritime incidents are caused by human errors, such as negligence of risk factors, lack of maintaining work, etc. (e.g., Maritime Injury Lawsuit, International Convention for the Safety of Life at Sea by the International Maritime Organization). Hence, the lack of *attentiveness to safety* resulted in minor incidents. Examples of minor incidents from the database follow:

- "*Mooring ropes parted whilst vessel was loading cargo, vessel shifted from berth, causing an oil loading hose to damage a manifold on vessel. Vessel later reported in service*."

- "*Had minor fire 8 miles east of Dover on 27/4/02. Crew extinguished fire and proceeded on voyage*"

The independent variables are the counts of minor incidents in one to three single year lags (years *t*-1. *t*-2, and *t*-3). Therefore, we omitted ships that were launched less than three years due to insufficient lagged data. We used three-year lags because preliminary analyses suggested that when the lag year was greater than three, there was no statistically significant association between the independent variable and dependent variable in the later years. Including the cumulative counts lags (i.e., from year *t*-1 to year *t*-3) in the models caused serious collinearity issue. We present an additional analysis of the cumulative counts and the mean of three years' counts on the dependent variable in Section 6.2. To measure lagged variables, we consolidated samples from the year 1981 to 2015 (a 35-year study period), allowing all the three years' lags to be included in the regressions.

*Interaction variables***.** We use Hofstede (2016)'s measures for the national culture dimensions for Power Distance, Individualism, Uncertainty Avoidance, and Long-term Orientation. The database consists of manager firms from 187 countries, we matched 96 individual countries to Hofstede (2016)'s database with their respective Power Distance, Individualism, and Uncertainty Avoidance scores (on a scale ranging from 0 to 100 with 100 being the highest), and matched 76 individual countries with

the Long-term Orientation scores. That is, some countries did not have scores for Hofstede's measures.

Control variables. We controlled for some variables that may impact on the likelihood of serious accidents. We calculate ship age as the difference (in days) between the accident date and launch date of the ship, divided by 365 days. The owner/manager firm same indicator variable is binary, taking a value of 1 if the two firms are the same, 0 otherwise. We use this variable to account for the potential effect of ownership structure on serious accidents. Similarly, the flag/manager country same variable takes a value of 1 if the two countries are the same, 0 otherwise. We use this variable to estimate whether "flag out" (i.e., having the ship registered to a country other than the manager firm country to take advantage of favorable rates of taxation) would affect serious accidents. Also, we included dummy variables for ship type and year to account for possible effects of ship's functional purposes, marine shipping policies, and technological changes over time on serious accidents.

4.4.2. Analysis

The unit of analysis is the ship year. A ship's internal *attentiveness to safety* can affect ship safety. The International Maritime Organization (IMO) assigns a unique and permanent number to each ship, and marine authorities compile incident reports based on ship-level investigations. Ships belong to manager firms, and manager firms reside in countries (e.g., for nested and cross-level data discussion, see Gray and Massimino 2014, p.1048). Ships belong to manager firms, and manager firms reside in countries. Manager firms are required to adopt "recognized quality and safety management

certificates" to comply with international standards (Panayides et al. 1997), yet the varying national culture dimensions of the country where the manager firms locate can affect the internal context of a ship. That is, the nationality of the ship's manager firm reflects the national culture imposed on the management of that ship. In the maritime shipping industry, the manager firm of a ship is responsible for the ship's safety, crewing, technical, and freight management, insurance, accounting, etc. (Mitroussi 2003). The national culture of the manger firm plays a key role in influencing disaster management on ships since they are ultimately responsible for implementing safety policies, responding to safety incidents, and making improvements to the ship. That is, for a ship to make improvements, the ship manager firm makes changes to the ship's processes, procedures, and technology (Mitroussi 2003, Panayides and Gray 1997), which depends on their national culture. Consequently, the manager firms play a critical role in translating near-misses into avoid future disasters. Numerous studies have demonstrated that a country's cultural characteristics have a critical influence on corporate governance structure (e.g., Hickson and Pugh 1995, Li and Harrison 2008). The decisions made by the management board are influenced by the national culture of the manger firms. Case studies show that manager firms continuously invest in teamwork and a team culture to counterbalance the adversity of multi-cultural teams through integrate crew training programs (Best Practice Ship Management Study 2013). Therefore, the national culture inherent in the country of the manager firm influences the day-to-day operations of the ship. We present additional analyses by incorporating multilevel regressions in a later section to address the endogeneity issue that may arise from using cross-level data.

Poisson and negative binomial regressions are most common methods to analyze count data. The likelihood ratio test results indicate that the Poisson method generates larger and statistically significant Chi-square statistics. As a result, the analysis uses the Poisson panel regression method. However, as a robustness test, we analyzed both methods and obtained consistent results.

Since "multilevel analysis models must incorporate random-effects" (Hox and Kreft 1994, p. 285-286), given the multilevel nature of our data, we use random estimation in our analysis (also see, e.g., Rothaermel and Hess 2007, Madsen 2009, Misangyi et al. 2006). Besides, in this study, the limitations of a fixed-effect estimation also pertain to: 1) some ships that did not experience a single accident during the observation period (i.e., panel members with all-zero dependent variables) will be dropped from a fixed-effect model (theses samples have no variations in the dependent variable under the Poisson distribution assumption, so no information can be added to the conditional Poisson fixed-effect estimation); 2) the higher-level variables (national culture dimensions) are time-invariant such that they will be automatically omitted from a fixed-effect estimation as no inferences can be made regarding the higher-level variance, rendering it difficult to test the effect of national culture. Therefore, after dropping the missing data, we used the 61,342 ship observations in the random-effect panel Poisson regression. The maximum and mean Variance Inflation Factor (VIF) in all models are 4.98 and 2.57, respectively, which is below the suggested threshold value of 10, suggesting there are no issues with multicollinearity (Berk 1977).

Table 4-2 presents the panel Poisson regression estimates on serious accidents. Model 0 introduces the control variables. Model 1 adds in the independent variables. Model

2 adds the interaction variables. Note that Model 2 has a smaller sample size due to some missing data of manager firm country in the accident database or the inability to match Hofstede (2016)'s measures of national culture (some countries in the ship accident data do not have culture dimension scores in Hofstede's database). Model 1 shows that the single-year lag minor incidents (t-1) and (t-2) are statistically significant and positive at 1% and 5% levels respectively, which supports H1. Model 2 includes the interaction variables of the four hypothesized national culture dimensions. As expected, the interactions of Power Distance and Individualism with minor incident counts in year t-1 and t-2 are statistically significant and positive (e.g., $p < 0.01$ for the Power Distance interaction term in years t-1 and t-2, and the Individualism interaction term in year t-1; $p < 0.05$ for the Individualism interaction term in year t-2). This suggests that countries with high Power Distance and Individualism strengthen the negative link between *attentiveness to safety* and the likelihood of a serious accident. Therefore, the empirical results support H2 and H3. Uncertainty Avoidance has a statistically significant and negative interaction with *attentiveness to safety*, implying that a high (low) level of Uncertainty Avoidance weakens (strengthens) the negative relationship between *attentiveness to safety* and the likelihood of a serious accident. This result supports H4. However, the interaction of Long-term Orientation does not have a significant interaction with *attentiveness to safety* for any of the time periods. Thus, the empirical results do not support H5.

Figures 4-2a, 4-2b, and 4-2c give the conditional effects plots for the three significant interaction effects of the dimensions of national culture (PDI, IVD, and UAI). The conditional effects plots show the effects of national culture at three

different percentile levels: low (10), medium (50), and high (90). These plots illustrate the effect of national culture on *attentiveness to safety*.

Table 4-2. Random-effect Panel Poisson Estimates of Ship Serious Accidents

	Model 0		Model 1		Model 2	
Variables	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	-0.3565***	(0.0291)	-0.3642***	(0.0289)	-0.3782***	(0.0391)
Ship age	0.0051***	(0.0004)	0.0026***	(0.0004)	0.0024***	(0.0005)
Owner/manager firm same (=1)	-0.0120	(0.0094)	-0.0112	(0.0094)	-0.0217*	(0.0115)
Flag/manager country same (=1)	-0.0107	(0.0115)	-0.0121*	(0.0115)	-0.0271**	(0.0128)
Bulk carrier	0.0409**	(0.0174)	0.0440	(0.0174)	-0.0008**	(0.0201)
Container ship	0.0769***	(0.0242)	0.0797**	(0.0242)	0.0598**	(0.0264)
Fishing	0.2325***	(0.0171)	0.2406***	(0.0172)	0.1768***	(0.0211)
General cargo	0.2033***	(0.0119)	0.2062***	(0.0119)	0.1596***	(0.0145)
Tanker	-0.6070***	(0.0161)	-0.6043***	(0.0161)	-0.5662***	(0.0187)
Year dummies	Not reported		Not reported		Not reported	
Minor incidents (*t*-1)			0.0970***	(0.0186)	0.0888***	(0.0213)
Minor incidents (*t*-2)			0.0460**	(0.0210)	0.0481**	(0.0239)
Minor incidents (*t*-3)			0.0191	(0.0231)	0.0380	(0.0256)
Individualism (IDV)					0.0002	(0.0002)
Long-term orientation (LTO)					-0.0007*	(0.0004)
Power distance (PDI)					0.0004	(0.0004)
Uncertainty avoidance (UAI)					-0.0007***	(0.0002)
Minor incidents (*t*-1)×PDI					0.0039***	(0.0013)
Minor incidents (*t*-2)×PDI					0.0034***	(0.0012)
Minor incidents (*t*-3)×PDI					0.0029**	(0.0012)
Minor incidents (*t*-1)×IDV					0.0074***	(0.0018)
Minor incidents (*t*-2)×IDV					0.0050**	(0.0020)
Minor incidents (*t*-3)×IDV					0.0048**	(0.0020)
Minor incidents (*t*-1)×UAI					-0.0047***	(0.0017)
Minor incidents (*t*-2)×UAI					-0.0068***	(0.0018)
Minor incidents (*t*-3)×UAI					-0.0028	(0.0018)
Minor incidents (*t*-1)×LTO					0.0040	(0.0027)
Minor incidents (*t*-2)×LTO					0.0002	(0.0029)
Minor incidents (*t*-3)×LTO					0.0024	(0.0030)
Observations	61,342		61,342		46,362	
Log-likelihood	-61,017.83		-61,000.70		-43,825.31	
Model fitness (Prob > Chi-square)	0.000***		0.000***		0.000***	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

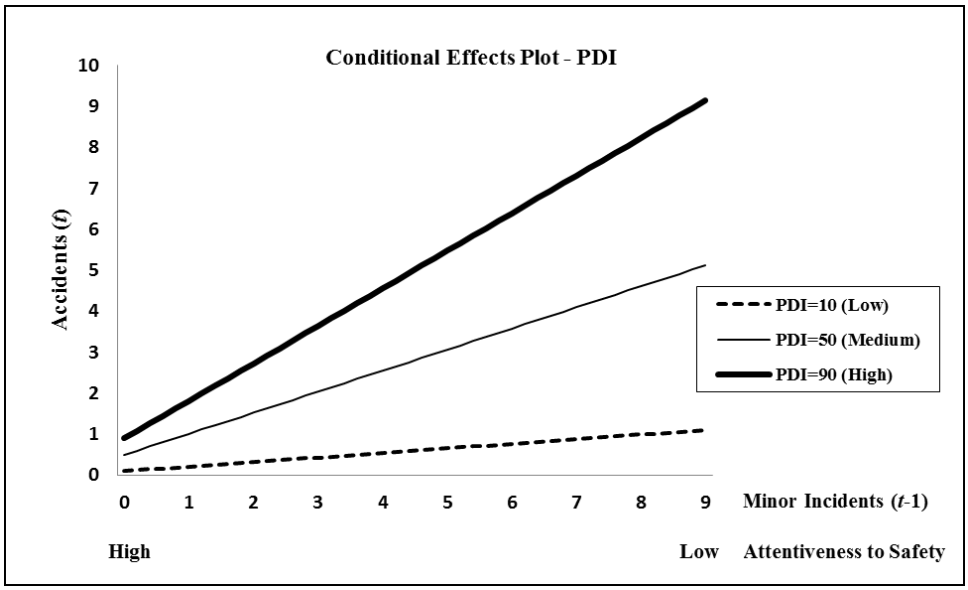

Figure 4-2a. Conditional Effects Plot - Attentiveness to Safety and PDI

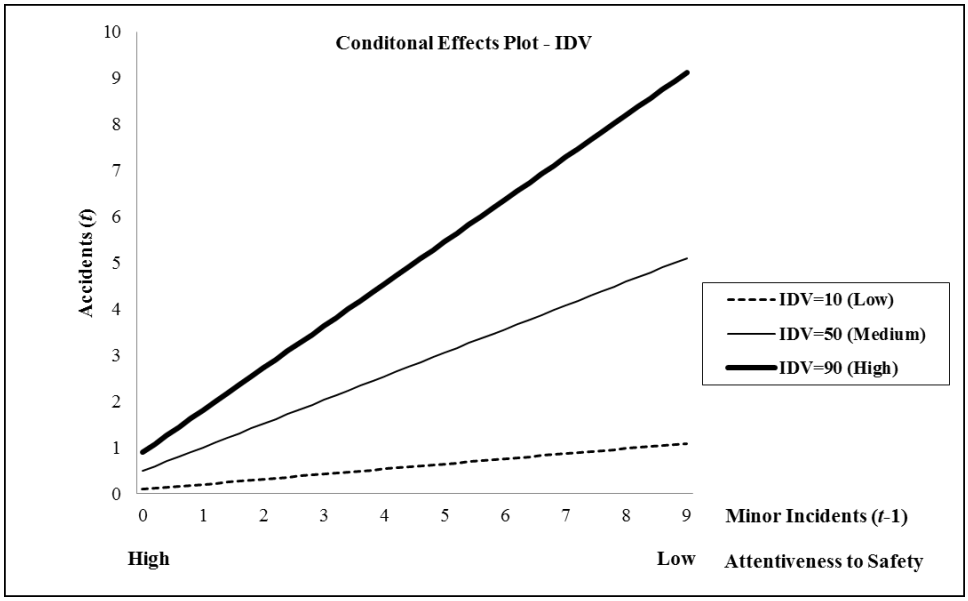

Figure 4-2b. Conditional Effects Plot - Attentiveness to Safety and IDV

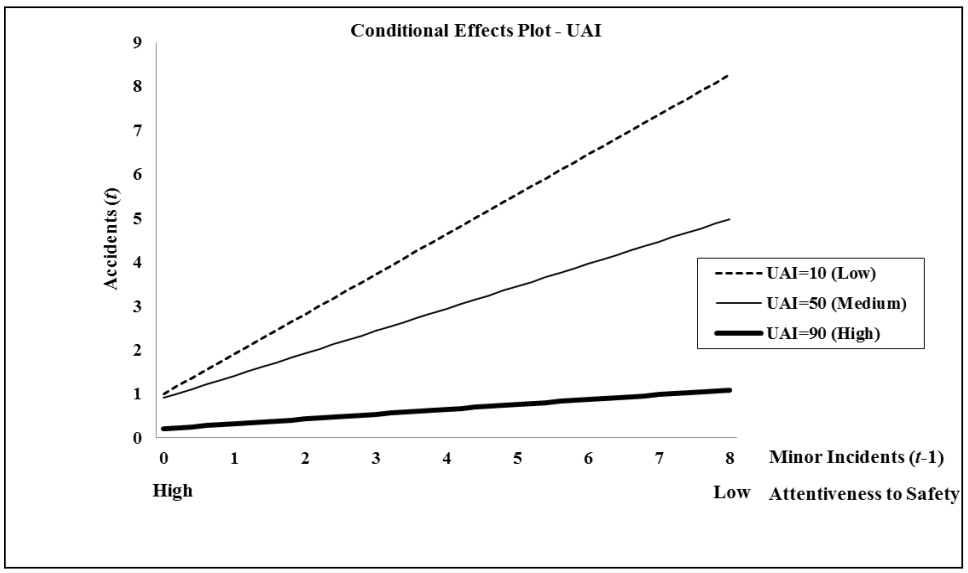

Figure 4-2c. Conditional Effects Plot - Attentiveness to Safety and UAI

4.5. Supplementary Analysis

4.5.1. Post hoc Analysis

Following Gray and Massimino (2014), we didn't hypothesize a relationship with the Masculinity and Indulgence dimensions of national culture. We conducted additional analysis including these variables. However, both the main effect and moderating effect of national culture were insignificant ($p > 0.1$) on serious accidents.

One natural question to ask is how previous ship serious accidents affect future serious accidents? That is, do the ships learn from previous serious accidents? Table 4-3 gives the original model but includes prior serious accidents in years *t*-1, *t*-2, and *t*-3 as independent variables, and their interactions with the four national culture dimensions. Prior studies report a significant negative effect of the previous serious accident and future accident likelihood (e.g., Baum and Dahlin 2007, Madsen 2009,

Madsen and Desai 2010). That is, organizations "learn from failure." Not surprisingly, the maximum likelihood estimates in Table 4-3 suggest that there is a statistically significant and negative association between prior serious accidents experience and future accident likelihood. That is, the previous serious accidents experience is a significant predictor of reduced future serious accidents. For example, the serious accidents (*t*-1) coefficient in Model 2 of Table 4-3 is negative and statistically significant ($p < 0.01$). The distinction between minor incidents and serious accidents should be clearly noted. Unlike minor incidents, ships learn from prior serious accidents. Moreover, Uncertainty Avoidance significantly moderates the main effect of previous serious accidents count and future accident likelihood (the coefficients of the serious accidents (*t*-1) and Uncertainty Avoidance interaction terms are statistically significant, $p < 0.05$), the other dimensions of national culture do not play significant roles in moderating such a relationship. Therefore, it turns out that a ship generally learns from its accident experience, which is less dependent on the effect of national culture.

Table 4-3. Random-effect Panel Poisson Estimates of Ship Serious Accidents (Post hoc Analysis)

	Model 1		**Model 2**	
Variable	Coefficient	SE	Coefficient	SE
Constant	-0.2998***	(0.0278)	-0.3152***	(0.0381)
Ship age	0.0047***	(0.0004)	0.0027***	(0.0005)
Owner/manager firm same (=1)	-0.0062	(0.0094)	-0.0118	(0.0117)
Flag/manager country same (=1)	-0.0101	(0.0115)	-0.0247*	(0.0131)
Bulk carrier	0.0087	(0.0174)	-0.0270	(0.0205)
Container ship	0.0450*	(0.0242)	0.0380	(0.0273)
Fishing	0.1813***	(0.0171)	0.1354***	(0.0213)
General cargo	0.1558***	(0.0120)	0.1195***	(0.0148)
Tanker	-0.5223***	(0.0162)	-0.5119***	(0.0195)
Year dummies	Not reported		Not reported	
Serious accidents (*t*-1)	-0.5829***	(0.0337)	-0.6678***	(0.0524)
Serious accidents (*t*-2)	-0.5312***	(0.0336)	-0.6212***	(0.0502)
Serious accidents (*t*-3)	-0.5490***	(0.0355)	-0.6460***	(0.0520)
Individualism (IDV)			-0.0003	(0.0004)
Long-term orientation (LTO)			-0.0001	(0.0005)
Power distance (PDI)			0.0003	(0.0003)
Uncertainty avoidance (UAI)			-0.0003	(0.0002)
Serious accidents (*t*-1)×PDI			-0.0001	(0.0023)
Serious accidents (*t*-2)×PDI			0.0018	(0.0021)
Serious accidents (*t*-3)×PDI			0.0033	(0.0022)
Serious accidents (*t*-1)×IDV			0.0008	(0.0044)
Serious accidents (*t*-2)×IDV			-0.0023	(0.0044)
Serious accidents (*t*-3)×IDV			-0.0008	(0.0046)
Serious accidents (*t*-1)×UAI			-0.0050**	(0.0023)
Serious accidents (*t*-2)×UAI			-0.0060***	(0.0022)
Serious accidents (*t*-3)×UAI			-0.0054**	(0.0023)
Serious accidents (*t*-1)×LTO			0.0042	(0.0035)
Serious accidents (*t*-2)×LTO			0.0011	(0.0034)
Serious accidents (*t*-3)×LTO			0.0037	(0.0035)
Observations	61,342		46,362	
Log-likelihood	-60,360.75		-41,333.85	
Model fitness (Prob > Chi-square)	0.000***		0.000***	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

4.5.2. Robustness Checks

We used the single-year minor incident count to measure the *attentiveness to safety* in the analysis. As a robustness test, we also used the three-year average and cumulative count(s) of years *t*-1, *t*-2, and *t*-3. Table 4-4 shows the estimated results from random-effect panel Poisson regressions. Both the average and cumulative minor incident counts are statistically significant and positive while the results of the interaction terms are largely consistent with the single-year count models, suggesting that the results are very robust.

Table 4-4. Robustness Checks

	Model 1 (Cumulative)				**Model 2 (Average)**			
	Model 1-0		Model 1-1		Model 2-0		Model 2-1	
Variables	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	-0.3639***	(0.0289)	-0.3760***	(0.0392)	-0.3639***	(0.0289)	-0.3780***	(0.0392)
Ship age	0.0050***	(0.0004)	0.0024***	(0.0005)	0.0050***	(0.0004)	0.0025***	(0.0005)
Owner/manager firm same (=1)	-0.0113	(0.0094)	-0.0203*	(0.0115)	-0.0113	(0.0094)	-0.0207*	(0.0115)
Flag/manager country same (=1)	-0.0118	(0.0115)	-0.0270**	(0.0128)	-0.0118	(0.0115)	-0.0276**	(0.0128)
Bulk carrier	0.0436**	(0.0174)	0.0014	(0.0201)	0.0436**	(0.0174)	0.0026	(0.0201)
Container ship	0.0795***	(0.0242)	0.0606***	(0.0264)	0.0795***	(0.0242)	0.0610**	(0.0264)
Fishing	0.2405***	(0.0172)	0.1789***	(0.0211)	0.2405***	(0.0172)	0.1781***	(0.0211)
General cargo	0.2058***	(0.0119)	0.1623***	(0.0144)	0.2058***	(0.0119)	0.1625***	(0.0144)
Tanker	-0.6044***	(0.0161)	-0.5693***	(0.0187)	-0.6044***	(0.0161)	-0.5684***	(0.0187)
Year dummies	Not reported		Not reported		Not reported		Not reported	
Minor incidents	0.0588***	(0.0111)	0.0610***	(0.0126)	0.1756***	(0.0334)	0.1811***	(0.0378)
Individualism (IDV)			0.0002	(0.0002)			0.0002	(0.0002)
Long-term orientation (LTO)			-0.0006	(0.0004)			-0.0005	(0.0004)
Power distance (PDI)			0.0003	(0.0004)			0.0002	(0.0004)
Uncertainty avoidance (UAI)			-0.0005**	(0.0002)			-0.0005**	(0.0002)
Minor incidents × PDI			0.0049***	(0.0013)			0.0047***	(0.0012)
Minor incidents × IDV			0.0092***	(0.0018)			0.0076***	(0.0019)
Minor incidents × UAI			-0.0061***	(0.0017)			-0.0083***	(0.0017)
Minor incidents × LTO			0.0051	(0.0026)			0.0017	(0.0028)
Observations	61,342		46,362		61,342		46,362	
Log-likelihood	-61,004.31		-43,846.57		-61,004.31		-43,847.04	
Model fitness (Prob > Chi-square)	0.000***		0.000***		0.000***		0.000***	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Random-effect Panel Poisson estimates of ship serious accidents

In this study, we constructed variables at the ship level. It is possible that nested within manager firms, ship-level data may inadequately capture internal safety context as every sea-going ship is operated by a manager firm whereby several ships may be managed by the same manager firm. That is, manager firm characteristics may better capture internal *attentiveness to safety*, thus affecting the dependent variable. To strengthen the validity of our findings based on ship-level constructs, we conducted multilevel mixed-effects Poisson regression by specifying a two-level model (i.e., ship level vs. firm level). The likelihood ratio test of manager firm-specific effects (variance = 0.0018) against ship-specific effects appears to be nonsignificant (chi-square = 2.29, $p > 0.05$), suggesting that there is no serious concern with nested data that may threaten our results based on a ship-level model.

We next assess the robustness of cross-level interaction effects. Specifically, consistent with prior studies (e.g., Rothaermel and Hess 2007), we used random-effect models to investigate the cross-level interaction effects. However, as cross-level random-effect estimations have at least one error term at each level, the results may be threatened by the endogeneity of the correlated lower-level covariates and higher-level residuals (Bell and Jones 2015). That is, the variance of the omitted variables would be absorbed into the error terms, which may be correlated with the covariates. This concern is similar with that of the "hierarchical nature of the error term in the regression model" (Gray and Massimino 2014). Following Enders and Tofighi (2007), and Hofmann and Gavin (1998), we group-mean centered ship-level variables (we centered ship-level variables around the mean of all the cases within the same country-level groups) and conducted a mixed-effect analysis. For the ease of computation and interpretation, we only included the one-year lag independent variable, i.e., minor

incidents (*t*-1), in the analysis. Table 4-5 gives the results of the mixed-effect analysis. The mean number of serious accidents across the countries (in row 2 of Model 1) is 0.7646, of which the corresponding variance component is 0.0028, which is significantly smaller than the random intercept estimate. This suggests that there is additional country-level variation unaccounted for in the model. To explain some country-level variance in the serious accidents, we further included country-level predictors, i.e., mean minor incidents (*t*-1) and country dummies. The variance component (random intercept) reduced to 0.0823, indicating that country-level variables indeed account for some of the variances in predicting serious accidents. Model 3 introduces centered minor incidents (*t*-1) and its interaction terms with country dummies to investigate the effect of the ship-level variable (i.e., minor incidents) across countries. The intercept in Model 3 is 0.5829, which refers to the expected serious accidents of a ship in a specific country under an average-controlled minor incidents count. The model fit statistics show that Model 3 is the most preferred model (AIC of Model 3 is the smallest). Hence, we confirm the validity of incorporating the cross-level interaction variables to test their effects on the dependent variable.

Table 4-5. Mixed Effect Analysis

Fixed-effects variance components	**Model 1**	**Model 2**	**Model 3**
Intercept	0.7646*	0.5795*	0.5829*
	(0.0028)	(0.1463)	(0.1440)
Mean_Minor incidents (*t*-1)		0.6897*	0.9635*
		(0.0365)	(0.0509)
Country dummies		Not reported	Not reported
Centered_Minor incidents (*t*-1)			0.0694
			(0.3802)
Mean × Centered			-0.6212*
			(0.0835)
Country dummies × Centered			Not reported
Random-effects variance components	Model 1	Model 2	Model 3
Intercept	0.0922*	0.0823 *	0.0826*
	(0.0016)	(0.0015)	(0.0016)
Centered_Minor incidents (*t*-1)			0.1615*
			(0.0131)
Residual	0.1769*	0.1761*	0.1666*
	(0.0015)	(0.0015)	(0.0015)
Model fit statistics			
Deviance	67345.60	65900.16	65079.28
AIC	67351.59	66104.15	65443.28

* $p < 0.05$

Standard errors are in parentheses.

4.6. Discussion

As organizations become more global in their operations, they need to manage safety across national boundaries. Recent serious accidents such as the Asiana Airlines crash and the Rana Plaza building collapse highlight the importance of taking national context when managing safety into consideration. Establishing a safety climate is critical to managing safety in organizations. However, an organization's internal safety climate may be influenced by the broader national culture in which they operate. The safety culture literature has generally neglected the broader national culture context (see, e.g., Pagell et al. 2005, Noort et al. 2006). This study uses a large sample of organizations from countries spanning a wide range of national cultures (96 countries) to investigate how the dimensions of national culture affect safety in

shipping operations. The results show that Hofstede's dimensions of Power Distance, Uncertainty Avoidance, and Individualism in national culture moderate the effect of the organization's *attentiveness to safety* on safety outcomes. A *post hoc* analysis further shows that organizations learn from prior serious safety accidents, which is only moderated by the Uncertainty Avoidance dimension of national culture. Collectively, the results show that an organization's internal safety context (*attentiveness to safety*) depends more on the national context than its ability to learn from serious accidents.

4.6.1. Theoretical Implications

The safety literature has discussed the importance of establishing a safety climate (Dillon et al. 2016, Zohar and Luria 2005), but research has not empirically connected the internal safety context to serious accidents. Our empirical results show that an organization's *attentiveness to safety* (measured by minor incidents) reduces the likelihood of future serious accidents. As a result, this study advances safety research by investigating how an organization's internal context affects serious accidents. That is, *attentiveness to safety* plays a critical role in predicting serious safety accidents. Organizations that are more *attentive to safety* will be less likely to 'normalize' minor incidents that can lead to serious accidents.

Johns (2006) argued that scholars have not sufficiently considered the broader context when conducting organizational research. Mowday and Sutton (1993: p. 198) defined context as "stimuli and phenomena that surround and thus exist in the environment external to the individual, most often at a different level of analysis". This research examines the role of an organization's internal context and national

context when managing safety. The analysis shows that an organization's safety performance is influenced by the broader national contexts. This research supports the *national specificity* hypothesis in the international management literature (Child and Kieser 1979, Rungtusanathama et al. 2005, Shenkar and Ronen 1987, Tregaskis and Brewster 2006), which argues that organizational practices need to be adapted to the national context to achieve the intended benefits. We investigate the effects of context on serious accidents at two different levels, i.e., organization's internal context (lower level) and national context (higher level). The findings contribute to the global operations management by delineating the roles played by organization's *attentiveness to safety* and national culture in influencing the likelihood of serious accidents.

The findings from random-effect panel Poisson regressions suggest that the effect of *attentiveness to safety* on accidents varies across dimensions of national culture. Consistent with Pagell et al. (2005)'s call for understanding the national culture in operations, this study demonstrates that the dimensions of national culture (Hofstede, 1980) significantly influence safety performance. The data of this study come from the global shipping industry, spanning a wide range of national cultures (96 different countries). This provides significant cross-country variations concerning the four dimensions of national culture, enabling us to examine the effect of national culture on safety through a highly diversified "global" perspective. As a result, the empirical results appear to be robust and generalizable. As expected, Power Distance, Individualism, and Uncertainty Avoidance level moderate the link between internal *attentiveness to safety* and accident likelihood in the global shipping context.

The results of this study inform the global operations management literature in two ways. First, conducting "cross-level/comparative research" (Johns 2006) in the global operations helps understand how national context influences operational outcomes. For example, in this study, *attentiveness to safety* and national culture represented by the ship (lower level) and national (higher level) contexts, respectively, jointly influence serious accidents. Understanding global operations necessitates understanding how higher-level contextual variables affect lower-level variables. This research shows how national culture influences a firm's internal operational context. Second, because global operations management cuts across diverse contexts that vary from country to country, taking a "one-size-fits-all" to global operations becomes problematic. In line with prior research on national culture in operations management (e.g., Flynn and Saladin 2006, Pagell et al. 2005), this study demonstrates that at a higher level, national culture dimensions significantly moderate the effect of internal safety context on serious accidents, revealing how the higher-level national context affects the lower-level organizational context in predicting safety performance.

In addition, the *post hoc* analysis results suggest that safety learning is less dependent on national culture. We only find that Uncertainty Avoidance significantly moderates the relationship between *attentiveness to safety* and serious accidents. So this finding suggests that *attentiveness to safety* and safety learning interact with national culture to affect serious accidents through different mechanisms. That is, organization's *attentiveness to safety* appears to be more dependent on national culture in affecting serious accidents while safety learning tends to be less dependent on national culture. Consequently, developing a learning orientation towards safety may be even more critical to managing safety in the global economy.

4.6.2. Practical Implications

This research has several important practical implications for managers. First, managers should understand the roles of both national culture and internal safety context in attaining safety performance. Managing safety requires understanding the role of the national context. In some countries, developing a strong internal *attentiveness to safety* will mitigate the negative effects of an unsupportive national culture (high individualism, high power distance, and low uncertainty avoidance). In addition, policymakers that want to enhance safety in the global economy need to consider the implications of national culture. For instance, in the Asiana Airlines safety incident, the South Korean Transportation Minister noted that they developed a strong internal *attentiveness to safety* within the cockpit of the airline to improve safety and counterbalance the influence of national culture (*The Diplomat*, July 16, 2013). Although airlines, in general, emphasize safety awareness in the cockpit, Asiana Airlines needed to place a higher level of safety awareness in the cockpit to overcome the effects of national culture. This may further imply that the optimal tradeoff between safety and productivity may be culturally dependent. As a result, by understanding the role of national culture, policymakers can develop more effective policies to promote safety. In some national settings, there needs to a stronger emphasis on *attentiveness to safety* to get the same level of safety outcomes.

Managers also need to understand how specific dimensions of national culture influence safety. Figure 4-2a, 4-2b, and 4-2c show the conditional effects plots of the dimensions of national culture on internal safety context and safety performance. For example, Figure 4-2c shows that as *attentiveness to safety* decreases, accident

likelihood increases more rapidly when Uncertainty Avoidance decreases. This implies that the marginal benefits of a strong internal *attentiveness to safety* increase as the level of uncertainty avoidance decreases. However, if organizations can develop a strong internal *attentiveness to safety*, they can more effectively prevent serious accidents in spite of the national culture. In other words, a strong internal *attentiveness to safety* counterbalances the potential negative effects of an unsupportive national culture. Table 4-6 summarizes the results of the effects of the four national culture dimensions on internal safety context and safety learning, respectively. Specifically, as Individualism, Uncertainty Avoidance, and Power Distance level play significant roles in affecting organization's internal safety context and serious accidents, managers should be aware of the culture levels in their countries along with their organizations' internal safety contexts. For instance, if the *attentiveness to safety* in an organization is low while the Power Distance (or Individualism) level in the national culture is high, managers should make efforts to improve *attentiveness to safety* to counterbalance the effect of national culture. Moreover, safety learning helps prevent future serious accidents. However, safety learning is influenced by Uncertainty Avoidance, but not the other national culture dimensions. More broadly, this suggests that internal *attentiveness to safety* is influenced by national culture more than safety learning. Finally, NGO's that at that attempt to influence safety practices in various part of the world need to understand how national culture affects their efforts to make a prosocial change.

4.6.3. Limitation and Future Research Directions

Like other empirical research, this study is subject to several limitations, which can be potential avenues for future studies. First, there is no information on any corrective

actions followed by an accident to improve safety. These corrective actions may have an impact on the likelihood of future serious accidents. However, the *post hoc* analysis shows a learning effect from prior accident experience, which suggests that organizations do learn from previous serious accidents. Thus the learning effect could be a result of the corrective actions. In addition, the safety certifications and inspections from organizations like the Port State Control (PSC) or Classification Society (e.g., IASC) may also play a role in ensuring ship safety. In this study we focus on the role of the national context in affecting *attentiveness to safety* and safety outcomes. Future research may investigate the effects of the certifying and investigation bodies on ship's safety performance. For example, do certifications from the different classification societies influence the likelihood of a ship's serious accidents? Although under the regulation of IMO, maritime authorities have established effective incident reporting system and enforced the mandatory reporting policy, there may still be few under-reporting minor incidents (serious accidents are very unlikely under-reported because of the severe impact to the maritime environment and ashore assistance from maritime authorities). However, excluding these under-reported minor incidents actually did not dilute but strengthened the support for Hypothesis 1 (because adding the potentially under-reported minor incidents would amplify the effect size of *attentiveness to safety*).

Chapter 5. Conclusions

This thesis is motivated by the critical challenge of managing safety and security in shipping and transport logistics operations with a socially responsible goal in the global economy. The research contexts are global logistics and shipping transport. However, the managerial insights from this thesis are generalizable to broader global operations and supply chain management. All multinational organizations encounter security and safety risks in managing global shipping and transport logistics, and all of them must pay attention to their supply chain resilience internally and externally. This thesis answers the call in the existing literature that operations management shall take into account socially responsible practices. Specifically, this thesis focuses on logistics security certification and ship accidents from an operations management

perspective in the global shipping and transport logistics contexts. Analyzing data from U.S. publicly-traded importer firms and historical ship accident records, I address the central research question (see Chapter 1.2.) guiding the three essays in this thesis. The empirical investigations uncover that logistics security standard (C-TPAT) adoption could benefit adopter firms through a signaling mechanism. In addition, I find that the likelihood of safety accidents could be affected by both internal safety and national contexts.

The topics of the thesis have critical research and managerial relevance, because the research questions are motivated by current industry practices. For example, SCS breaches have causes damages to supply chain partners. Therefore, stakeholders need to assess the benefits of implementing SCS practices. As highlighted by Van de Ven (2007), research results should be able to address challenges in supply chain and operations practices. The findings of this thesis help practitioners make strategic decisions related to security and safety management (e.g., to implement logistics security certification or not by considering their transport logistics contingencies, i.e., upstream supply chain complexity). In addition, this thesis provides important and timely extensions to the existent safety and security literature by offering novel and theoretically grounded empirical insights for managing safety and security in global shipping and transport logistics operations by uncovering the knowledge structure of existing SCS research (Essay 1), the underlying mechanism that facilitates adopter firms of logistics security certification to gain benefits (Essay 2), and ascertaining how internal and national contexts influence accident performance (Essay 3). However, more research is needed to overcome the limitations and answer the research questions posed in each essay. I hope this thesis can motivate other

researchers to pursue follow-up inquiry to address the remaining issues of safety and security management in shipping and transport logistics research.

Collectively, the empirical results and theorizing contribute to the development of theories in logistics and shipping operations and practical implications for the related industry sectors. I discuss the specific contributions of this thesis in the following aspects: (1) How the research objectives stated in Chapter 1 are achieved; (2) The major academic, practical, and policy-making implications derived from this thesis; (3) Limitations and future research directions; and (4) Concluding remarks.

5.1. Research Objectives Achieved

This thesis has achieved the intended three research objectives stated in Chapter 1. Specifically, to examine "*what is the knowledge structure and content of existing SCS studies*?", Essay 1 outlines the clusters (research domains) of the SCS literature and sketches the knowledge structure by using CNA and MPA, respectively. This essay not only shows a holistic structure of the SCS knowledge but also helps identify research gaps in existent SCS research. That is, few studies used objective data to measure operational performance of firms after implementing logistics practices, and the underlying mechanism that facilitates SCS practice adopters to improve operational performance is under-developed. These identified gaps motivate the second study (Essay 2) in this thesis.

Therefore, the second individual study (Essay 2) addresses the research gaps and answer the research question of "*does C-TPAT certification adoption improve*

importer firms' operational performance? If so, how would the level of upstream complexity (detail, dynamic, and spatial complexity) influence the singling benefit from C-TPAT certification?" by first using CEM to identify control firms for sample firms. This substantially reduces the selection bias inherent in the matching process compared with other popular matching approaches (e.g., propensity score matching). The use of Difference-in-Difference regression effectively removes stable sources of between-firm variability, which makes the results more robust. In addition, instead of focusing on how internal *process* is improved to contribute to superior operational performance in adopter firms, I draw upon a more rational theoretical lens, i.e., a non-operational mechanism that is the "signaling effectiveness", to examine how adopter firms could improve operational performance where the effectiveness of certification could depend on the ability of stakeholders in reducing information asymmetry to convey commitment to SCS (see Gray et al. 2014). This line of reasoning explains the effectiveness of logistics certification adoption in the contemporary global economy, and it fits better with the theorizing of the effects of upstream logistics transport contingencies in this study. The second research objective in Chapter 1 is then achieved.

Essay 3 investigates the third research question of "*what is the role of the internal safety context of a ship and national culture on the ship's safety accidents*?" in Chapter 1. That is, to examine the impacts of an organization's internal safety context and national culture on safety accident performance. The empirical results show that the higher-level context (national context) moderates the relationship between the lower-level context (organizations' internal safety context) and ship accident performance. Specifically, I show that internal safety context significantly

influences ship's accident performance while the national culture dimensions of Power Distance, Individualism, and Uncertainty Avoidance play a significant role in moderating the relationship between internal context and safety performance. The multi-level analysis suggests that safety management in global maritime shipping operations should take both internal and national contexts into account.

5.2. Academic, Practical, and Policy-making Implications from This Thesis

The results in this thesis inform scholars, practitioners, and policy-makers in logistics and shipping operations as follows: In the first place, Essay 1 sets as an example to employ CNA and MPA, which are considered as more objective methods to cluster research domains and analyze knowledge structures in literature review (prior methods for literature review largely rely on the scholar's personal decisions). In identifying research gaps in prior logistics studies, I find that prior studies on logistics security fail to fully account for the selection bias in data collection and the underlying mechanism that facilitates firms to improve operational management through logistics security practice adoption is under-explored.

Essay 2 conceptually and empirically investigates the signaling effects of C-TAPT certification on U.S importer firms. The findings suggest that C-TPAT certified firms could benefit from a signaling mechanism by conveying commitment-to-SCS to their stakeholders, suggesting that the value of management standard adoption could be attributed to the non-operational mechanism enabled by signaling effectiveness. Also,

I show that three types of upstream supply chain complexity (*detail*, *dynamic*, and *spatial*) significantly affect the signaling benefits of C-TAPT certification. This study contributes to security management in logistics operations by showing the signaling benefits from standard certification adoption and how firms' upstream complexity influences such benefits. From a practical perspective, the results inform operations mangers that firms with a high level of upstream supply chain complexity can benefit more from C-TPAT certification than firms that have a low level of upstream supply chain complexity. The regulatory agency (e.g., CBP) should accord a higher priority to firms with a greater level of complexity in supplier portfolio in promoting the C-TPAT programme.

Essay 3 contributes to the literature on managing safety in global operations by exploring the role of national context (national culture) in the organization's internal safety context and accident performance. Few studies have paid attention to the multi-level analysis of the impacts of organization's internal and national contexts on safety accident performance. This study informs scholars in global shipping operations that organization (ship)'s internal safety context influences the likelihood of accidents. However, the national context (national culture) significantly moderates the effect of organization's internal safety context on accidents. As a result, operations managers should understand that organizations need to place a greater emphasis on developing a strong internal safety context when operating in the environment characterized by unsupportive national culture (i.e., high Power Distance, high Individualism, and low Uncertainty Avoidance). In addition, ship registration and classification bodies should pay attention to incident records that are indicative of the internal safety context of the ships when renewing their registrations.

5.3. Limitations and Future Research Directions

Like other empirical studies, the individual studies in this thesis are also subject to several limitations. I explain the limitations which can be addressed by future research.

In Essay 1, as the CNA algorithm relies on the mutual number of citations between two published articles in the database, the estimation of "edge-betweenness" may be affected by the year of publication because more recently published articles tend to have fewer citations. As a result, this algorithm may fail to cluster some recent articles into the cluster (research domain). Future research can modify the CNA mechanism by considering the year of publication. For example, one may give certain weights to more recently published articles in estimating "edge-betweenness". Also, based on the results of CNA and MPA, I show that the extant research mainly uses primary data and fails to fully account for selection bias in data collection. Therefore, future research could explore whether and how security management initiatives can improve adopter firms' operational performance measured by objective data such as financial metrics (ROA and sales growth) by investigating the underlying mechanism that facilitates operational improvement. This stream of study is encouraged to use secondary data, which are considered more reliable and less liable to selection bias to construct variables.

In Essay 2, as the primary goal of logistics security certification is to help adopter firms reduce security risks in logistics operations, future research can find a way to

measure how security risks/breaches have been reduced due to logistics security certification. That is, instead of focusing on second-order metrics such as firm's financial performance, scholars can estimate first-order performance metrics (security performance) to examine the effectiveness of certification. Also, complexity is present in various ways in global supply chains, and the upstream supply chain complexity (*detail*, *dynamic*, and *spatial*) is only one form of complexity. As a result, future research is encouraged to study other forms of complexity in supply chains that may affect the effectiveness of security practice implementation.

One limitation in Essay 3 pertains to the unidentified corrective actions after accidents. That is, the internal safety context may be affected by organization's corrective actions taken to lessen the harm generated from accidents. Therefore, future research could collect relative data on how organizations take corrective actions to improve the internal safety context in managing shipping operations.

5.4. Conclusion Remarks

This thesis focuses on safety and security issues in logistics and shipping operations by presenting three independent but interrelated essays. The theorizing and empirical investigation offer critical implications for theory development, practice, and policy-making. Limitations are identified to direct future research on managing safety and security issues in global logistics and shipping operations. I hope this thesis can motivate more research on security and safety management in shipping and logistics operations.

Herein, I would like to further provide my view upon future research and its potential. The three individual research used objective methodology (CNA) or objective data collected from the publicly available database (e.g., COMPUSTAT) to examine different research questions. Although the objective methodology and data have obvious advantages (the results obtained may be less influenced by subjective judgment and the data is less biased), alternative methods could have also been applied to compare the advantage and disadvantages between one another. For example, survey or case study can be applied to explore how some qualitative measures (e.g., emotion) could affect safety. In other words, safety and security can be affected by various subjective variables. Therefore, some qualitative studies can be used to explore further research questions such as how fear, anticipation, and regret that is triggered by faith, emotion, and belief can affect security and safety in operations.

Appendix. Research articles in each research domain

Research focus/domain	**Papers**
1.*SCS Conceptualization and Application*	Bakshi and Kleindorfer (2009); Bearzotti et al. (2012); Braunscheidel and Suresh (2009); Chopra and Sodhi (2004); Christopher et al. (2011); Kleindorfer and Saad (2005); Knemeyer et al. (2009); Kouvelis et al. (2006); Laeequddin et al. (2009); Lockamy and McCormack (2010); Lodree and Taskin (2008); Marley et al. (2014); Neiger et al. (2009); Papadakis (2006); Qi et al. (2010); Revilla and Sáenz (2014); Sheffi and Rice Jr (2005); Skipper and Hanna (2009); Smith et al. (2007); Stewart et al. (2009); Tomlin (2006); Trkman and McCormack (2009); Wakolbinger and Cruz (2011); Wilding et al. (2012); Wilson (2007); Wu et al. (2007)

2. *Security Management Systems*	Autry and Bobbitt (2008); Dobie (2005); Hameri and Hintsa (2009); Kumar et al. (2008); Lu and Koufteros (2014); Marucheck et al. (2011); Meixell and Norbis (2012); Pero and Sudy (2014); Prokop (2012); Roth et al. (2008); Russell and Saldanha (2003); Sheu et al. (2006); Speier et al. (2011); Voss et al. (2009a); Voss and Williams (2013); Whipple et al. (2009); Williams et al. (2008); Williams et al. (2009a); Williams et al. (2009b)
3. *Transportation Security*	Berle et al. (2011); Chang et al. (2014); Kumar and Verruso (2008); Lee et al. (2008); Lee and Whang (2005); Lee et al. (2011); Lun et al. (2008); Marlow (2010); Sarathy (2006); Thai (2009); Thibault et al. (2006); Voss et al. (2009b); Yang and Wei (2013); Yang (2010); Yang (2011)
4. *Terrorism*	Bakshi and Gans (2010); Mannisto et al. (2014); Manuj and Mentzer (2008); Pinker (2007); Wang and Zhuang (2011); Zhuang et al. (2010)

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