ESSAYS ON ENVIRONMENTAL ISSUES IN OPERATIONS MANAGEMENT: THE IMPACT OF ENVIRONMENTAL VIOLATIONS

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Essays on Environmental Issues in Operations Management: The Impact of Environmental Violations

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CERTIFICATE OF ORIGINALITY

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___________________________________(Signed)

_______YI ZHOU____________________(Name of student)

To my beloved wife – Caren

To my lovely SiuSiu

Abstract

This research comprehensively examines the environmental issues in Operations management in the following three studies.

The first study is a citation network analysis, which systematically reviewed 246 articles related to environmental concerns in the nine most reputable peer-reviewed OM journals. Analyzing the citation network of these 246 articles, we used the Girvan-Newman (2002) algorithm to identify four main clusters. In each cluster, we presented central knowledge development and suggested areas for further research. In this research, we identified the research gap and the needs to study the impact of environmental violations.

In the second study, we conducted a short-term event study to estimate the impact of environmental violations on firms' short-term performance (i.e., market value). This study based on the 618 environmental violations data published by China's Institute of Public and Environmental Affair (IPE) and the financial data of the public manufacturing firms in China. We found that the market reacted negatively to the environmental violation announcements. Also, we investigated the financial, operational, and social factors that could moderate the relationship. Lastly, we found that environmental violations caused by Chinese firms can have a significantly negative impact on the market value of their overseas customers.

In the third study, we extended the sample in the second study and conducted a long-term event study based on the 1600 violations committed by 439

manufacturing firms. We examined the long-term impact of environmental violations and tried to find out whether a firm can maintain its short-term economic benefits of violating environmental rules in the long run. Based on the concept of supervised machine learning, we discovered the significant factors that may lead to more pollution for a firm. Also, we developed a prediction model with the aim to help China government identifying high-risk firms before they pollute.

Publications arising from the thesis

Published papers:

Lo, C.K.Y., Tang, C.S., Zhou, Y., Yeung, A.C.L., Fan, D. (2018). Environmental Incidents and the Market Value of Firms: An Empirical Investigation in the Chinese Context. *Manufacturing & Service Operations Management*, 20(3), 422-439.

Working papers:

Lo, C.K.Y., Tang, C.S., Zhou, Y. (2018). Environmental Violations in China: evaluating their long-term impact and predicting future violations. **(Plan to submit to *Management Science*)**

Zhou, Y., Lo, C.K.Y. (2018). Environmental Sustainability in Operations Management: A Citation Network Analysis. **(Submitted to *International Journal of Production Economics*)**

Zhou, Y., Linderman, K., Lo, C.K.Y., Yeung, A.C.L. (2018). Using Social Network Analysis to Examine Buyer's Influence on Supplier's Environmental Compliance **(Plan to submit to *Management Science*)**

Other papers arising during the Ph.D. period:

Fan, D., Zhou, Y. (2018). Operational safety: The hidden cost of supply-demand mismatch in fashion and textiles related manufacturers. *International Journal of Production Economics*, *198*, 70-78.

Fan, D., Zhou, Y., Lo, C.K.Y. (2018). A Multi-stakeholder perspective on the impacts of safety violation: An event study of manufacturing firms **(Submitted to *Journal of Business Ethics*, under major revision)**

Lee, S., Zhou, Y., Lo., C.K.Y., Ha-Brookshire, J. (2018). "Luxury fashion brands vs. mass fashion brands: data mining analysis of social media responses toward corporate sustainability", In Lo, C.K.Y., & Ha-Brookshire, J. (Ed.) *Sustainability and Luxury Fashion Business.* Springer Publishers (2018).

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A special thanks to my family. Words cannot express how grateful I am to my parents and grandparents for all of the sacrifices that you've made on my behalf. Most importantly, I would like to thank my beloved wife, Caren. Thank you for supporting me for everything. To my lovely SiuSiu, thank you for bringing me happiness and enjoyment.

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Chapter 1. Introduction

1.1. Research Background and Motivation

The environmental sustainability is always one of the many challenges for economic growth. Undermining economic growth to halt environmental pollution might be acceptable for developed countries because they have achieved substantial economic growth and development (Omoju, 2014). However, it is more challenging for developing countries to focus on environmental goals until they achieve the sustainable living standard for their people.

Developing countries, such as China, have jeopardized its environment and people's health in exchange for the rapid economic growth. Since 1978, China's annual GDP growth rate was 10% on average during the past few decades of the market reform (World Bank, 2018). Meanwhile, the environmental problems including air and water pollution, industrial waste, and the abuse of natural resources have become nationwide. Zhang et al. (2014) reported that China is facing extreme environmental pollution: The Carbon dioxide emissions per capita increased by 2.82 times in the last 20 years (World Bank, 2014), polluted air shortens the lifespan of people in Northern China by 5.5 years (Chen et al., 2013), and more than 1.5 million people died directly or indirectly because of air pollution in China in 2016 (Health Effects Institute, 2018). Thus, it is an urgent need for developing countries to maintain environmental sustainability to balance the economic growth and environmental performance.

One of the effective ways to maintain environmental sustainability is to improve the environmental performance from the causes. Thus, this thesis focuses on the manufacturing industry as its operations are the major sources of pollution in developing countries. For instance, a total of 20% of rivers (Miao et al., 2015; Yang, 2012) and more than 10% of the arable lands in China are poisonous due to industrial waste, which has potential to cause food shortage in the future (Du, 2010). Manufacturers in emerging markets usually prioritize on economic and operational performance instead of environmental performance to remain competitive due to the pressures from various stakeholders such as customers, supply chain parties, competitors and the governments (Delmas & Toffel, 2004; Mitchell et al., 1997). Customers crave for products at a lower price. In particular, the fast fashion trend constitutes customers' overconsumption behavior, creating serious environmental problems, from excessive materials to unsold clothes. Most international brands accelerate the traditional low-cost country sourcing (LCCS) strategy to cope with this new customer behavior. For example, the fast fashion trend asks for the cooperation of unavoidable short production time, so those international brands outsource their production to manufacturers in developing countries for low labor and production cost (Doh, 2005), and (maybe more importantly) for less critical (and fewer) enforcement on the environmental misconducts, which could speed up their production without complying to environmental laws. Consequently, the manufacturers over consume their society assets (i.e., environment and public health) for economic benefits as they have nowhere to shift the cost and pressure from their supply chain parties.

To survive in keen global competition, manufacturing firms in developing countries often chose to over-consume on environmental resources, such as overexploitation of natural resources (for lower material costs). Also, they cut corners to save operating cost (Jiang, 2009), such as discharging untreated wastes and ignoring environmental regulations (for faster production and lower production costs). These over-consumption and cut-corner activities overtly brought short-term economic benefits to the firms. Nevertheless, the increased environmental cost and waste have caused severe pollution problems and threatened the public health.

Given the context discussed above, it is crucial for firms in developing countries to be aware of the harmful effects of the environmental violations and operate in an environmental-friendly way. The exposure of the violative actions may cause an adverse market reaction and impose some covert influence on the company, such as reputational damage, government interventions, and penalties (Iwata & Okada, 2011).

Maintain environmental sustainability requires not only firms' corporations but also government involvements. As one of the world's largest developing countries, China starts to rebalance the economy towards the quality of growth (World Bank, 2018). In the last decade, the Chinese government demonstrated their commitment to manage the on-going pollution problems and maintain environmental sustainability. China's 13th five-year (2016-2020) plan (2016) emphases on sustainable development, which provides detailed plans on solving pollution problems and maintaining environmental sustainability in China. To improve the environment, most government environmental agencies, either in developing or developed countries, are taking post-hoc remedial actions towards firm's misconducts, or performing real-time monitoring of some types of waste discharges (depending on the availability of technology). For instance, the monitoring approach commonly used for the violations that have already caused damages to the environment and the public health. On the contrary, it is rare that environmental agencies would take proactive actions to identify high-risk firms to prevent environmental violation or pollution.

1.2. Research Objectives and Design.

The goal of this thesis is to understand the impact of environmental incidents in emerging markets better and help firms and developing countries to maintain environmental sustainability. Thus, I organized the three independent, but interrelated essays as follows.

In essay one, I used Citation Network Analysis (CNA) to identify research domains (clusters) under a specific research area such as environmental sustainability in operations management studies. Also, I further conducted Main Path Analysis (MPA) to identify major knowledge for each research domain and the research gaps. Compare to traditional systematic reviews, the CNA and MPA can minimize the subjective judgments on the classification of research papers and identification of their knowledge development. The merging trend of environmental management practice and green supply chain management clusters expressed the growing interest in the research gap of environmental sustainability in emerging markets, which are complementary to each other.

The research gap and trend identified by the essay 1 motivated me to conduct the study (essay two). Specifically, empirical evidence existed in the positive impact of environmental initiatives on a firm's performance in the context of developed economies (e.g., Klassen and McLaughlin 1996, Jacobs et al. 2010, Lo et al. 2012), but few studies have examined the negative impact of environmental incidents on a firm's performance in developing countries such as China. In the study, I examined the short-term impact of environmental incidents on manufacturing firms' market performance in China. Also, I explored the factors that might cause investors to react differently on firms' environmental incidents due to its unique political and social system. Most importantly, I investigated the effects of those incidents passed on a firm's overseas supply chain partners.

In essay three, I extended the sample in essay two to study the long-term impact of environmental violations on manufacturing firms' performance in China. Besides, I proposed a supervised machine learning prediction model through the lens of operations management to address the urgent needs of the government environmental agencies to identify the high-risk firms. Also, the agencies and firms could make use of the model and facilitate an effective and efficient environmental monitoring process for preventive and remedial purposes.

In summary, we tried to understand the impacts of environmental violations from different stakeholders' perspectives, such as firms, investors, governments, NGOs, and customers. The findings can act as a reference to the stakeholders for developing effective mechanisms for attenuating environmental violations in China. The later version of essay two, entitled “The Impact of Environmental Incidents on Market Value of Firms in China: Social Capital, Legitimacy and Political Ties” has been published on *Manufacturing & Services Operations Management*. I attached the license of using the publications in this dissertation in Appendix C.

Chapter 2. Essay 1: Environmental Sustainability in Operations Management: A Citation Network Analysis

2.1. Introduction

Environmental sustainability, a critical pillar in corporate social responsibility (CSR), has received much attention from operations management (OM) scholars (Kleindorfer et al., 2005; Linton et al., 2007). Our search found 246 papers that studied environmental sustainability in the OM field as of 2016. However, only eight literature reviews were published, the environmental concerns mentioned in these reviews were either too broad or specific. Thus, reviewing the relevant knowledge structures and identifying future research trends are essential.

Among all eight literature reviews, three of them were published in 2005 and 2007. Kleindorfer et al. (2005) described the development of sustainable Operations Management (OM) and reviewed "sustainability" in the first 50 issues of *Production and Operations Management* (POM). They traced the development back to 1985 as people started to concern about "the future of people (internal and external to companies) and the future of planet Earth." Researchers and industry players increasingly connected OM to sustainability due to the emerging of new legitimacy concerns at that time, such as the triple bottom line (3BL), the three Ps (people, profit, and the planet), and the goal of maintaining viable social franchises (Kleindorfer et al., 2005). Their review summarized that green product and process development, lean and green operations, remanufacturing and closed-loop supply chains were the three main focuses of the first 50 issues of POM, which had built a solid foundation for sustainable OM research in the past two decades before 2005. Also, Cohen et al. (2007) reviewed Paul Kleindorfer's contributions to risk management, such as the environmental, health and safety risk, in OM; this review could be considered as a supplementary review of the Kleindorfer et al. (2005). The two reviews discussed the environmental sustainability literature based on the framework of sustainable OM. The knowledge development and trends in environmental sustainability itself were still not concluded at that time.

Linton et al. (2007) examined the literature on environmental management and operations and provided a background to strengthen the understanding of supply chain and sustainability. They tried to interact sustainability to each supply chain process such as product design, by-products produced during product use, product life extension, product end-of-life, recovery processes at end-of-life. They showed that "all encompassing definition of sustainability raised more questions than answers" and the discussion on how to achieve sustainability is still in an early stage.

The Linton et al. (2007)'s view on environmental sustainability was supported by Kleindorfer et al. (2005) as they stated in their review:

"The issue is not 'will all of the things we mention happen in the future?' As in global warming, we have passed this stage. The questions are when and how big will the impact be and how fast will the transition be?"

Thus, reviewing the knowledge development of environmental sustainability during the past three decades is extremely helpful to seek answers to when and how to achieve environmental sustainability.

Later reviews focused on a specific area under the theme of sustainability. Hassini et al. (2012) reviewed the sustainable supply chain literature from 2000 to 2010 and provided a framework for sustainable supply chain management and performance measures. Each of these reviews mentioned environmental concerns but did not prioritize them. By examining the peer-reviewed literature from 1990 to 2011, Chen et al. (2014) provided a research agenda for manufacturing facility location and sustainability. Ghadimi et al. (2016) reviewed the literature on buyer-supplier relationships in sustainable procurement. Zhu et al. (2016) focused on China and analyzed the literature on green marketing and consumerism. All these studies reviewed a small portion of the environment-related literature, leaving the entire knowledge development of environmental sustainability unknow. So, in this study, we tried to fill this research gap by conducting a comprehensive review of environmental sustainability in the OM literature.

Previous systematic literature reviews (SLRs) are mostly objective, but the subjective judgments on the knowledge structure and research domains are primarily based on the authors' experience and capability (Colicchia et al., 2012). Recent research has employed citation network analysis (CNA) and main path analysis (MPA) to address these concerns. CNA subjectively classifies research domains based on the citations between all the research papers, and MPA identifies main research paths according to the citations within a research domain (e.g., Fan et al., 2014 and Fahimnia et al., 2015). In Fahimnia et al. (2015)'s review, they used a bibliometric and network analysis to examine the development of green supply chain management literature. Although their selected literature may have some overlaps with ours, their review focused on the sustainable operations from the supply chain perspective as all combinations of their keyword search included "supply chain." Also, their paper search was not based on OM literature exclusively as their journal selections included the journals in other disciplines such as Ecological Economics and Computer Aided Chemical Engineering.

To complement the knowledge structure of the OM literature review on environmental sustainability, we took the following steps to perform a comprehensive and systematic review of environment-related literature in the OM field:

1. Visualize the knowledge structure of relevant environmental studies;
2. Identify essential research domains and analyze the content in each domain;
3. Propose possible future research opportunities on environmental concerns based on analysis of the relevant literature.

2.2. Sample and Descriptive Statistics

In this study, we obtained an initial sample set from the Web of Science Core Collection Database. We searched the literature by using the following keywords: “environment(al),” “management,” “performance,” “incident,” “problem,” “misconduct,” and “event.” We also used possible combinations of these keywords, such as “environment(al) AND management,” “environment(al) AND performance,” “environment(al) AND incident,” “environment(al) AND problem,” “environment(al) AND misconduct,” and “environment(al) AND event.” We searched the “article” type literature by the year “2016” in the following Web of Science Categories: “business,” “management,” and “operations research management science.” To ensure our search cover the environmental sustainability literature completely, we have also tried other keywords such as “sustainable(ity),” “ecology(ical),” “ethics(al),” “social,” “green,” ”pollution,” and “violation.” Searching these keywords increased our literature pool significantly without adding environment-related literature because they are not only related to environmental sustainability but also link to other topics such as health and safety. Thus, we excluded them from our search.

To restrict our search to studies in the OM domain, we selected the ten most reputable peer-reviewed OM journals, namely *International Journal of Operations & Production Management* (IJOPM), *International Journal of Production Economics* (IJPE), *International Journal of Production Research* (IJPR), *Journal of Operations Management* (JOM), *Manufacturing and Service Operations Management* (MSOM), POM, *Management Science* (MS), *Journal of Supply Chain Management* (JSCM), *Omega International Journal of*

Management Science (Omega), and *Decision Science* (DS). The search found 288 papers using the criteria above. We carefully read each article and then eliminated 34 of them for not being related to environmental concerns. We removed eight more papers, as they were literature reviews on the topic and may have different citation network. Thus, 246 sample papers remained and were used in our analysis. We present a descriptive statistical analysis of the papers in Figure 2-1 to 2-6 and Table 2-1 to 2-3 by using *HistCite*.

Figure 2-1 presents the distribution of articles by the journal. Research articles on environmental concerns frequently appeared in IJPE, accounting for 35.77% (88/246) of total publications. The second most productive journal on environmental topics was IJPR, accounting for 21.95% (54/246). IJOPM and POM ranked third and fourth, with 13.41% (33/246) and 10.98% (27/246) of total publications respectively. Collectively, the four journals accounted for more than 80% of research articles related to environmental concerns.

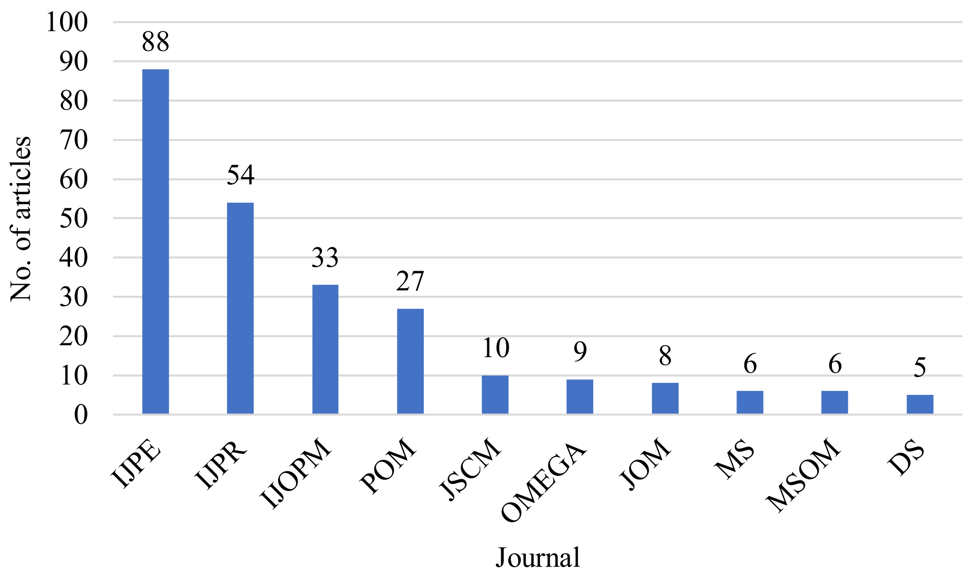


Figure 2-1. Distribution of articles by journal

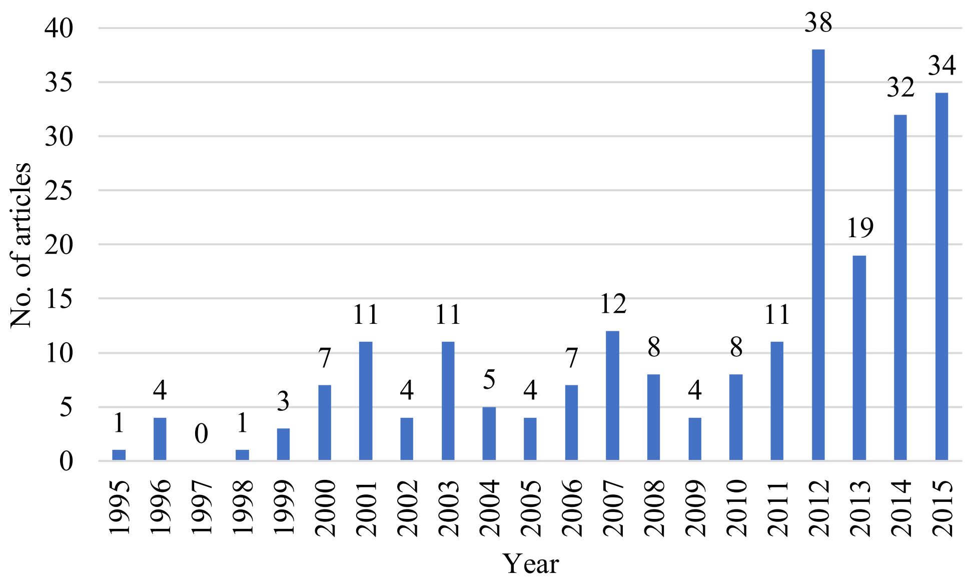


Figure 2-2. Distribution by year

Figure 2-2 presents the distribution of environmental-related papers by year. Publications on the topic began appearing in 1995 and then increased in number in 2001. From 2001 to 2011, the number of publications per year was fairly stable, demonstrating that scholars remained interested in environmental concerns. The number of publications increased dramatically in 2012, and interest in the topic remained high after that.

Figure 2-3 presents environmental-related papers by article type. The most common type was empirical study, with 160 papers (65.04%), followed by 66 modeling papers (26.83%) and only 20 conceptual papers (8.13%).

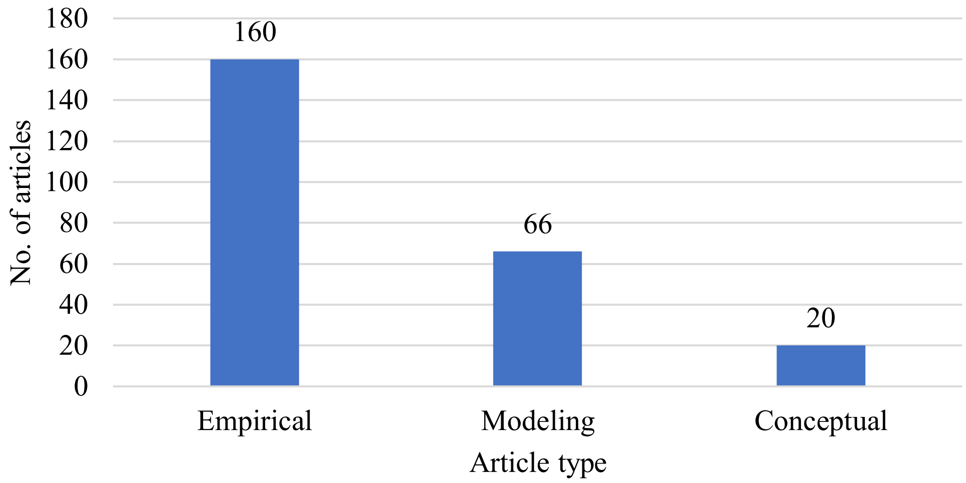


Figure 2-3. Distribution by article type

Among the 160 empirical studies, 80.00% (128/160) used statistical models, 17.50% (28/160) were case studies, and the remaining 2.5% (4/160) used multiple methods (Please see Figure 2-4). Most of the empirical research studied manufacturing industry (77.50%, 124/160), while the sub-industry segment food industry (10.48%, 13/124) and automotive industry (10.48%, 13/124) received the most attention among the manufacturing industry. We further examine the distribution of 160 empirical studies by study country in Figure 2-5: 66.25% (106/160) focused on the developed countries, 20.00% (32/160) studied the developing countries, and the remaining 13.75% (22/160) investigated into multiple countries. Figure 2-6 shows the distribution by year for each country category. Researchers continuously pay attention to the developed countries during the past two decades, while they are interested in developing countries started in 2012. Thus, the research for developing countries may have a 15-year lag comparing to those for developed countries.

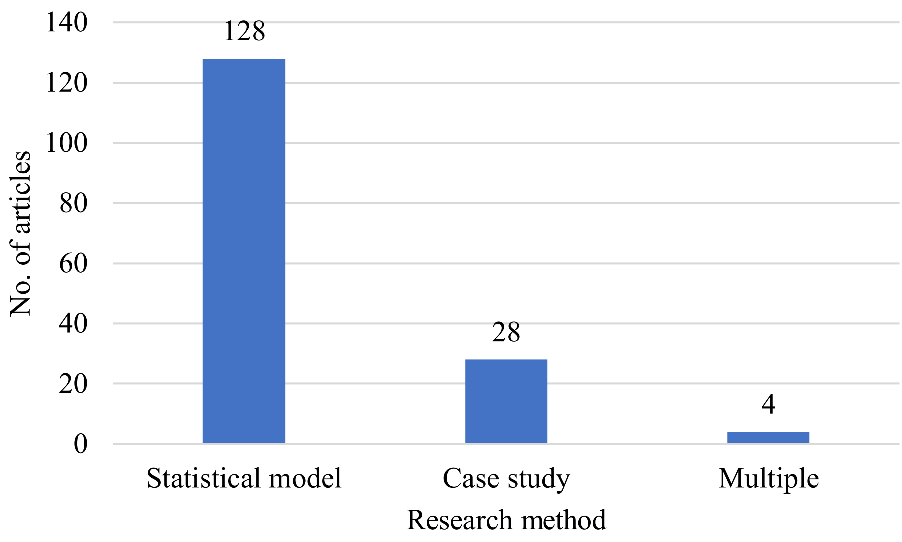


Figure 2-4. Distribution by research method (empirical)

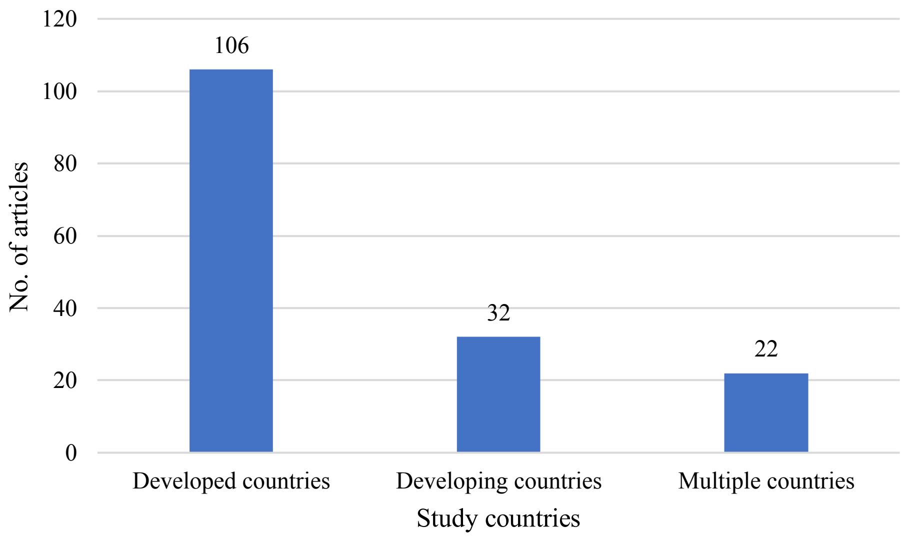


Figure 2-5. Distribution by study country (empirical)

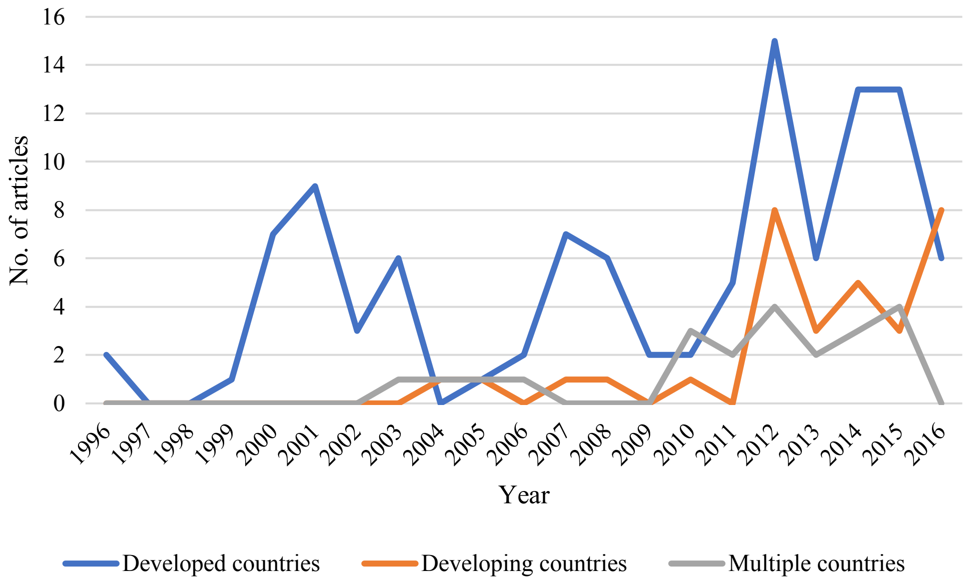


Figure 2-6. Distribution by year (study countries in empirical studies)

Table 2-1 reports the ten most productive researchers in this topic. As shown in the table, Robert Klassen is the most productive researcher with the second most substantial impact (second largest number of cited count). Joseph Sarkis is the second productive researcher with the third most substantial impact. Interestingly, Qinghua Zhu is listed as the seventh productive research but has the third strongest impact (total times cited count) and the most substantial impact (the highest number of citations per publication).

Table 2-1. The top ten productive researchers and their total times cited count

Author	No. of articles	Total Times Cited Count	No. of citations per publication
Robert Klassen	12	2,678	223
Joseph Sarkis	11	2,091	190
Mike KH Lai	10	567	57
Stephan Vachon	7	1,264	181
Mark Pagell	7	704	101
Christina WY Wong	7	176	25
Qinghua Zhu	6	1,706	284
Ravi Subramanian	6	382	64
Brain Jacobs	5	219	44
Angappa Gunasekaran	5	176	35

2.3. Citation Network Analysis: Major Research Clusters

In this study, we used Citation Network Analysis (CNA) to identify the primary research domains of the 246 environment-related articles. Compare to the previous systematic literature review which the quality varies due to the author's understanding on the research papers, CNA provides a subjective way to classify research domains based on the citations between all the research papers. It reduces human intervention to the lowest level. In CNA, the Girvan–Newman algorithm, which focuses on the edges in a network that are the least central and the most "between" clusters, is used to cluster the primary research domains. Girvan and Newman introduced the concept of "edge-betweenness" (EB) as "the number of shortest paths between pairs of vertices that run along it." The algorithm calculates the betweenness for all edges in the network and removes the intercluster edges with the highest EB each time to detect potential clusters. (Girvan and Newman, 2002). To create a high-density cluster that is loosely connected with others, we used the Q-value proposed by Newman and Girvan (2004) as follows:

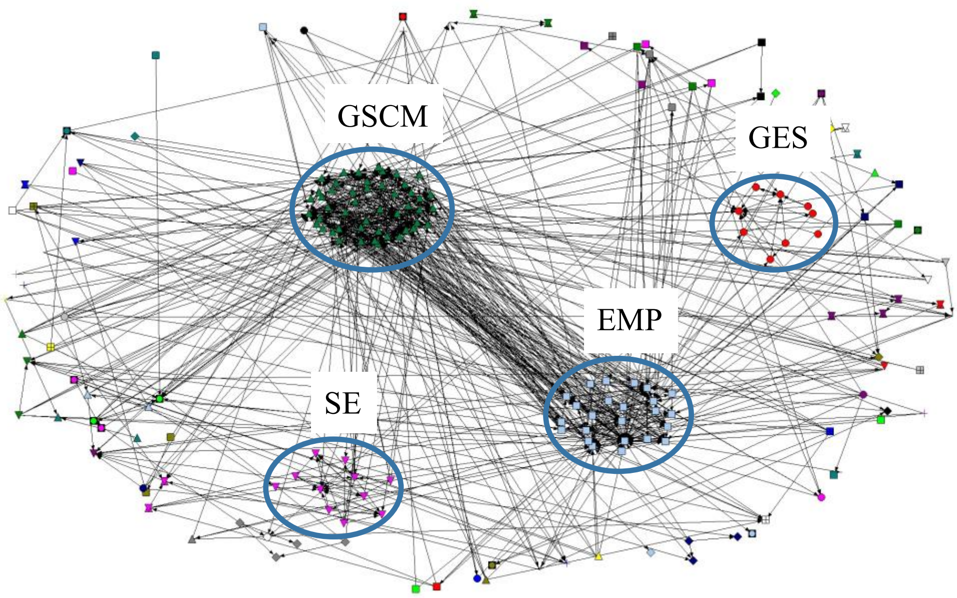
$$Q = \sum_{c=1}^{n} \left[\frac{e_c}{E} - \left(\frac{d_c}{2E} \right)^2 \right] \quad \text{(E.2-1)}$$

where n denotes the number of clusters in the network, c represents a cluster, E is the total number of edges, e_c is the number of edges in cluster c, and d_c is the sum of the node degrees in c^{th} cluster (Yang et al., 2009). To optimize the number of clusters, we maximized the possible number of edges in each given cluster and minimized the number of clusters in the network. More details can be found elsewhere (Newman and Girvan, 2004; De Meo et al., 2011). We used UCINET

6.644 software to calculate the optimal Q-value to determine the ideal number of clusters.

For our sample of 246 papers, the optimal number of clusters was determined to be 24 (Q = 0.201). The four clusters that contained five or more nodes (articles) were defined as the major research domains. The 19 clusters with five or fewer nodes (articles) were defined as "scattered clusters." A total of 79 (32.11%) articles were separate nodes that did not fall into clusters. The high percentage of nonclustered articles relative to other research topics [e.g., health and safety (Fan et al., 2014; Tong, 2017)] reflects that environmental concerns are usually studied in combination with other research topics. For example, in their article studying the relationship between the incentives and penalties that buyers use to encourage their suppliers to comply with social and environmental standards, Porteous et al. (2015) gave equal importance to social and environmental concerns. Barcos et al. (2013) examined the effects of CSR practices on firms' inventory policies and found a U-shaped relationship between them. The primary environmental concern they considered was the sway of environmental activists, and even this was only a small part of the research. In the 79 nonclustered articles, environmental concerns were not the primary focus. Combining these nonclustered articles into the main clusters could have led to a broader citation network including other concerns; thus, our literature review exclusively examined articles that focused on environmental concerns. Figure 2-5 presents the citation network and clusters derived from the 246 papers. The four red circles are the primary research domains, as follows: green supply chain management (GSCM, green triangles), environmental management practice

(EMP, light blue squares), supplier evaluation (SE, pink triangles), and green extended supply chain (GESC, red circles).



Green triangles: Green supply chain management (GSCM)
Light blue squares: Environmental management practice (EMP)
Pink triangles: Supplier evaluation (SE)
Red circles: Green extended supply chain (GESC)

Figure 2-5. Citation network of the sample articles

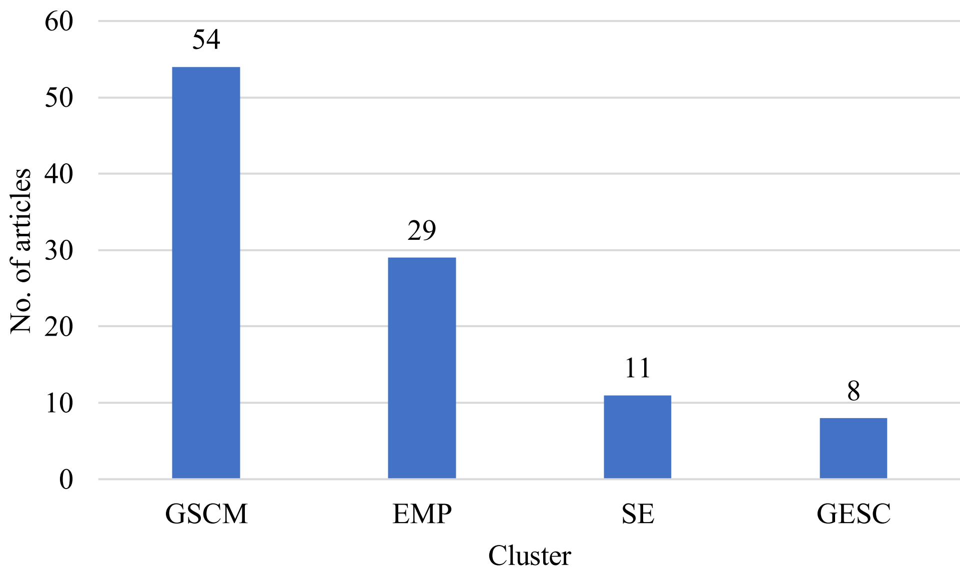


Figure 2-6. Distribution of the clusters by research domain

Figure 2-6 presents the distribution of sample papers across each research domain. GSCM was the most popular research domain, with 54 articles (21.95%). EMP was the second largest domain (29 articles, 11.79%), followed by SE (11 articles, 4.47%) and GESC (8 articles, 3.25%). Please refer to Appendix A for all the research articles in each domain. Complete cited papers are provided in the reference list.

2.4. Main Path Analysis: Knowledge Structure of Major Research Domains

For a comprehensive understanding of the knowledge structure of each research domain, we conducted main path analysis (MPA). This process identifies the leading citation path in each domain by identifying the nodes (articles) with the highest citation centrality. We followed Fan et al. (2014) to weight the citations for articles in all four main clusters and to identify the most critical citation using the following equation:

$$Weight_{ij} = \frac{TP_{ij}}{TPS_j} \quad \text{(E.2-2)}$$

where TP_{ij} denotes the total number of citations for a particular article i in network j, and TPS_{ij} is the total number of citation paths between sources (i.e., the earliest article in the network) and sinks (i.e., most recent articles that are not cited by others) in network j (Fan et al., 2014). After calculating the weighted citation for each article, we identified articles with the highest ratios as those containing the most cited and essential knowledge. They comprised the central path knowledge in the cluster. We used Pajeck 2.05 to conduct MPA (Fan et al., 2014; De Nooy et al., 2011). In sections 2.4.1 to 2.4.4, we explore the knowledge structure of each cluster, and areas for further research are identified at the end of each section.

2.4.1. Green Supply Chain Management

Figure 2-7. Knowledge structure of GSCM cluster

GSCM was the most densely populated cluster in our citation network. Articles in this domain primarily focused on environmental management and practices from the supply chain perspective. Figure 2-7 presents the knowledge structure of the cluster. From the supplier perspective, Bowen et al. (2001) examined the role of supply management capabilities in green supply and argued that an organization's specialized internal resources (e.g., proactive corporate stance on environmental concerns) are more critical than external pressures in GSCM. Klassen and Vachon (2003) broadened the examination of proactive corporate environmentally behavior (i.e., investment in eco-friendly technologies) toward customers. They found that plant-level (supplier) investment in environmental management increased when customer-initiated collaborative activities increased (Klassen and Vachon, 2003). Zhu and Sarkis (2004) expanded GSCM to emerging markets such as China. They found that Chinese enterprises exhibited stronger environmental and economic performance when they had higher levels of GSCM (e.g., closely supervised the environmental performance of suppliers) (Zhu and Sarkis, 2004).

In GSCM articles, managing supply chain partners' environmental practices was a primary focus. Vachon and Klassen (2008) introduced "environmental collaboration" under the context of GSCM as "joint environmental goal setting, shared environmental planning, and working together [with supply chain partners] to reduce pollution or other environmental consequences." They found that increased environmental collaboration with suppliers led to more efficient process-based performance (e.g., delivery and flexibility); and that increased environmental collaboration with customers led to improved product-based performance (e.g., cost and quality) (Vachon and Klassen, 2008). In addition to environmental collaboration, Reuter et al. (2010) and Yang et al. (2010) introduced the concept of sustainable global supplier management (SGSM) into GSCM. If firms embrace SGSM earlier than others, it could have a competitive advantage; but such advantages could be moved by external stakeholder pressure (Reuter et al., 2010). Yang et al. (2010) stated that firms were more likely to develop a proactive environmental management program if they had close relationships with their suppliers.

After establishing the fundamentals of GSCM, researchers began to study GSCM more comprehensively by using different empirical settings, such as mediating or moderating the effects between GSCM drivers, initiatives, and practices. The most commonly examined mediating GSCM driver was environmental investment (e.g., Ates et al., 2012; Simpson, 2012). Both Ates et al. (2012) and Simpson (2012) found that environmental investment mediated the effects between GSCM initiatives (e.g., proactive environmental strategy and external pressure) and GSCM practices (e.g., environmental performance and waste reduction performance). Wu et al. (2012) examined GSCM drivers and practices more broadly by considering green purchasing, cooperation with customers, eco-design, and investment recovery as GSCM drivers and by considering organizational support, social capital, and government involvement as GSCM practices; they ultimately found a positive relationship between GSCM drivers and GSCM practices. Moreover, they suggested that regulatory pressure had positive moderating effects on the relationship, whereas competitive pressure had adverse moderating effects (Wu et al., 2012).

Instead of studying simple buyer or supplier relationships in GSCM, scholars studied environmental management across multitier networks, especially in the food industry. Mena et al. (2014) examined the transparency of demand information, quality management, process controls, shelf-life management, and packaging design in UK food supply networks and identified the principal causes of food waste in each tier of the network. Graham and Potter (2015) also investigated the UK food manufacturing industry and found that environmental proactivity improved supply chain environmental collaboration on both the supplier and customer sides.

As manufacturing firms in emerging markets started to apply GSCM, scholars also devoted their attention to emerging markets. The repercussions of GSCM were mixed. Kusi-Sarpong et al. (2016) examined the mining industry in

Ghana and found that greening the mining supply chain could have environmental benefits. Esfahbodi et al. (2016) compared manufacturing firms in China and Iran and found that in both countries, improving GSCM could improve a firm's environmental performance, but they found no evidence that GSCM could improve cost performance. Li et al. (2016) studied the supply chain processes of Chinese-based high-tech firms and found that improving GSCM could improve a firm's environmental performance but may not directly affect a firm's financial performance. Given the mixed results from implementing GSCM, future research on this topic may contribute to understanding the mechanism of GSCM, especially in developing countries.

2.4.2. Environmental Management Practice

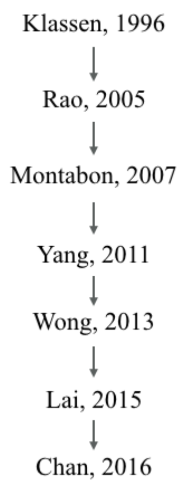


Figure 2-8. Knowledge structure of EMP cluster

EMP was the second largest cluster in our citation network, and it had the most extended history. Figure 2-8 presents the knowledge structure of the cluster. In contrast to the GSCM cluster, which focused on the environmental management activities of supply chain members, the knowledge path in the EMP cluster focused on the firm itself. Scholars and operations managers have paid much attention to the costs and benefits of implementing environmental management. Klassen and McLaughlin (1996) were the first to examine the relationship between environmental management and a firm's environmental and financial performance. Using secondary data and short-term event study, they found that environmental performance, as determined by environmental management initiatives, positively affects a firm's financial performance and the effect varies by industry. They also found that financial markets increasingly value stronger environmental performance. Most importantly, they provided insights into the debate over the importance of environmental management. Klassen and Whybark (1999) examined how operations managers' environmental initiatives affect a firm's investment in eco-friendly technologies. They found EMP measurement challenging because environmentally oriented projects affect nearly all of the functional areas of a firm (Klassen and Whybark, 1999; Kleiner, 1991).

Subsequent research also faced the challenge of measuring EMP. Sroufe (2003) studied how environmental management systems (EMSs), such as ISO14001 certification, affect environmental practices and operations performance. He classified environmental practices into design, recycling, and waste practices and attempted to cover a full range of functional areas within a firm. Montabon et al. (2007) used a more comprehensive set of practices to test relationships between EMP and a firm's business performance. They designed an Environmental Practices Matrix (EPM) to classify practices as operational, tactical, or strategic, providing a useful reference that enabled subsequent studies to measure environmental practices. Rao and Holt (2005) extended the definitions to the South East Asia Region and find environmental initiatives improve the EMPs.

After gaining the knowledge of how to measure environmental practices, scholars began to explore the antecedents and consequences of EMP. Yang et al. (2011) investigated lean manufacturing practices (i.e., just-in-time flow, quality management, and employee involvement) as antecedents of EMP and found that they improve EMP. They also studied the consequences of EMP and found EMP to be positively related to a firm's market, environmental, and financial performance. The most studied antecedent topics related to EMPs are quality management (Curkovic and Sroufe, 2007; Narasimhan and Schoenherr, 2012; Wiengarten and Pagell, 2012) and green decision-making (Wu and Pagell, 2011; Ubeda et al., 2011). The most examined EMP consequences are a firm's financial performance (Hofer et al., 2012; Thoumy and Vachon, 2012), operational performance (Schoenherr, 2012), and shareholder value changes (e.g., Jacobs et al., 2010).

After knowing the importance of integrating EMP into a firm's daily operations, scholars started to investigate how to develop the capacity to conduct EMP with limited resources. Based on dynamic capabilities theory, Wong (2013) proposed that environmental information integration contributes to environmental management capabilities (i.e., corporate environmental innovativeness and adaptability) and found that sharing environmental information with customers (rather than suppliers) improves a firm's environmental management capabilities; they also found that internal information sharing improves a firm's environmental adaptability. The research thus proved that environmental management capabilities have a positive relationship with a firm's environmental and financial performance (Wong, 2013). As a supplement to Wong's (2013) study, Lai et al. (2015) found that improved information sharing with suppliers can strengthen profits and environmental performance. These studies comprehensively explained the role of information sharing in environmental management capability development and laid the groundwork for subsequent studies on this topic.

As the final node of the main path in the EMP domain, Chan et al. (2016) expanded the knowledge structure of EMP to service OM, which they defined as green services (GSs). This study attempted to understand GS from the supply chain perspective and developed a GS measurement model by generating a set of GS practices oriented toward pollution prevention, product, and long-term development. These conceptualized GS and multi-item measurement scales provided insights into EMP in service OM. Based on these concepts and measurement scales, future research may study the effects of GS practices such as customer satisfaction, customer loyalty, operations costs, corporate reputation, and revenue growth (Bastič and Gojčič, 2012; Chan et al. 2016; Kassinis and Soteriou, 2003; Yee et al. 2009).

2.4.3. Supplier Evaluation

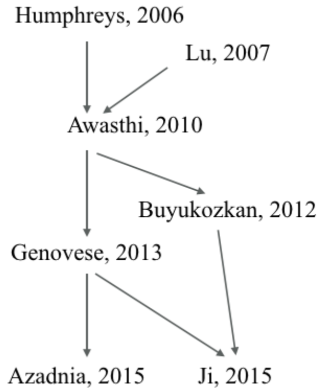


Figure 2-9. Knowledge structure of SE cluster

The SE cluster was the third largest research domain in our citation network. Figure 2-9 presents the knowledge structure of the cluster. Research in the cluster mainly focused on helping firms choose greener suppliers. Humphreys et al. (2006) reviewed the supplier selection process and found that firms considered delivery capacity, processes, technical status, supplier status, financials, and supplier culture in the selection process. They used fuzzy logic to account for environmental concerns along with other criteria and simulated a supplier selection model with subjective preferences for different criteria. Considering the environmental selection criteria of Humphreys et al. (2006) as horizontal to other criteria, Lu et al.'s (2007) approach to a supplier's pre- and post-manufacturing processes could be a vertical examination of environmental concerns. Lu et al. (2007) proposed an analytical hierarchical decision-making model to examine a supplier's GSCM in the premanufacturing, product manufacturing, distribution and packaging, product use and maintenance, and end-of-life stages. In addition to the SE models of Humphreys et al. (2006) and Lu et al. (2007), Awasthi et al. (2010) presented a fuzzy multicriteria approach and added linguistic assessments to rate the various environmental criteria of suppliers. Furthermore, Büyüközkan (2012) used a fuzzy analytic hierarchy process to determine the relative weights of various environmental evaluation criteria and used an axiomatic design-based fuzzy group decision-making approach to rank green suppliers.

Genovese et al. (2013) reviewed the SE and selection models that had appeared in international scientific journals and conducted a questionnaire survey and two in-depth interviews about green supplier selection. The results showed that "while interest in the literature is growing, there is little empirical evidence of the transfer of these applications into the real world" (Genovese et al., 2013).

To address the poor adoption described by Genovese et al. (2013), scholars began to extend sustainable SE and selection to specific problems. Azadnia et al. (2015) used a fuzzy analytical hierarchy process and a multiobjective mathematical model for sustainable supplier selection and order allocation. They also combined the model with the multiperiod multiproduct lot-sizing problem to minimize total cost, maximize total social score, maximize total environmental score, and maximize total economic qualitative score. Their model is more practical for companies than the previous single objective model (Azadnia et al., 2015). Ji et al. (2015) provided full consideration to "recycling different types of material wastes from manufacturers" and "focusing on the cooperative tendency in the relationship between buyers and suppliers" to design an evolutionary game model for the green purchasing relationship. Additional studies should investigate solutions to practical problems, such as the influence of different stakeholders (Ji et al., 2015) as well as the uncertain and dynamic nature of the parameters that affect supplier selection (Azadnia et al., 2015).

2.4.4. Green Extended Supply Chain

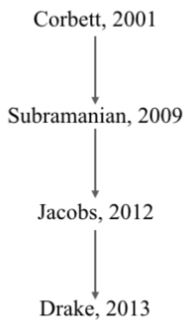


Figure 2-10. Knowledge structure of GESC cluster

The knowledge in the GSCM cluster (section 2.4.1) focused on the environmental collaboration in a simple or multiple layer buyer-supplier network. The GESC cluster focused on environmental management in extended supply chains, which emphasized on managing environmental sustainability by all (internal and external) units involved in designing, producing, storing, delivering, and using a product. Each step (unit) in the extended supply chain had its unique role and responsibility to manage environmental sustainability and would affect other units' performance. Figure 2-10 presents the knowledge structure of the GESC cluster. Corbett and Kleindorfer (2001) were the first to emphasize environmental priorities in the extended supply chain. They identified ten key drivers and opportunities to improve environmental performance in different parts of the extended supply chain, including suppliers and reverse logistics, production (including remanufacturing), packaging and outgoing logistics, customer end-use efficiency, lifecycle accounting, and recycling.

Based on the GESC concept, modeling scholars began to examine extended producer responsibility (EPR), which focuses on the lifecycle environmental performance of products (Subramanian et al., 2009). Subramanian et al. (2009) modeled a re-manufacturable product supply chain and demonstrated how charges during use and post-use of a product affect environmentally favorable product design. Jacobs and Subramanian (2012) extended EPR from product design to product recovery and examined the economic and environmental performance associated with the sharing of responsibility for product recovery.

Based on Paul Kleindorfer's contributions to sustainable OM, Drake and Spinler (2013) identified five OM fields that can improve firms' ecological efficiency in the GESC. The five fields are product design, production technology choice, transportation systems, forward supply chain, and closed-loop supply chain. These provide further research directions for OM scholars.

2.5. Discussion

In this study, we systematically reviewed 246 articles related to environmental concerns in the ten most reputable peer-reviewed OM journals, namely IJOPM, IJPE, IJPR, JOM, MSOM, POM, MS, JSCM, Omega, and DS. Analyzing the citation network of these 246 articles, we used the Girvan-Newman (2002) algorithm to identify four main clusters: GSCM, EMP, SE, and GESC. In each cluster, we presented their central knowledge development. Our literature review concludes three types of future research directions as follows.

Suggested areas for further research in each cluster. Based on the final node of each cluster, we have suggested that further research may focus on (1) further understanding the mechanism of GSCM by studying different mediating and moderating factors, (2) the effects of GS practices especially customer satisfaction, customer loyalty, operations costs, corporate reputation, and revenue growth (Bastič and Gojčič, 2012; Chan et al. 2016; Kassinis and Soteriou, 2003; Yee et al. 2009), (3) designing sustainable supplier selection/evaluation solutions by considering the influence of different stakeholders (Ji et al., 2015) and elements (Azadnia et al., 2015), and (4) how to improve ecological efficiency in the stage of product design, production technology choice, transportation systems, forward supply chain, and closed-loop supply chain.

Cross-cluster research opportunities. Besides identifying the knowledge development within clusters, we also propose the cross-cluster research opportunities for future research. Although knowledge in the GSCM and EMP clusters are well developed, the two clusters may merge in the future. One of the latest EMP research interests is environmental information integration, which requires information sharing with suppliers. Such development may blur the citation network boundary between these two clusters because supplier coordination is one of the leading knowledge types in GSCM. Probably, these two clusters may merge into one large cluster with comprehensive knowledge on EMP in the supply chain.

Research opportunities for developing countries. As we presented in the descriptive statistics (section 2.3), the research for developing countries in the stream of environmental sustainability emerged in the past few decades. However, it is still underdeveloped compared to the research for developed countries. This finding is proven by our later analysis in the cluster of GSCM (section 2.4.1). The scholars' attention devoted to the manufacturing firms in emerging markets as they started to apply GSCM in the past decades. Although there are few types of research in the GSCM cluster to study the developing countries, the mechanism of GSCM is still not well-understood. The knowledge development of other clusters (i.e., EMP, SE, GESC) in the context of developing countries is also insufficient, which leave many research gaps to fill.

Our review contributes to the review of environmental sustainability literature in several ways. First, by systematic reviewing the literature in the past three decades, our review fulfills the needs for reviewing the knowledge development of the environmental sustainability literature in the past decade as the latest review on the topic was published in 2007. Second, although we are not directly answering the question raised by Kleindorfer et al. (2005): "*when and how big will the impact be and how fast will the transition be?*", we provide a clearer picture of when and how to achieve environmental sustainability in different situations by clustering the literature into four clusters and reviewing the knowledge of each cluster. Operations and supply chain managers can follow the summarized environmental practices from the strategic levels to operations levels. However, our review has several limitations. First, the CNA does not consider the negative citation (cite articles with opposite meaning for criticizing)

(Fan et al., 2014). Second, some citations may be more critical than other citations, but we do not assign a weight to each citation. Further research may give a weight to each citation to differentiate the importance. Third, although the CNA is an objective analysis for literature review, our journal selection may be partially subjective. Future research may include Journal of Cleaner Production, Journal of Business Ethics or other journals to study the environmental sustainability papers in multi-disciplines.

In summary, the CNA results indicate that the interest in researching environmental concerns in emerging markets is increasing in the GSCM cluster because of the broad implementation of GSCM in manufacturing firms in developing countries. Also, studying a firm's EMP and its repercussions through the supply chain may contribute to the merging trend of the EMP and GSCM clusters. Therefore, in our following studies, we plan to contribute to the two clusters by understanding the effects of Chinese manufacturing firms' environmental violations on firm and supply chain performance.

Chapter 3. Essay 2: The Impact of Environmental Incidents on Market Value of Firms in China: Social Capital, Legitimacy and Political Ties

3.1. Introduction

Essay one demonstrated the increasing interest in researching the knowledge of environmental management practice in the supply chain, especially in emerging markets. Essay two studies the short-term effects of Chinese manufacturing firms' environmental incidents on firm and supply chain performance, which contributes to building up comprehensive knowledge on environmental concerns in emerging markets.

In this chapter, we plan to study the short-term impact of firms' environmental incidents comprehensively in the Chinese context. We examine the stock market reaction of 618 environmental incidents associated with 294 manufacturing firms publicly listed in China from 2006 to 2013. We examine the hypotheses regarding the contingency effects associated with a firm's social capital, legitimacy, and political ties that are pertinent to the Chinese context. We also explore the possible impact of environmental incidents resulting from Chinese firms on the market value of their overseas customers. The below Figure 3-1 shows the research framework and the hypotheses (Hs).

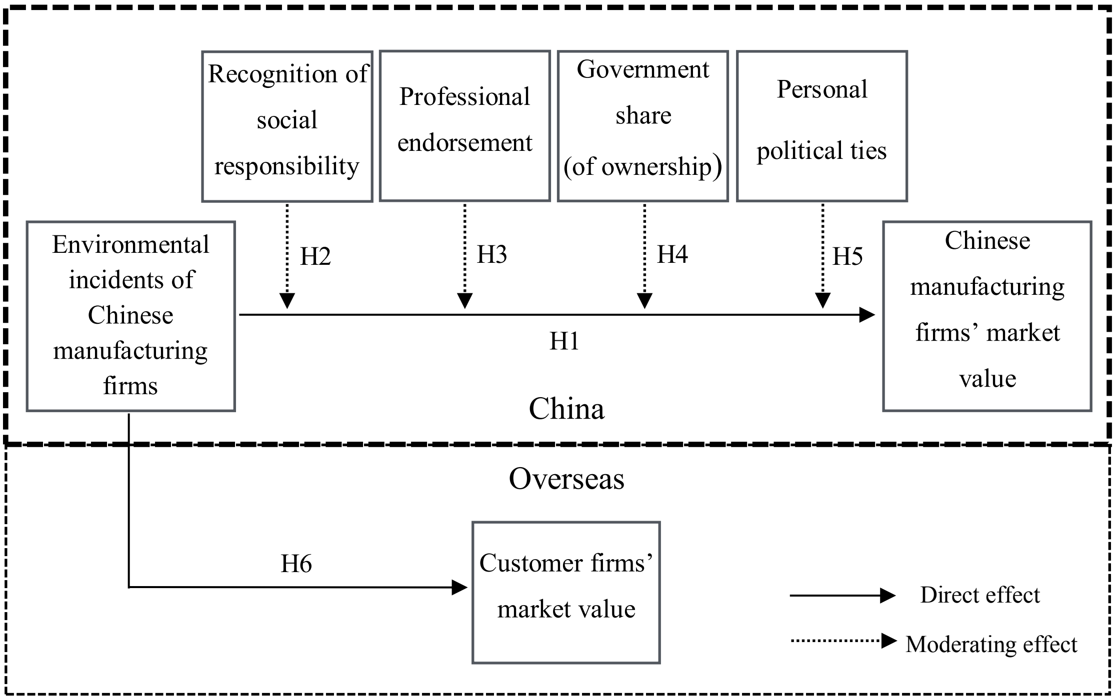


Figure 3-1. A Research Framework of Direct and Moderating Effects

Through H1, we examine the direct relationship between Chinese firms' environmental incidents and its market value. The H2 to H5 represent the moderating effects of social capital, legitimacy, and political ties on the direct relationship (H1) in the Chinese context. Studying the H1 to H5 can contribute to the knowledge of environmental management practices in China. Also, H6 represents the direct effect of Chinese firms' environmental performance on their overseas customer firms' market value, which examines the environmental incidents from a supply chain perspective and contributes to the knowledge of green supply chain management.

This study focuses on the short-term impact from the market perspective, which directly relates to stakeholders such as investors and customers. The effects of moderating factors are related to stakeholders such as public, government, and top management. In conclusion, the findings through H1 to H6 provide us with a comprehensive understanding of the short-term impact of environment incidents through the supply chain by taking different stakeholders into account. We will elaborate each question in the following part.

3.2. Literature and Hypotheses.

3.2.1. Direct Impact of Environment Incidents in China.

Although there is empirical evidence about the positive impact of environmental initiatives on a firm's performance in the context of developed economies (e.g., Klassen and McLaughlin 1996, Jacobs et al. 2010, Lo et al. 2012), few studies that examines the negative impact of environmental incidents on a firm's performance in developing countries such as China.

Klassen and McLaughlin (1996) found that the market reacts positively toward environmental improvements, whereas it reacts negatively after environmental crises. Jacobs et al. (2010) examined the market reaction to Corporate Environmental Initiatives (CEIs) and Environmental Awards and Certifications (EACs) in the U.S. market. They found that "Philanthropic gifts for environmental causes" and "ISO 14001 certifications" are associated with a positive market reaction, whereas "voluntary emission reductions" are associated with a negative market reaction. Pil and Rothenberg (2003) indicated that superior environmental performance could act as a significant driver of superior product quality. González-Benito and González-Benito (2005) found that environmental management generates competitive outcomes for firms such as higher product quality and more effective processes.

In the context of emerging markets, Gupta and Goldar (2005) examined the impact of environmental ratings on the stock prices of 50 large Delhi-based Centre for Science and Environment (CSE)-rated pulp and paper, auto, and chloralkali firms in India. They found a positive correlation between market returns and the levels of firms' environmental performance. Using survey data from Indian manufacturing firms, Mitra and Datta (2014) examined the relationships between green supply chain practices and firm performance, and they found that supplier collaboration for environmental sustainability had a positive impact on environmentally sustainable product design and logistics, which in turn led to improved competitiveness and economic performance for these firms.

In general, weak environmental performance typically has a negative effect on a firm's stock price, brand value, and reputation (Klassen and McLaughlin 1996, Brown and Dacin 1997, Porter and Kramer 2006), whereas a stronger environmental performance improves a company's profitability (Jacobs et al. 2010, Lo et al. 2012, Mitra and Datta, 2014). However, China's social and political systems are different from those of other countries. In general, the Chinese traditionally rely more on certain types of formal or informal personal ties to conduct business transactions (Jacobs et al., 2010). Due to the lack of policy and market transparency and the lack of easy access to reliable information (Yiu & Lau, 2008), individuals and organizations might perceive that the information obtained through their relationships is more "trustworthy, richer, and more useful" (Luo, 2003). Also, due to strong collectivistic culture, social capital is considered very important in the Chinese society (Acquaah,

2007) especially because China has been "governed by people in power rather than ruled by law" for many centuries (Luo, 2003). When operating in an emerging market, the government policy and regulations change frequently, and law enforcement is often weak and inconsistent. As the business and legal environment is different from that of developed countries, many Chinese firms handle environmental incidents differently, which may cause investors to react to Chinese firms' environmental incidents differently. These observations motivated us to examine our first hypothesis.

H1. Stock markets react negatively to an environmental incident in China.

When operating in a less stable business environment, Chinese firms are more likely to rely on certain types of strategic resources and social capital such as social recognition, professional endorsement, and government and personal relationships, to succeed (Acquaah, 2007; Hitt, Dacin, Levitas, Arregle, & Borza, 2000; Peng & Heath, 1996; Pfeffer & Salancik, 1978; Powell, 1990). These observations motivated us to examine particular types of legitimacy and political ties as talismans for protecting Chinese firms from unfortunate incidents. We will elaborate on these factors in the following text.

3.2.2. Recognition of Social Responsibility

China is a shame-based society, and most people fear being shamed (Hong and Chiu 1992, Li et al. 2004). To avoid "shame," many Chinese firms develop a name by demonstrating their commitment to social responsibility, which includes gaining recognition of social responsibility under the purview of the Chinese government. Recognition of social responsibility (e.g., CSR awards) are considered as social capital and particularly critical for gaining *social and political legitimacy* in the Chinese context, where weak formal institutions and firms rely heavily on these forms of "informal mechanisms" (Porta et al. 1998). Many Chinese firms use such social capital to build public trust and reputation due to the opaque business environment in China.

On the other hand, one may also argue that more recognition of social responsibility may also lead to more negative market reactions caused by the environmental incidents. This market drop may be because of the effects of high expectancy on firms' environmental performance. As the public trust and reputation on a firm increase in stakeholder expectations regarding the firm's behavior (Shapiro 1983), which generates speculation that drives shareholders to invest in such firms (Stigler 1983). The expectation built up by the trust and reputation may collapse easily when environmental incidents are disclosed. Thus, investors may modify their beliefs and adjust their investment to the firms (Cyert and DeGroot 1987), which may lead to a more severe drop in the firms' market value. With the aforementioned opposing viewpoints, we raise our second hypothesis to examine whether recognition of social responsibility moderates the negative impact of environmental incidents.

H2a. The Chinese firms' social recognition moderates the negative market reactions to the firms' environmental incidents.

H2b. The Chinese firms' social recognition aggravates the negative market reactions to the firms' environmental incidents.

3.2.3. Professional Endorsement from External Certifications

The external certification usually requires third-party audits and assessments, which provides a professional endorsement for firms' performance. The firm's legitimacy from such professional endorsements send positive signals to the market and show that the firm is running healthily. In this research, we focus on ISO 14001 certification because it is the most popular environmental certification in the World. Essentially, the environmental management system of an ISO 14001 certified firms is verified and approved by an independent certification body, ensuring that there are formal processes and procedures for environmental performance reviews, process improvements and problem corrections (Delmas, 2001; Tibor & Feldman, 1996). In fact, the ISO14001 certification provides a Chinese manufacturing firm with an internationally recognized *legitimacy* that facilitates international trades (Bansal & Hunter, 2003). When an environmental incident occurs, the market would expect that an ISO14001 certified firm (relative to a non-ISO 14001 certified firm) is more capable of resolving the underlying environmental issues as the firm is supposed to have a certified process to respond to environmental incidents and to resolve environmental problems swiftly. On the other hand, environmental incidents may lead to a more severe drop in the firm's stock price. Following the same argument for the recognition of social responsibility, we argue that the expectation built up by obtaining ISO 14001 may collapse when environmental incidents are exposed. Thus, we examine the moderating effect of such professional endorsement in our third hypothesis.

H3a. The professional endorsement of Chinese firms moderates the negative market reactions to the firms' environmental incidents.

H3b. The professional endorsement of Chinese firms aggravates the negative market reactions to the firms' environmental incidents.

3.2.4. Political Ties from Government and Individuals

In developing countries such as China, building a social network with government is a common way to reduce uncertainty (Park & Luo, 2001; Xin & Pearce, 1996). A close tie with the central or local Chinese government generates more "social capital," which enables firms to gain operational benefits and legitimacy benefits. Specifically, operational benefits include "smooth running of daily operations," "foresight information on future government policies," and "administrative approvals" (Davies, Leung, Luk, & Wong, 1995). Also, legitimacy benefits may bring in administrative priorities, such as better resource allocations from the government, greater protection on assets, and more favorable tax rates (Alston, 1989; Lau, Tse, & Zhou, 2002). In the case that an environmental incident occurs, the operational and legitimacy benefits might enable a firm to be more responsive and resilient. For example, when an environmental incident was disclosed, factory inspections and government authorization might be required to resume operations, and close ties to the government might facilitate such processes more efficiently. Also, when dealing with a serious environmental incident, a firm may need financial support to rectify the problems and restore operations; however, a close link to the government provides the bank and investors with greater confidence to finance the related activities. According to Sun et al. (2015), there are two major types of political ties between a firm and the Chinese government: (a) an organizational association through government ownership, and (b) a personal political association between senior management and government officials. In the following content, we will elaborate on the moderating effect of these two types of political ties.

3.2.4.1. Political Ties from Government: Government Share of Ownership

The Chinese government has converted many state-owned enterprises (SOEs) into shareholding corporations since 1997. At the same time, to attract foreign direct investments and to improve SOE competitiveness, the Chinese government concurrently encourages SOEs to seek "mixed ownership" as a solution to the financial problems facing many of China's SOEs (Meyer and Wu 2014). Also, the Chinese government acquires private firms for the strategic development of a particular industry. Despite the call for mixed ownership, mixed-ownership companies with a higher percentage of government ownership can ensure superior resource allocation, greater protection of assets, and more favorable tax rates (Alston 1989, Lau et al. 2002). In the event of a severe environmental incident, a firm with a higher percentage of government ownership is more likely to receive stronger financial and legal support from the central government, which provides Chinese investors with greater confidence. So, we seek to reaffirm the moderating role of government ownership in the fourth hypothesis.

H4. The higher government ownership of Chinese firms moderates the negative market reactions to the firms' environmental incidents.

3.2.4.2. Political Ties from Individuals: Personal Political Ties

Although the government share of ownership provides direct support for a firm to operate successfully in China, one general belief is that conducting business in China also requires "personal political ties." A conventional approach for a firm to develop such personal political ties is by concurrent appointments in the firm and government or the hiring of former government officials, so that the firm can secure operational benefits (e.g., faster license/permit approval through individual political relationships; Peng and Luo 2000). When the environmental incidents are disclosed, investors may believe that such personal political ties are more likely to cover up the environmental problems, which would assist in protecting a firm through personal government networks. So, the market will react less negatively to environmental incidents.

However, such "cover-up" activities may cause doubtfulness in public. Many government officials in China can use their administrative authorities to cover up negative incidents (Chen and Wu, 2007) because they want to conceal any incidents to protect their reputations (Lu, 2000, Zhou, 2010). A firm's senior executives with a political background are more capable of concealing the issue so that what is reported appears to be much less serious than what has occurred (Chen and Wu 2007, Zhou 2010). If the truth (i.e., the real consequences of the environmental incident) were to be eventually revealed, the company would need to pay a much higher price than what was originally reported. So, if the environmental incidents are disclosed, the firms with personal political ties are likely to attract extra media attention and cause doubtfulness in public. Such doubtfulness caused by the "personal pollical ties" may lead to greater uncertainty in the stock market. Given the above-opposing viewpoints, we test the moderating effect of personal political ties in the fifth hypothesis.

H5a. The personal political ties of Chinese firms moderate the negative market reactions to the firms' environmental incidents.

H5b. The personal political ties of Chinese firms aggravate the negative market reactions to the firms' environmental incidents.

3.2.5. Overseas Customers

The Chinese government developed Open Environmental Information (OEI) measures to revoke its image of being a global polluter. Such OEI measures require governmental organizations to publicize environment-related information proactively (Tan 2014). The OEI measures have enabled Institute of Public and Environmental Affair (IPE) to develop an online database on environmental incidents for which Chinese firms are responsible, which has become a "go-to place" for multinational corporations (MNCs) and non-governmental organizations (NGOs) in Western countries for monitoring the environmental performance of their Chinese suppliers. With increased environmental transparency and tighter monitoring, multinational brands' supply chains are facing public scrutiny (Plambeck et al. 2012). Therefore, environmental incident committed by an upstream supplier can trigger consumers to boycott downstream customers who have sourced from irresponsible suppliers. Hence, environmental incident by an upstream supplier can create a negative impact on the financial performance of its downstream firms (Klein and Smith et al. 2004).

However, environmental incidents involving Chinese suppliers might have no impact on their overseas customers. Some empirical evidence shows that the Rana Plaza disaster, the second-worst industrial incident in history, did not have a negative impact on the stock prices of retailers that sourced from Bangladesh (Jacobs and Singhal, 2017). Also, recent socially irresponsible labor practices at Foxconn appear to have had a little negative impact on Apple's sales growth. Consumers may expect that pollution is prevalent in developing countries and believe that the issue is not the responsibility of individual buyers (Josephs 2014). The supplier's incidents might have been considered to be beyond the control of retailers as contracted buyers. Similarly, investors might perceive that environmental incidents in China are beyond the control of overseas buyers and thus buyers should not be held accountable. From the opposite viewpoints, we examine the impact of environmental incidents in China on the stock market reactions of their overseas customers in sixth hypothesis.

H6. Environmental incidents by Chinese suppliers lead to a negative stock market reaction for their overseas customers.

3.3. Data Collection

This chapter focuses on the impact of environmental incidents associated with manufacturing firms in China (manufacturing firms on either the Shanghai or Shenzhen Stock Exchange). Among all developing countries, we focused on China because (1) environmental incidents are most severe in China, (2) environmental incidents are relatively well documented by local and international NGOs in China, (3) China's stock market data are accessible with detailed archival data for analysis, and (4) empirical evidence on the impact of environmental incidents to a Chinese firm's performance is not well understood.

3.3.1. Environmental Incidents

Although information associated with environmental incidents is monitored and controlled by the Chinese government, actual data are scattered over various Chinese government offices located in different cities, provinces, or in Beijing's central government. It has been a challenge for researchers to collect information on environmental incident announcements from disaggregated data sources. This situation remained unchanged until 2006, when IPE, a Beijing-based NGO, with the central government's support, was established. IPE aims to "promote widespread public participation in environmental governance" by collecting and disseminating all historical and current environmental incident announcements from various government offices (i.e., cities, provincial, and central). IPE has concurrently compiled information from other sources, including newspapers and companies' corporate social responsibility reports. IPE also interacts with violators to provide updates of their follow-up or corrective measures on the Website. In the research community, IPE is recognized as a trusted resource of environmental incident announcements in China, and the data provided by IPE are commonly referenced by academic publications, such as *Journal of Operations Management* (e.g., Gualandris et al. 2015), *Production and Operations Management* (e.g., Porteous et al. 2015), *Journal of Business Ethics* (e.g. Tan 2009), *Harvard Business Review* (e.g., Lee 2010), and *Nature* (e.g., Qiu 2010).

This research focuses on manufacturing firms (i.e., Industries C13 to C43 based on the classification from the China Securities Regulatory Commission) because manufacturing operations constitute a significant source of pollution in China. By 2014, 1,675 listed manufacturing firms existed in China. For each of these 1,675 manufacturing firms, we used their respective unique stock code and company name to search for announcements in the IPE's environmental incidents database.

From the IPE database, we found 1,833 environmental incidents for which 524 manufacturing firms were responsible between 2004 and 2013. Although IPE was established in 2006, its database contains companies' environmental incidents data since 2004. We deleted 377 routine monitoring reports that were published daily or monthly that were not considered major environmental incidents (e.g., NOx emission level over the standard by 0.1 in a monthly monitoring report). We then removed 311 duplicate announcements in IPE to avoid double-counting. We further eliminated 257 incidents, which included firms under trade suspension on the announcement date, which did not have stock price data for event study method used in the research. We discarded 45 announcements because of the lack of historical stock price data (200 trading days from Day −11 before the incident), which were required to conduct our event study. We also discarded 62 incidents that announced in and before 2005, the year in which the Chinese government implemented a Non-Tradable Share (NTS) reform. It is against the assumption of market efficiency for a short-term event study. We also discarded five announcements related to nuclear or radiation incidents. These events differ considerably from most other types of environmental incidents and may receive additional attention from the government and the public. We discarded 158 incidents with confounding events from our sample (Confounding events are identified in the section 3.3.1.2). We excluded six announcements with a negative price-to-book ratio, and 15 announcements without sufficient sales data to calculate firm diversification. Table 3-1 shows the steps on how we constructed our final sample set; we recorded the announcement date, location, fine, legal action, source of the announcement, and incident type.

Table 3-1. Number of Announcements and Firms in the Sample

Announcements	Number of Announcements
Number of environmental announcements collected from IPE	1,833
not classified as routine monitoring reports	1,456
without duplication issues	1,145
with trading data	888
with sufficient historical stock price data to conduct the event study	843
in or after 2006	781
unrelated to nuclear or radiation	776
without confounding events	618
Effective announcements for H1	**618**
with sales data for calculating firm diversification	603
without negative price-to-book ratio	597
Effective announcements for H2 - 5	**597**
with at least one publicly listed overseas customer	64
Effective announcements for H6	**64**

Firms	Number of Firms
Number of firms in China's stock market	2,684
Manufacturing firms	1,675
with environmental incidents	524
after eliminations of unsuitable announcements	294
Final sample manufacturing firms for H1	**294**
Final sample manufacturing firms for H2 - 5	**285**
Final sample manufacturing firms for H6	**51**

3.3.1.1. Date of Environmental Incidents

Because IPE summarizes various government-issued environmental incident reports, the date of the incident announcement reported by IPE may not be the earliest date that the public received it. To ensure that we captured the public notification date correctly, we deployed two teams of research assistants to search through WiseNews for all related news associated with each of the 1,145 incidents. We found 119 cases with different announcement dates from those reported in the IPE database. In 65 cases, we found earlier announcement sources, while in 54 cases the date recorded by IPE was incorrect. We corrected the announcement date of each of these 119 cases in our sample. If the news online time is after 3:00 PM (the closing time of the stock market in China), then the date of the incident (i.e., Day 0) is the next trading day. We then checked the confounding events based on the revised public notification date.

3.3.1.2. Confounding Events

We removed the influence generated by confounding events, which included the declaration of dividends, the announcement of an impending merger, the signing of a major government contract, the announcement of a new product, the filing of a major damage lawsuit, the announcement of unexpected earnings, and changes in a key executive; McWilliams and Siegel 1997). We used a 4-day period (i.e., Day -2, Day -1, Day 0, and Day 1) in our confounding events search (Klassen and McLaughlin 1996). By searching for various confounding events from WiseNews, we found 142 announcements in our sample with confounding events covering two days before and one day after the event date (Klassen and McLaughlin 1996). WiseNews (wisernews.wiser.net), the most comprehensive Chinese news database, covers 1,600 newspapers and periodicals published in mainland China, Hong Kong, and Taiwan. We also found 16 announcements that included firms with a fluctuating stock price because of market rumors within a

15-day period before the event. In total, we discarded 158 incidents with confounding events from our sample. Finally, we included 618 environmental incidents committed by 294 manufacturing firms in our analysis.

3.3.1.3. Classifications of Environmental Incidents

We classified the environmental incidents into four major types. First, IPE traditionally classifies environmental incidents with direct pollution into two major types: air (Type 1) and water (Type 2) pollution. IPE also reports the government announcements of environmental violations through government inspections (Type 3). Next, for environmental incidents caused by firms that operate without the required Environmental Impact Assessments (EIAs; Gu and Sheate 2005), we classified these incidents as Type 4. Finally, if more than one of the four types was involved in an announcement, we coded it as Type 5 in our analysis. Table 3-2 lists the types of environmental incidents.

Table 3-2. Classifications of Environmental Incidents

Classification	Number of announcements
Air (Type 1)	153
Water (Type 2)	232
Environmental violations through government inspections (Type 3)	228
Incidents caused by operations without the EIAs (Type 4)	52
Multiple (Type 5)	47
Total*	**618**

*Total = Type 1 + Type 2 + Type 3 + Type 4 - Type 5

3.3.2. Variables

3.3.2.1. Financial Data

For each of these 294 firms, we collected a firm's financial data (e.g., the stock price, market value, and other accounting data) from the Thomson Reuters Eikon database. Table 3-3 shows the descriptive statistics of the financial data of our sample firms.

Table 3-3. Descriptive Statistics of the Sample Firms in the 618 Announcements (for H1)

	Total Assets (RMB 000,000)	Sales (RMB 000,000)	Net Income (RMB 000,000)	Number of Employees (000)	ROA	Debt-to-Equity Ratio	Price-to-Book Value	Market Value (RMB 000,000)	Outstanding Stock (000,000)	Stock Price (RMB)
Mean	12,384.64	10,533.06	582.88	9.86	0.05	1.19	3.12	11,384.97	1,008.24	12.69
Median	4,123.02	3,053.35	137.27	4.00	0.05	0.81	2.66	4,877.37	483.88	9.66
Std. Error	23,807.38	20,209.13	1,741.79	17.67	0.07	1.74	15.68	21,724.19	1,840.52	9.69
Max.	202,008.00	191,558.99	19,307.69	177.62	0.50	30.74	63.58	316,441.84	17,512.00	71.95
Min.	143.81	39.77	-8,022.28	0.03	-0.73	0.00	-360.98	390.16	73.39	2.08

Note. Market value, outstanding shares, and stock price data are for Day −10

3.3.2.2. Recognition of social responsibility (*Recognition_of_social_responsibility*$_i$)

We obtained data for the recognition of social responsibility (e.g., general CSR awards; environmental awards; awards related to integrity, credibility, and honesty; and charity awards) through a three-step approach. We first collected award information from the official website (or annual report) of each of the 294 firms. Next, we performed a search by company name to determine whether the firms have received either or both of the two most prestigious CSR and environmental awards in China (i.e., China CSR Award Submit and China Environmental Award). Finally, we performed keyword searches (e.g., [company name or stock code] + [award]) on popular search engines (e.g., Google and Baidu) and Chinese news portals regularly used by investors (e.g., Xinhuanet.cn, Sina.com, ifeng.com, 163.com, and the Thomson Reuters Eikon database). At the first step, we collected information on 623 awards in total and added 12 awards in Step 2 (no award was added at Step 3).

We measured each firm's recognition of social responsibility (*Recognition_on_social_responsibility$_i$*) based on the number of awards received by the firm since the year of incorporation up to the year before the environmental incident. However, the value of an award is likely to depreciate over time. We thus set an exponential depreciation rate at 20% per year by assuming that the value of an award depreciates by approximately half in every 3-year period.[1] Our results remain robust when we set the depreciation rates to 30% or 10%. The exponential function on the value of social recognition for a firm is set as follows:

$$Recognition\_of\_social\_responsibility_{i,t} = \sum_{t=ic}^{ev-1} AW_t * (1 - DR)^{ev-1-t} \quad \text{(E.3-1)}$$

where $Recognition\_on\_social\_responsibility_{i,t}$ denotes social recognition of firm i in year t, ev is the year that the event occurred, ic is the year that the firm is incorporated, AW_t is the number of awards received in year t, and DR is the depreciation rate.

[1] Assuming a firm won an award in 2006 and the environmental incident happened in 2010, the value of the award depreciates by $1 \times (0.8)^3 = 0.512$. We would not include any award in the event year (i.e., 2010). There would be no discount in 2009, a 20% discount in 2008, and so on.

3.3.2.3. External Certification (***ISO14001$_i$***)

We obtained the certification records of the environmental management system (i.e. ISO 14001) from the Certification and Accreditation Administration of the People's Republic of China (http://www.cnca.gov.cn/). We used a dummy variable for ISO14001-certification (certified = 1 when an environmental incident is announced, otherwise = 0).

3.3.2.4. Government Share of Ownership (***Government_share$_i$***)

We measured the government share of ownership (*Government_share$_i$*) according to the percentage of the government-owned shares for each firm *i* by using data from the Thomson Reuters Eikon database.

In the regression model in section 3.4.2., one may challenge the segmentation of the government share maybe quite distinctive in certain industries, because government ownership and industry may be correlated. The purpose of government investment in certain firms maybe "maximizing employment, financing key industries, and maintaining social stability (which includes social and environmental responsibility) rather than maximizing profits" in the country (Li, Yue, & Zhao, 2009; Tian & Estrin, 2007; Li & Zhang, 2010). Given such potential correlations, it is hard to interpret the coefficients of the moderating variables. However, as shown in the correlation table 3-14, the relationships between government and other factors in our sample were typically not markedly strong. In other words, no single major factor affected the government determining its ownership of a firm. For example, we found that government ownership is not related to firm size as measured by the market value of equity (correlation = 0.067; $p > .05$). Government ownership is only weakly related to firm diversification (correlation = 0.088, $p < .05$) and recognition of social responsibility (correlation = -0.156, $p < .01$). Moreover, we conducted further tests and found that government ownership was not related to firm age regarding years after being publicly listed (correlation = -0.083; $p > .05$) and firm efficiency regarding industry-adjusted ROA (correlation = -0.036, $p > .05$).

To further examine if a certain industry cluster dominates government ownership, we classified 26 industries in China's standard industrial classification into five major categories, as listed in Table 3-4, which shows that the average percentage of government ownership was relatively consistent across different major industrial types.

Table 3-4. Government ownership by industry

Industry	Number of events	The average percentage of government share
Metal and non-metallic mineral products (C30 - 33)	160	27.10%
Chemical products (C26-29, except C27)	138	20.58%
General equipment manufacturing (C34 - 41)	97	21.48%
Textiles and paper products (C17-18, C20, C22)	63	18.78%
Pharmaceutical manufacturing (C27)	62	17.97%
Others (all other not included)	77	18.58%
Total	597	21.75%

3.3.2.5. Personal Political Ties ($Personal\_political\_ties_i$)

To collect data on personal political ties, we examined the background of TMT/board members for each of the 294 firms at the year of the 618 announcements. We identified the names of the directors of each firm and their past and concurrent position(s) at the various governmental organization(s) (if any) from the GTA's financial database. GTA is a leading global provider of

China financial market data who provides integrated financial research solutions for over 2000 educational, research and financial institutions around the world. Researchers at more than one thousand universities and financial institutions widely use its databases. Over 1700 academic papers published in leading Journals (such as Journal of Finance and The Journal of Financial Economics) were based on GTA databases.

If a TMT/board member was currently or previously employed by a governmental organization when an environmental incident was announced, we considered the company to have one effective personal political tie. Several types of political ties are associated with different governmental organizations under the Chinese political system; however, we focused on those with ministries under the State Council and Local People's Government. Both governmental organizations are administrative authorities responsible for developing and executing government policies specifically related to the country's industrial and commercial sectors. Departments under these two units are concerned with customs, taxation, industry and commerce, food and drug administration, environmental protection, work safety, and so on. They directly regulate the industrial and commercial sectors. Personal political ties with ministries under the State Council might aid firms in gaining additional administrative support, market intelligence, and policy insight. We do not count TMT/board members who hold concurrent position(s) at the People's Congress, the People's Court and the People's Procuratorate, Chinese People's Political Consultative Conference, or the Congress of the Communist Party of China as political ties in our analysis because these organizations do not have direct power in regulating company operations. For robustness checks, we also tested the effects of these four types of political ties but found no significant impact on abnormal stock returns. For the data on all government positions, we differentiated governmental organizations into four levels according to the Chinese government's official classification system: (i.e., national, provincial, city, and district). We assigned scores to the four levels (4 = national, 3 = provincial, 2 = city, and 1 = district level) based on the assumption that national-level political ties are the most powerful of these ties.

To measure the personal political ties of each firm *i* ($Personal\_political\_ties_i$), we first counted the number of personal political ties for each firm *i*. We then multiplied the value by the corresponding score assigned for the governmental level. Finally, we added the results to obtain a personal political ties score for each firm *i* for when an environmental incident was announced. Previous research has adopted a similar approach in measuring political ties. For example, Fan et al. (2007) trace the political connections of senior management and boards of directors according to whether they are current or former officers of a local or central government. Hillman (2005) measures political ties according to the number of board directors with political experience at the local or national level.

In Table 3-5, we provide an example of five firms from the sample with information on different types of environmental incidents, the aforementioned moderating effects, and the corresponding abnormal stock returns.

Table 3-5. Examples of five sample firms involved in different types of environmental incidents, the four moderating effects (i.e., *Recognition_on_social_responsibility*$_i$, *ISO14001*$_i$, *Government_share*$_i$, *Personal_political_ties*$_i$) and the corresponding abnormal stock returns for each firm.

Company Code	**Company Name**	**Business Nature**	*Recognition_of_social_responsibility*$_i$	*IOS 14001*$_i$	*Government_share*$_i$	*Personal_political_ties*$_i$	**Description of Environmental Incidents**	**Incident Type**	**Incident Year**	**Day -1**	**Day 0**	**Day -1 to 0**
600623	DOUBLE COIN HOLDINGS LTD.	Rubber and plastic products industry	No	Yes	66.99%	9	The factory did not comply with wastewater discharge standards and discharged excessive pollutants with their wastewater.	Water	2008	-0.70%	0.65%	-0.05%
600367	GUIZHOU REDSTAR DEVELOPING CO., LTD.	Raw chemical materials and chemical products	A score of 0.85	Yes	52.13%	0	The factory did not comply with standards on air pollutant emissions (e.g., toxic gas - hydrogen sulfide) and wastewater discharge and was ordered to stop the wastewater and air pollutant discharge immediately.	Multiple	2008	-1.15%	1.31%	0.16%
000488	SHANDONG CHENMING PAPER HOLDINGS CO., LTD.	Papermaking and paper products	No	Yes	24.06%	2	The factory discharged a large number of water pollutants into the Xiaoqing River, causing severe environmental problems to the neighborhood.	Water	2007	-1.00%	-0.95%	-1.95%
000731	SICHUAN MEIFENG CHEMICAL INDUSTRY CO., LTD.	Raw chemical materials and chemical products	No	Yes	4.42%	3	The factory did not comply with the wastewater discharge standards (e.g., toxic chemical indicated by the presence of ammoniacal nitrogen [NH_3-N]).	Water	2010	-0.18%	-0.37%	-0.55%
002420	GUANGZHOU ECHOM SCIENCE&TECHNOLOGY CO., LTD.	Rubber and plastic products industry	No	Yes	0.00%	4	The factory did not comply with air pollution requirements; insufficient use of air pollutants filtering/handling facilities	Air	2012	-6.45%	-4.02%	-10.47%

3.3.2.6. Control Factors

We used the following control factors to ensure that our results are robust. We collected related financial data (e.g., sales, market value, and other accounting data) from the Thomson Reuters Eikon database. Unless stated otherwise, the factors are based on the fiscal year ending before the announcement date.

Incident history ($Incident\_history_i$). We controlled for each firm's history of environmental incidents, which is firm *i*'s yearly average number of environmental incidents disclosed before the current incident and since becoming publicly listed. Pollution history may affect a firm's reputation and investors' perceptions of the firm.

First company event ($First\_company\_event_i$) and **first company event in the year** ($First\_company\_event\_year_i$). To distinguish between the first-time incident versus repeat offenses, we used a dummy variable ($First\_company\_event_i$: 1 = first-time offender, 0 = repeat offender) to control for the effect of the number of offenses. Although certain firms might be involved in multiple environmental incidents, recent events are likely to have a stronger impact on investor perceptions. Therefore, we controlled for this factor ($First\_company\_event\_year_i$: 1 = first incident of the year, 0 = second or additional incidents within the fiscal year).

Damage ($Damage_i$). We differentiated the events between regulatory violations versus those with actual damage to the environment according to the content of the announcements; for this, we used the dummy variable $damage_i$ (1 = event with actual damage, 0 = regulatory violations without specifying the actual damage) to reflect the severity of the event, which may affect investors' judgments.

Source of information ($Source\_of\_information_i$). We coded environmental incidents uncovered by the government (e.g., through government inspections) as 1; otherwise, we coded the variable as 0 (e.g., reports from news media).

Daily ($Daily_i$). For announcements made on a daily basis instead of some other regular schedule (e.g., monthly or quarterly), we coded this variable as 1; otherwise, it is coded as 0 (i.e., regular/scheduled announcements). Approximately 90% of the announcements are from unscheduled daily sources, whereas the other 10% are made through regular/scheduled announcements (but still published by daily news sources).

Firm diversification ($Firm\_diversification_i$). Firm diversification is the Herfindahl index of a firm's sales by industry segment. Firms that are more diversified are likely to be less negatively affected because an environmental incident might affect the operations of only a certain product type, leaving other business lines unaffected.

Firm size ($Market\_value\_of\_equity_i$). We measured firm size by the natural logarithm of a firm's market value of equity 10 days before the announcement date. Larger firms are more likely to have a stronger financial position and management capability and thus be less affected by a single negative incident.

Three-year averaged industry-adjusted operating returns on assets (ROA_i). ROA_i is measured as a firm's operating profits divided by total assets and adjusted by industry. We used the 3-year average industry-adjusted ROA before the environmental incident to prevent 1-year ROA volatility. Firms with higher profitability give investors the impression that they are more efficiently managed and are thus more capable of solving underlying environmental issues.

Other control factors. We controlled for industry-specific effects (e.g., the likelihood of environmental incidents by industry or the perceived severity of an event because of the nature of the industry) by using a dummy variable for industry ($Industry\_Dummy_i$). We also controlled for the year of the announcement ($Year\_Dummy_i$) because general economic conditions vary between years.

3.3.2.7. Overseas Customers

To obtain information on each firm's downstream customers, we reviewed the financial reports of firms for the years in which environmental incidents occurred. We identified the names of their five largest customers, which are disclosed at the discretion of firms. Of the 618 environmental incidents committed by 294 Chinese firms, we identify 64 incidents (committed by 51 Chinese firms) that reported at least one publicly listed overseas customer in their top-five supplier records in the year's annual reports. Specifically, in 42 incidents, we found only one publicly listed overseas customer; in 15 announcements, we found two overseas customers; in six announcements, we found three overseas customers; and in one announcement, we found five overseas customers. Therefore, from these 64 announcements, we identified a total of 95 publicly listed overseas customers (i.e., 42 × 1 + 15 × 2 + 6 × 3 + 1 × 5) linked to the 64 environmental incidents of their Chinese suppliers. We deleted seven customer firms because of a lack of historical stock price data for the 200-day event period before the incident. We removed nine incidents with confounding events that occurred during the event period. Finally, we obtained 79 customer incidents involving 56 overseas customers operating in 12 overseas markets.

The China Securities Regulatory Commission (CSRC) requires firms to report the percentage of sales contributed by their top five customers. Such reporting action is the reason we focus on the top five rather than all major customers. However, the regulation does not require firms to report the names of their customers (although it is highly encouraged by the CSRC). We believe that firms with more prestigious customers tend to reveal their names. Thus, our results might apply to highly reputable overseas customers. We are unaware of any legal definition for "major customers," but they are all top five customers of the Chinese firms. Our data show that on average each of these overseas customers accounts for 13.67% of the Chinese firms' total sales. We believe that this value is quite significant given that the customer is just one in the top five list and not the largest customer.

From our 618 effective announcements, we find that 23.2% of the firms reported the name of at least one customer that is publicly listed (locally or overseas). Furthermore, 11.4% of the firms reported the name of at least one publicly listed overseas customer. Thus, we have the names of only 95 publicly listed overseas customers and 79 effective sample firms.

We found that despite the regulations, only 389 of the 618 announcements contain the percentage accounted by the top five customers in their annual reports. Please refer to the following tables (3-6 and 3-7) for the demographics of the Chinese sample and a comparison between the firms that reported customer sales and those that did not. Although it appears that larger firms (regarding total assets and sales) tend to report the percentage accounted by their top five customers, their profitability regarding ROA and their evaluation regarding price-to-book value are very similar. In fact, the non-reporting firms appear to have a higher price-to-book ratio, reflecting a higher market value. We thus believe that there is no clear systematic difference between these two groups.

Table 3-6. Descriptive Statistics for the Sample Firms that Report Top-Five Customer Sales in Their Annual Reports (n = 389)

	Total Assets (RMB 000,000)	Sales (RMB 000,000)	Net Income (RMB 000,000)	Number of Employees (000)	ROA	Debt-to-Equity Ratio	Price-to-Book Value	Market Value (RMB 000,000)	Outstanding Stock (000,000)	Stock Price (RMB)
Mean	14,411.39	11,674.56	590.86	11.05	0.05	1.30	2.97	12,082.88	1,104.88	12.65
Median	5,399.36	3,616.24	149.72	4.27	0.05	0.85	2.65	5,070.52	522.71	9.80
Std. Error	25,428.94	20,613.86	1,451.77	20.40	0.07	2.04	19.21	19,368.58	1,820.75	9.40
Maximum	176,969.16	120,994.85	9,396.66	177.62	0.50	30.74	63.58	188,161.45	14,667.71	63.85
Minimum	341.02	77.48	-8,022.28	0.29	-0.73	0.00	-360.98	936.94	90.00	2.08

Note: Market value, outstanding shares, and stock price are data on Day −10.

Table 3-7. Descriptive Statistics of the Sample Firms that do not Report Top-five Customer Sales in their Annual Reports (n = 229)

	Total Assets (RMB 000,000)	Sales (RMB 000,000)	Net Income (RMB 000,000)	Number of Employees (000)	ROA	Debt-to-Equity Ratio	Price-to-Book Value	Market Value (RMB 000,000)	Outstanding Stock (000,000)	Stock Price (RMB)
Mean	8,941.80	8,594.02	569.31	7.84	0.05	1.00	3.36	10,199.42	844.08	12.76
Median	2,763.99	2,530.18	126.43	3.83	0.05	0.74	2.71	4,344.70	402.11	9.58
Std. Error	20,359.17	19,392.87	2,150.13	11.41	0.05	1.02	6.16	25,228.87	1,866.16	10.18
Maximum	202,008.00	191,558.99	19,307.69	94.27	0.26	9.15	27.40	316,441.84	17,512.00	71.95
Minimum	143.81	39.77	-2,845.87	0.03	-0.16	0.00	-72.20	390.16	73.39	2.10

Note: Market value, outstanding shares, and stock price are data on Day −10

The top three overseas markets in our sample are Hong Kong (24 announcements), United States (19 announcements), and Japan (10 announcements). Table 3-8 shows the distribution of the stock markets.

Table 3-8. Distribution of Stock Markets

Stock market	Country	Number of announcements
Hong Kong Stock Exchange	Hong Kong	24
New York Stock Exchange	United States	19
Tokyo Stock Exchange	Japan	10
Korea Exchange	Korea	9
Frankfurt Stock Exchange	Germany	5
Taiwan Stock Exchange	Taiwan	3
London Stock Exchange	United Kingdom	2
National Stock Exchange of India	India	2
Singapore Exchange	Singapore	2
Copenhagen Stock Exchange	Denmark	1
Euronext Brussels	Belgium	1
Euronext Paris	France	1
Total		79

The announcement online times (Beijing time) were converted to the local time of each corresponding overseas market. If the announcement was made after the closing time of the overseas stock market, then the date of the incident is marked as the next trading day. We obtained the stock price on the announcement date of these downstream customers from the Thomson Reuters Eikon database. Table 3-9 shows the descriptive statistics of the announcements involving overseas customers, respectively. The currency used in different markets is converted to US dollars based on the exchange rate on the event date.

Table 3-9: Descriptive Statistics of Overseas Customers (n = 79)

	Total Assets (USD 000,000)	Sales (USD 000,000)	Net Income (USD 000,000)	Number of Employees (000)	ROA	Debt-to-Equity Ratio	Price-to-Book Value	Market Value (USD 000,000)	Outstanding Shares (000,000)	Stock Price (USD)
Mean	47,354.05	37,020.19	2,357.47	88.80	0.11	0.91	2.34	26,891.34	2,749.30	93.16
Median	7,714.40	5,940.33	369.72	25.50	0.10	0.56	1.79	5,704.36	1,079.77	11.33
Std. Error	98,919.04	51,971.03	8,492.59	164.72	0.09	1.05	2.07	47,700.72	9,318.14	289.48
Max.	797,769.00	189,142.26	28,135.71	1,290.00	0.49	5.00	15.04	209,058.35	80,932.37	1,392.53
Min.	30.55	11.27	-28,695.00	0.06	-0.13	0.00	0.12	62.85	2.17	0.03

Note. Market value, outstanding shares, and stock price data are for Day −10

Figure 3-2 summarizes a flowchart of our data collection process from the multiple sources.

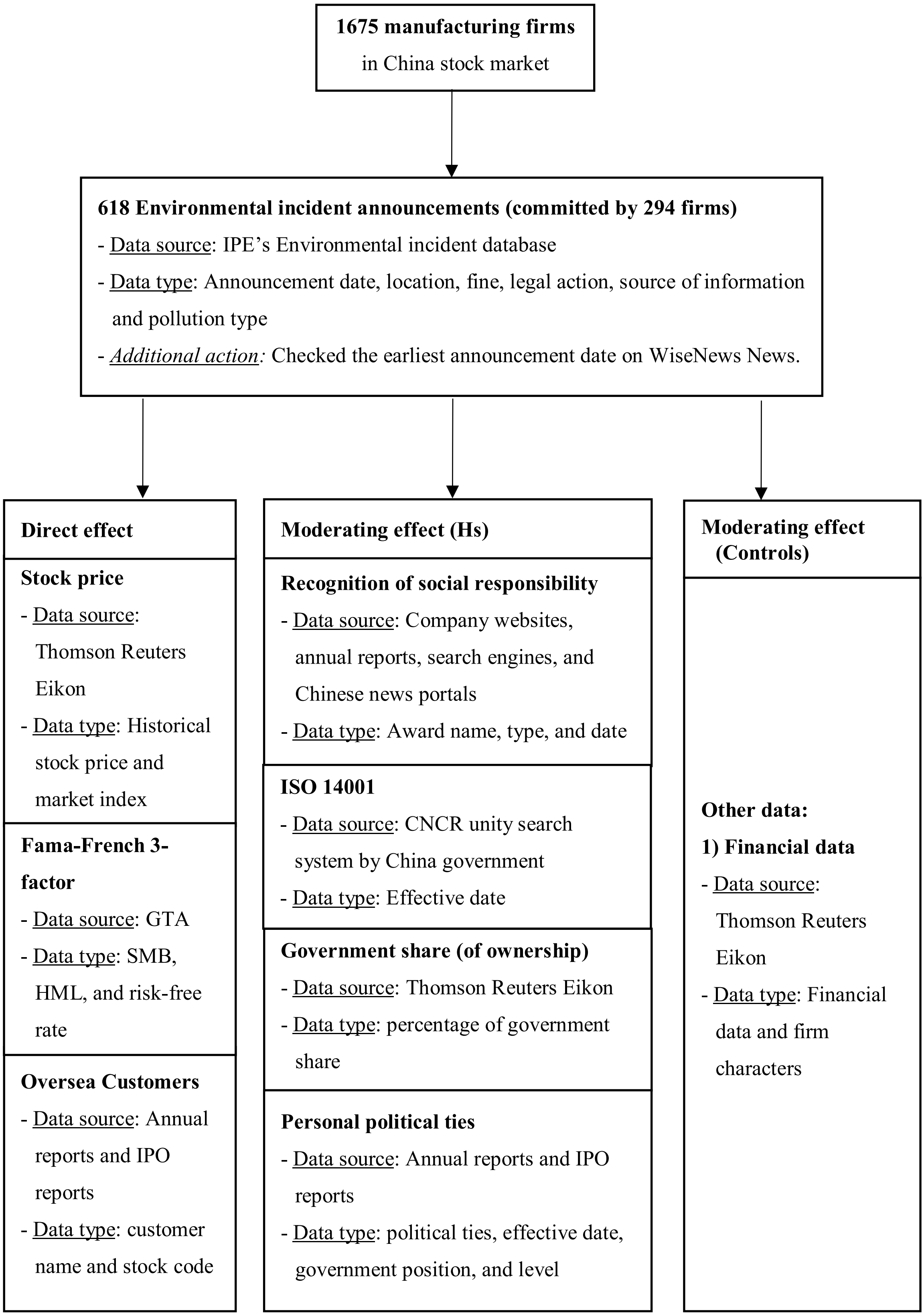


Figure 3-2. Data collection process and data source

For these 294 Chinese manufacturing firms, we collected the historical stock price, market index, and Fama-French three factors based on the estimation period (stated in the following part) and environmental incident announcement date, and the market values of equity based on 10 days prior to the announcement date. Data on political ties, incident history, and ISO14001 certifications prior to the announcement date were considered. Data on social responsibility recognition (number of related awards) and other financial indicators were collected based on the most recent fiscal year ending prior to the announcement date. Figure 3-3 shows the data collection timeline of each type of indicator corresponding to the timing of an environmental incident announcement.

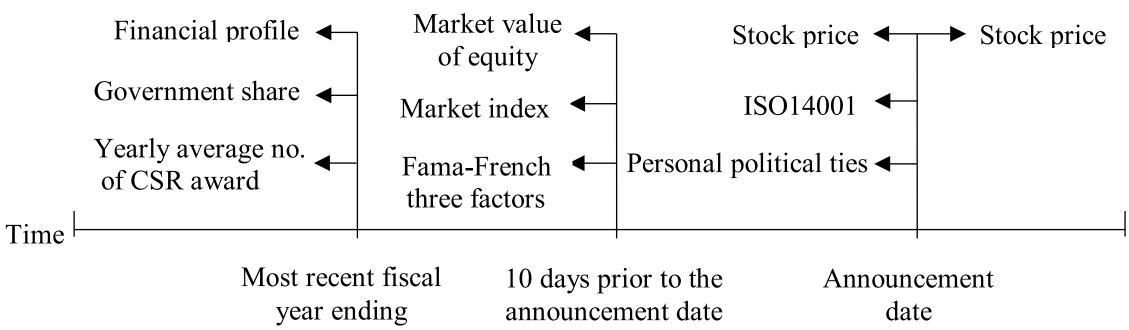


Figure 3-3. The timeline of the data corresponding to the incident's announcement

3.4. Analysis and Results.

3.4.1. Direct Effect of Environmental Incident

We used the event study methodology (e.g., Brown and Warner 1985) to measure market reactions to the announcements of environmental incidents. We assumed that the impact of an event is reflected in the stock price (Jacobs and Singhal 2014, MacKinlay 1997). We calculated the abnormal returns (an estimate of the percentage change in stock price associated with an event) on stock prices by adjusting them with market-wide movements (MacKinlay 1997).

Consistent with previous event studies conducted in different contexts (e.g., Brown and Warner 1985, Hendricks and Singhal 2009, Jacobs and Singhal 2014), we used a 2-day event period (the announcement day and the trading day preceding the announcement day) to measure abnormal stock returns. The event period includes the day of the announcement and the trading day preceding the announcement to account for the possibility of event information leakage one day before the publication of the announcement (Hendricks and Singhal 2009, Jacobs and Singhal 2014). To translate the calendar days into event days, we used Day 0 to represent the announcement date, and Day -1 to represent the trading day before the announcement. Figure 3-4 shows the timeframe of our event study.

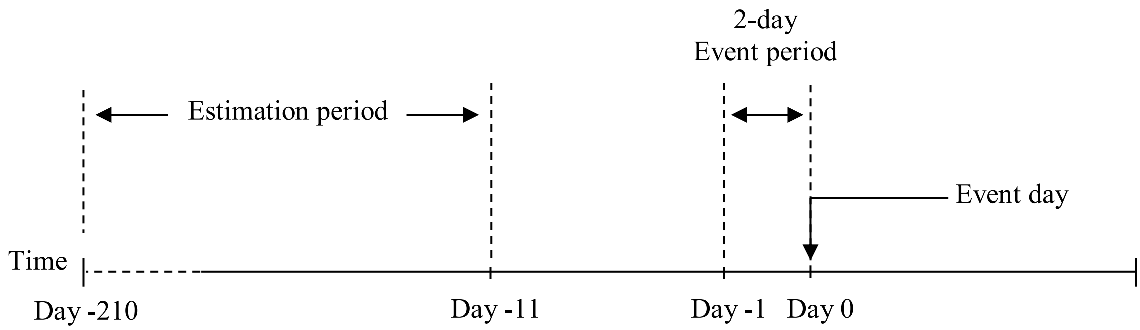


Figure 3-4. The Event Study

We also used the three-factor model (Fama and French 1993) to estimate abnormal returns in our event study. Explicitly, this model assumes a linear relationship between the return of any stock and three factors (i.e., company size, company price-to-book ratio, and market risk) over a period, as follows:

$$R_{it} = \alpha_i + R_{ft} + \beta_{i1}\left[R_{mt} - R_{ft}\right] + \beta_{i2}SMB_t + \beta_{i3}HML_t + \varepsilon_{it}$$

(E.3-2)

where R_{it} is Day *t* return of stock i, α_i denotes the intercept of the relationship for stock *i*, R_{ft} is the risk-free return on Day *t*, R_{mt} is the market return on Day *t*, SMB_t is the small [market capitalization] minus big portfolio return on Day *t*, and HML_t denotes the high [book-to-market ratio] minus low portfolio return on Day *t*. β_{i1}, β_{i2}, and β_{i3} are the slopes of the relationship for stock *i* with respect to the market return minus risk-free returns, SMB, and HML, respectively. ε_{it} is the error term for stock *i* on Day *t*.

We used the 200-day estimation period (from Day -210 to Day -11) to compute the expected returns for each sample firm (Jacobs and Singhal 2014). The estimation period ends 10 trading days prior to the event day to shield the estimates from the effects of the announcement and ensure that any non-stationary in the estimates was not an issue (Jacobs et al. 2010). We estimated parameters $\hat{\alpha}_i$, $\hat{\beta}_{i1}$, $\hat{\beta}_{i2}$, $\hat{\beta}_{i3}$, and $\hat{S}^2_{\varepsilon_i}$ (the variance of ε_{it}) associated with the Fama–French three-factor model by using ordinary least squares regression over the 200-day estimation period. The abnormal return A_{it} for firm *i* on Day *t* was defined as the difference between the actual and expected returns, as follows.

$$A_{it} = R_{it} - \left(\hat{\alpha}_i + R_{ft} + \hat{\beta}_{i1}\left[R_{mt} - R_{ft}\right] + \hat{\beta}_{i2}SMB_t + \hat{\beta}_{i3}HML_t\right)$$

(E.3-3)

To test whether the abnormal return A_{it}, as stated in (E.3-3) associated with our 618 environmental incident announcements, differed statistically from the normal stock returns, we used the Wilcoxon signed-rank test to test for the statistical significance of the median abnormal returns and the binomial sign test to determine whether the percentage of negative abnormal returns during the event period was significantly greater than 50%. We also reported t-test results, and *the mean abnormal returns*, $\bar{A}_t$, for Day *t* are expressed as

$$\bar{A}_t = \sum_{i=1}^{N} \frac{A_{it}}{N} \tag{E.3-4}$$

where A_{it} is the abnormal return for firm *i* on Day *t*, resulting from Equation (E.3-3), and *N* denotes the number of announcements in the sample.

Each A_{it} is divided by its estimated $\hat{S}_{\varepsilon_i}$ value (i.e., the standard deviation of ε_{it}) to grant a standardized abnormal return, so that the statistical significance, TS_t, of the mean abnormal return can be tested in Eq. (E.3-5). The abnormal returns are assumed to be independent across events, with a mean of 0 and a variance of $\hat{S}^2_{\varepsilon_i}$ under the null hypothesis. Based on the central limit theorem, the sum of the N standardized abnormal returns is approximately normal, with a mean of 0 and variance N. Thus, *the test statistic for single-day period*, TS_t, for Day *t* is

$$TS_t = \sum_{i=1}^{N} \frac{A_{it}/\hat{S}_{\varepsilon_i}}{\sqrt{N}} \tag{E.3-5}$$

The equation for *Cumulative abnormal returns*, $CAR(t_1, t_2)$, over a period [t_1, t_2], is the sum of the daily mean abnormal returns, $\bar{A}_t$.

$$CAR(t_1, t_2) = \sum_{t=t_1}^{t_2} \bar{A}_t \tag{E.3-6}$$

The multiple-day period test statistics, TS_e, is obtained in a manner similar as for a single day:

$$TS_e = \sum_{i=1}^{N} \frac{\left(\sum_{t=t_1}^{t_2} \overline{A_t}\right) / \sqrt{\sum_{t=t_1}^{t_2} \hat{S}^2_{\varepsilon_i}}}{\sqrt{N}} \tag{E.3-7}$$

Table 3-10 lists the abnormal returns for the day preceding the announcement (Day -1) and the day of the announcement (Day 0). We also analyzed the cumulative abnormal returns over 2-day periods: from Day -1 to 0.

Table 3-10. Abnormal Returns of the 618 Environmental Incident Announcements

	Day -1	Day 0	Day −1 to 0
n	618	618	618
Mean abnormal returns	-0.0020	-0.0020	-0.0041
t statistic	-2.18*	-2.05*	-3.05**
Median abnormal returns	-0.0031	-0.0028	-0.0057
Wilcoxon signed-rank *Z* statistic	-3.73**	-3.32**	-4.22**
% Abnormal returns negative	57.8%	55.7%	58.1%
Binomial sign test *Z* statistic	-3.82**	-2.90**	-4.03**

Note. All tests are two-tailed: *$p < 0.05$; **$p < 0.01$

We first examined the impact of environmental incident announcements on abnormal returns on a single day; namely Day -1 and Day 0. Table 4 shows that the mean (median) abnormal returns for Day -1 was -0.20% (-0.31%), and it was significantly less than zero at the 5% (1%) level. Also, 57.8% of the abnormal returns were negative, which is significantly greater than 50% at the 1% level. Similarly, the mean (median) abnormal returns for Day 0 were negative at -0.20% (-0.28%) and significantly less than zero at the 5% (1%) level. Moreover, 55.7% of the abnormal returns were negative, which is significantly greater than 50% at the 1% level. We examined the cumulative impact over a 2-day period from Day -1 to 0. The mean (median) abnormal return was -0.41% (-0.57%), significantly less than zero at the 1% (1%) level. Also, 58.1% of the abnormal returns were negative, significantly greater than 50% at the 1% level. The result displayed in Table 4 shows that the stock market in an emerging market reacts negatively to environmental incidents, which is consistent with those obtained based on developed countries (e.g., Klassen and McLaughlin 1996).

3.4.1.1. Robustness Test for Direct Effect

Confounding event window (Tables 3-11)**.** Because the stock market in emerging countries such as China is less mature, the influence of confounding events may be more severe. We conducted an additional robustness test based on different time-windows for searching confounding events (from 2 to 5 days around the event; Jacobs et al. 2010, McWilliams and Siegel 1997, Meznar et al. 1994). The above sample selection leads to changes in the sample size, but the results were largely consistent with the 4-day event window.

Table 3-11. Abnormal Returns for Environmental Incidents in China's Market with No 200-Day Prior Incidents and Different Time Windows Capturing Confounding Events

	Model 1: No Prior Environmental Incident During the 200-Day Estimation Period			Model 2: 2-Day Confounding Event Time-Window			Model 3: 3-Day Confounding Event Time-Window			Model 4: 5-Day Confounding Event Time-Window		
	Day -1	Day 0	Day -1 to 0	Day -1	Day 0	Day -1 to 0	Day -1	Day 0	Day -1 to 0	Day -1	Day 0	Day -1 to 0
n	504	504	504	662	662	662	638	638	638	604	604	604
Mean abnormal returns	-0.0024	-0.0019	-0.0042	-0.0023	-0.0019	-0.0042	-0.0019	-0.0019	-0.0039	-0.0020	-0.0022	-0.0042
t statistic	-2.28*	-1.64	-2.79**	-2.48*	-2.02*	-3.23**	-2.07*	-2.00*	-2.92**	-2.06*	-2.20*	-3.07**
Median abnormal returns	-0.0040	-0.0027	-0.0058	-0.0031	-0.0027	-0.0055	-0.0030	-0.0027	-0.0056	-0.0030	-0.0029	-0.0058
Wilcoxon signed-rank *Z* statistic	-3.91**	-3.05**	-3.91**	-4.04**	-3.26**	-4.45**	-3.76**	-3.26**	-4.19**	-3.60**	-3.50**	-4.23**
% Abnormal returns negative	58.93%	55.75%	58.53%	58.01%	55.74%	57.70%	57.84%	55.49%	57.68%	57.78%	55.96%	58.44%
Binomial sign test *Z* statistic	-3.96**	-2.68**	-3.83**	-4.08**	-3.04**	-3.97**	-3.92**	-2.86**	-3.88**	-3.78**	-3.02**	-4.15**

Note. All tests are two-tailed: *$p \leq 0.05$; **$p \leq 0.01$

Cross-sectional dependence test (Table 3-12)**.** We conduct a crude dependence test to test for potential clustering effects among our observations. A clustering effect may inflate the magnitude of abnormal returns, rendering our statistical tests oversensitive because the events may be clustered by industry and time

(Brown and Warner 1980, Jacobs and Singhal 2017). The statistical results remain negatively significant for all periods, supporting the robustness of our analysis.

Table 3-12. Test Statistics of the Crude Dependence Test

	Day -1	Day 0	Day -1 to 0
n	618	618	618
Mean abnormal returns	-0.0020	-0.0020	-0.0041
t statistic	-1.82^{+}	-1.82^{+}	-2.64**

Note. All tests are two-tailed: $^{+}p \leq 0.10$; $*p \leq 0.05$; $**p \leq 0.01$

Environmental pollution incidents versus regulatory violations. In our sample of 618 environmental incidents involving 294 firms, we include both environmental pollution incidents and regulatory violations without immediate damage. We analyze possible differences in investor reactions between these two types of events. We find that Chinese investors reacted to both environmental incidents with damage ($n = 458$) and regulatory violations ($n = 160$) in a similarly negative manner, with a mean (median) drop of 0.39% (0.68%) and 0.45% (0.38%), respectively, but the result is insignificant.

Using the market model, prior environmental incidents, and length of confounding event time-windows. We conduct additional robustness tests to verify our findings. First, we rerun the analysis using the market model instead of the Fama–French three-factor model.

The market model assumes a linear relationship between the return of any stock and that of the market portfolio over a period:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \tag{E.3-8}$$

where R_{it} denotes the Day t return of stock i, R_{mt} is the market return on Day t, α_i is the intercept of the relationship for stock i, β_i denotes the slope of the relationship for stock *i* with respect to the market return, and ε_{it} is the error term for stock *i* on Day *t*.

We used the 200-day estimation period (from Day -210 to Day -11) to compute the expected returns for each sample firm (Jacobs and Singhal 2014). The estimation period ends 10 trading days prior to the event day to shield the estimates from the effects of the announcement, and to ensure that any non-stationarity in the estimates is not an issue (Jacobs et al. 2010). We estimated the market model parameters $\hat{\alpha}_i$, $\hat{\beta}_i$, and $\hat{S}^2_{\varepsilon_i}$ (the variance of ε_{it}) performing ordinary least squares regression over the 200-day estimation period.

The abnormal returns, A_{it}, for firm *i* on Day *t* were defined as the difference between the actual and the expected return, as follows:

$$A_{it} = R_{it} - (\widehat{\alpha_i} + \widehat{\beta_i} R_{mt}) \quad \text{(E.3-9)}$$

The calculation for mean abnormal returns ($\overline{A_t}$) for Day *t*, cumulative abnormal returns ($CAR(t_1, t_2)$) over a period [t_1, t_2], the test statistic (TS_t) for Day *t*, and multiple-day period test statistics (TS_e) is provided in Eq. (E.3-4, E.3-5, E.3-6, and E.3-7). The results were largely consistent with the Fama–French three-factor model shown in Table 3-13.

Table 3-13. Abnormal Returns for Environmental Incidents in China for the Market Model

	Day -1	Day 0	Day -1 to 0
n	618	618	618
Mean abnormal returns	-0.0021	-0.0017	-0.0039
t statistic	-2.25*	-1.76⁺	-2.88**
Median abnormal returns	-0.0034	-0.0022	-0.0049
Wilcoxon signed-rank *Z* statistic	-3.69**	-2.75**	-3.83**
% Abnormal returns negative	58.9%	54.7%	58.3%
Binomial sign test *Z* statistic	-4.38**	-2.29*	-4.11**

Note. All tests are two-tailed: $^{+}p \leq 0.10$; $^{*}p \leq 0.05$; $^{**}p \leq 0.01$

3.4.2. Role of Recognition of Social Responsibility, External Certification, Government Share, and Personal Political Ties

We examined whether a negative stock market reaction toward environmental incidents is moderated by three strategic resources: *Recognition of social responsibility*, *ISO14001, government share of ownership*, and *personal political ties.* We developed the following regression model to evaluate the factors affecting CAR_i which represents the "cumulative abnormal stock returns" of firm *i* over a 2-day period (i.e., Day -1 to Day 0):

$$CAR_i = \beta_0 + \beta_1 Recognitions\_of\_social\_responsibility_i + \beta_2 ISO14001_i + \beta_3 Government\_share_i + \beta_4 Personal\_political\_tie_i + \beta_5 Industry\_Dummy_i + \beta_6 Year\_Dummy_i + \beta_7 Air_i + \beta_8 Water_i + \beta_9 Government\_assessment_i + \beta_{10} Others_i + \beta_{11} Multiple_i + \beta_{12} Incident\_History_i + \beta_{13} First\_company\_event_i + \beta_{14} First\_company\_event\_year_i + \beta_{15} damage_i + \beta_{16} Source\_of\_information_i + \beta_{17} Daily_i + \beta_{18} Firm\_diversification_i + \beta_{19} Market\_value\_of\_equity_i + \beta_{20} ROA_i + e_i \quad \text{(E.3-10)}$$

where e_i is the error term of the regression model. Unless stated otherwise, the independent variables were based on the fiscal year ending prior to the announcement date. Table 3-14 shows the correlation of the variables. Table 3-15 lists the results of our regression model.

Table 3-14. Correlation of the Variables

No	Variables	Mean	Std. Deviation	1	2	3	4	5	6	7	8	9	10	11	12
1	*Incident_history*$_i$	0.13	0.19												
2	*First_company_event*$_{i\ (D)}$	0.48	0.50	-0.635**											
3	*First_company_event_year*$_{i\ (D)}$	0.83	0.37	-0.432**	0.429**										
4	*Damage*$_{i\ (D)}$	0.74	0.44	-0.022	-0.019	0.019									
5	*Source_of_information*$_{i\ (D)}$	0.79	0.41	0.099*	-0.105**	-0.005	-0.162**								
6	*Daily*$_{i\ (D)}$	0.90	0.31	-0.045	0.073	0.068	-0.077	-0.138**							
7	*Firm_diversification*$_i$	0.49	0.25	-0.060	0.064	-0.037	0.052	0.009	-0.010						
8	*Market_value_of_equity*$_{i\ (NL)}$	15.52	1.11	0.238**	-0.189**	-0.118**	-0.051	0.051	-0.013	0.090*					
9	*ROA*$_i$	-0.01	0.05	0.020	0.027	-0.048	0.078	-0.003	0.031	0.095*	0.273**				
10	*Recognition_on_social_responsibility*$_i$	0.42	1.08	0.181**	-0.179**	-0.064	0.008	-0.010	-0.026	-0.057	0.223**	0.023			
11	*ISO14001*$_{i\ (D)}$	0.45	0.50	0.186**	-0.168**	-0.073	-0.046	-0.062	0.009	0.050	0.189**	0.100*	0.052		
12	*Government_share*$_i$	0.22	0.24	-0.068	0.148**	-0.015	0.035	-0.008	0.029	0.088*	0.067	0.028	-0.186**	-0.177**	
13	*Personal_political_ties*$_i$	1.46	2.44	-0.005	-0.049	-0.007	0.037	-0.042	0.040	-0.026	0.186**	0.084*	0.004	0.064	0.074

N=597

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

(D): Dummy variable; (NL): Natural logarithm;

Note: The *Industry_dummy*$_i$, pollution type dummies (i.e. *Air*$_i$, *Water*$_i$, *Government_assessment*$_i$, *EIA*$_i$, and *Multiple*$_i$), *Year_dummy*$_i$ are not shown in this table. They are categorical dummy variables.

Table 3-15. Regression Results for the Event Period Day -1 to 0

Variable	Model 1 (Control Model)	Model 2 (Full Model)
Intercept	0.008 (0.293)	-0.025 (-0.914)
$Industry\_dummy_i$	-	-
$Year\_dummy_i$	-	-
Air_i	-0.003 (-0.805)	-0.004 (-1.002)
$Government\_assessment_i$	-0.001 (-0.313)	-0.003 (-0.846)
EIA_i	0.004 (0.605)	0.001 (0.197)
$Multiple_i$	0.003 (0.512)	0.003 (0.554)
$Incident\_history_i$	0.020 (2.040)*	0.014 (1.412)
$First\_company\_event_i$	0.000 (-0.007)	0.000 (-0.127)
$First\_company\_event\_year_i$	0.006 (1.533)	0.006 (1.558)
$Damage_i$	0.000 (0.010)	-0.001 (-0.212)
$Source\_of\_information_i$	-0.004 (-1.213)	-0.005 (-1.370)
$Daily_i$	-0.012 (-2.495)*	-0.011 (-2.276)*
$Firm\_diversification_i$	-0.001 (-0.084)	-0.001 (-0.205)
$Market\_value\_of\_equity_i$	-0.001 (-0.473)	-0.002 (-1.215)
ROA_i	0.015 (0.472)	0.033 (1.070)
$Recognition\_on\_social\_responsibility_i$		0.003 (2.422)*
$ISO14001_i$		0.004 (1.210)
$Government\_share_i$		0.026 (3.661)**
$Personal\_political\_ties_i$		-0.001 (-2.498)*
N	597	597
Model F Value	1.687**	2.072**
R^2	12.1%	15.7%
Adjusted R^2	4.9%	8.1%

Note: All tests are two-tailed: *$p \leq 0.05$; **$p \leq 0.01$; $Water_i$ as pollution type dummy is excluded by the statistical software because of their mutual exclusivity with other dummy variables; t-statistics are in the parenthesis.

Model 1 concerns the parameter estimates and *t*-statistics only for the control variables. Model 2 is our full model, accounting for H2 to H3 (i.e., recognition of social responsibility, ISO14001, government share, and personal political ties). In Model 2, the coefficient of *Recognitions_on_social_resposibility* was significantly positive at the 5% level, implying that the negative consequences (abnormal stock returns) of a firm's environmental incidents were less severe for firms with more recognition of social responsibility. The coefficient for *Government_share* was positive and significant at the 1% level, which indicated that the negative consequences (abnormal stock returns) of a firm's environmental incidents were less severe when a firm had a higher percentage of government share. A high government share proportion is a valuable strategic resource for buffering the negative impact of environmental incidents. The coefficient for *ISO14001* was positive but not significant, which implied that the negative consequences of a firm's environmental incidents were not affected by the firm's ISO14001 statement. This result suggests that the external professional endorsement, such as IOS14001, is considered as a fundamental requirement for firms rather than a protection mechanism when environmental incidents are disclosed. Finally, the coefficient for *Personal_political_ties* was negative and significant at the 5% level, which means that the market reacted more negatively if the sample firm had personal political ties. The personal political ties became a liability in case of environmental incidents, and they exacerbated the negative impact of environmental incidents on firms' stock price.

Overall, our regression models were highly significant, with F values of 1.687 and 2.072 for Model 1 (control model) and Model 2 (full model), respectively. For Model 2, the R^2 (adjusted R^2) value was 15.7% (8.1%), and the R^2 changes (adjusted R^2 changes) comprised 3.6% (3.2%). They were acceptable because our regression was based on cross-sectional data, and the figures were comparable to those reported in the previous studies that had obtained their findings using a similar method on abnormal stock prices with a smaller sample (e.g., Klassen and McLaughin 1996). We also calculated the variance inflation factor (VIF) of each independent variable. The VIF values ranged from 1.034 to

2.129 for our models, indicating that our regression coefficients should not have been adversely affected by the multicollinearity issue.

3.4.2.1. Robustness Test for Moderators

We develop a two-stage model to rerun our test to prevents correlation among the moderating factors and any of the control factors from driving the results. At the first stage, the cumulative abnormal returns CAR_i from Day -1 to 0 are regressed against all the control variables, and the residuals ($Residual_i$) from the first-stage regression are obtained. At the second stage, the residuals ($Residual_i$) obtained at the first stage (as a dependent variable) are regressed against recognition of social responsibility, ISO14001, government share of ownership, and personal political ties. The formula is shown below.

Stage 1:

$$\begin{aligned} CAR_i = \beta_0 &+ \beta_1 Industry\_Dummy_i + \beta_2 Year\_Dummy_i + \beta_3 Air_i \\ &+ \beta_4 Water_i + \beta_5 Government\_assessment_i \\ &+ \beta_6 EIA_i + \beta_7 Multiple_i + \beta_8 Incident\_History_i \\ &+ \beta_9 First\_company\_event_i \\ &+ \beta_{10} First\_company\_event\_year_i + \beta_{11} damage_i \\ &+ \beta_{12} Source\_of\_information_i + \beta_{13} Daily_i \\ &+ \beta_{14} Firm\_diversification_i \\ &+ \beta_{15} Marke\_value\_of\_equity_i + \beta_{16} ISO14001_i \\ &+ \beta_{17} ROA_i + Residual_i \end{aligned} \quad \text{(E.3-11)}$$

Stage 2: (E.3-12)

$$Residual_i = \beta_{00} + \beta_{01}Recognition\_of\_social\_responsibility_i$$
$$+ \beta_{02}Government\_share_i$$
$$+ \beta_{03}Personal\_political\_ties_i + e_i$$

where e_i is the disturbance term of the regression model. Table 3-16 lists the results of two-stage regression model.

Table 3-16: Two-Stage Regression Results for the Event Period Day -1 to 0

Variable ^	Stage 2
Recognition_on_social_responsibility$_i$	0.003 (2.632)**
ISO14001$_i$	0.001 (0.565)
Government_share$_i$	0.016 (2.985)**
Personal_political_ties$_i$	-0.001 (-2.577)*
N	597
Model F Value	4.708**
R^2	3.1%
Adjusted R^2	2.4%

Note: All tests are two-tailed: *p ≤ 0.05; **p ≤ 0.01
Water$_i$ as pollution type dummy is excluded by the statistical software because of their mutual exclusivity with other dummy variables; t-statistics are in the parenthesis.; ^the control variables were included in the test at the stage 1, but the value is not reported here to save space

Stage 1 concerns the parameter estimates and *t* statistics only for the control variables, which is the same model as Model 1 in Table 3-16. At Stage 2, we examine the four moderating factors. The results from the two-stage regression models are similar to that of our regression model, which shows that our moderating factors are not capturing some of all of what the control factors were put in purposefully to capture. Overall, it supports our arguments above.

In addition, we rerun the regression analysis based on the abnormal returns derived from the market model, subsample excluding firms with prior environmental incidents during the 200-day estimation period, and the three models with different time windows for removing confounding events (see Section 3.4.1.1.). The results based on the different tests remain mostly identical to the main results of the moderating effects.

3.4.3. Suppliers' Environmental Incidents on their Downstream (Overseas) Customers' Performance

To examine the impact of environmental incidents of Chinese firms (i.e., supplier) on their overseas customers, we used the "market model" for this analysis, instead of the Fama–French three-factor model presented in Section 5, because the daily value of the three factors was not readily available in all stock markets. To compare abnormal returns across different stock markets, every overseas firm's stock return was compared only against its stock market performance. The formulas using the market model to calculate abnormal returns are provided in Section 3.4.1.1. We estimated the abnormal returns in the same event period (Day -1 and Day 0), and additionally, on Day 0 to Day 1, because we had to consider the possibility of information delay between the China market and overseas markets. Table 3-17 lists the abnormal returns for overseas customers.

Table 3-17. Abnormal Returns for the Environmental Incidents of the Downstream Overseas Customers.

	Day -1	Day 0	Day 1	Day -1 to 0	Day 0 to 1
Overseas Customers (n = 79)					
Mean abnormal returns	0.0000	-0.0056	-0.0057	-0.0055	-0.0113
t statistic	0.02	-2.33*	-2.43*	-1.78+	-3.08**
Median abnormal returns	0.0008	-0.0035	-0.0029	-0.0031	-0.0023
Wilcoxon signed-rank *Z* statistic	-0.28	-2.83**	-1.81+	-1.91+	-2.29*
% Abnormal returns negative	44.3%	65.8%	54.4%	57.0%	57.0%

Binomial sign test *Z* statistic	-0.9	-2.70**	-0.79	-1.13	-1.13

Note. All tests are two-tailed: +*p* < 0.10; **p* < 0.05; ***p* < 0.01

Table 3-17 shows that the mean (median) abnormal returns for Day -1 was 0.00% (0.08%), which was nonsignificantly different from zero. Also, 44.3% of the abnormal returns were negative, which is nonsignificantly greater than 50%. However, the mean (median) abnormal returns for Day 0 was negative at -0.56% (-0.35%), and significantly less than zero at the 5% (1%) level. Moreover, 65.8% of the abnormal returns were negative, which is significantly greater than 50% at the 1% level. The mean (median) abnormal returns for Day 1 was -0.57% (-0.29%), which is significantly less than zero at the 5% (10%) level. Also, 54.4% of the abnormal returns were negative but nonsignificantly greater than 50%. We examined the cumulative impact over a 2-day period from Day -1 to 0. The mean (median) abnormal returns was -0.55% (-0.31%), significantly less than zero at the 10% (10%) level. The mean (median) abnormal returns for the 2-day period from Day 0 to 1 was -1.13% (-0.23%), significantly less than zero at the 1% (5%) level. For the 2-day event periods, 57.0% of the abnormal returns were negative, which is nonsignificantly greater than 50%. The results show a Chinese supplier's environmental incident has a negative impact on its overseas customer firms' stock price.

3.4.3.1. Robustness Test for Overseas Customers

Removing Hong Kong-listed firms as overseas customers. Although the Hong Kong stock market is highly internationalized with global institutional investors, it might still differ from other markets because of its proximity to Mainland China. To test for robustness, we excluded firms listed in Hong Kong as overseas customers (from the list of Chinese suppliers). The results revealed that the impact of environmental incidents of Chinese firms on overseas customers remained significantly negative after the deletion of Hong Kong-listed firms (Table 3-18).

Table 3-18. Abnormal Returns for Overseas Customers (Hong Kong-listed Firms Excluded)

	Day-1	Day 0	Day 1	Day -1 to 0	Day 0 to 1
n	55	55	55	55	55
Mean abnormal returns	-0.0001	-0.0070	-0.0071	-0.0071	-0.0141
t statistic	-0.02	-2.87**	-2.28*	-1.88+	-3.07**
Median abnormal returns	0.0005	-0.0044	-0.0034	-0.0031	-0.0025
Wilcoxon signed-rank *Z* statistic	-0.66	-3.12**	-1.74+	-2.22*	-2.54*
% Abnormal returns negative	45.5%	70.9%	56.4%	60.0%	61.8%
Binomial sign test *Z* statistic	-0.54	-2.97**	-0.95	-1.35	-1.62

Note. All tests are two-tailed: $+p \leq 0.10$; $*p \leq 0.05$; $**p \leq 0.01$

3.5. Discussion

We examined the impact of environmental incidents on the market value of the firms in China as well as their overseas customers. In the Western context, Klassen and McLaughlin (1996) found that major environmental awards led to an increase of 0.82% in market value, whereas environmental incidents led to a drop of 1.50%, which is approximately equal to US$390 million. However, Klassen and McLaughlin (1996) only focused major “environmental crises” in certain highly selective, most well-established firms in the United States with a sample of 18 environmental incidents involving 16 firms. Consisted of the results studied in developed markets, we found that environment incidents in China did lead to significant negative changes in the market value of firms. Although the market capitalization of stock-listed firms in an emerging country such as China is relatively small, investors and the public response to environmental incidents in a similar negative manner. Moreover, we found that a Chinese supplier's environmental incidents led to an average drop of 0.55% in the market value of the overseas customers from Day -1 to Day 0, which is equal to a drop of US$135 million. From Day 0 to Day 1, the drop was even higher, at 1.13% (i.e., US$208.84 million). In addition, our study proved that social capital is helpful in Chinese context in the case of environmental incidents. Specifically, firms' social recognition and government ownership can be considered as the relational and structural social capital, which are extremely useful to build up trust and legitimacy to moderate the negative market effect of the environmental incidents. The cognitive social capital such as the ISO14001 professional endorsement does not moderate the negative effects. This may represent that the Chinese public consider the shared goals and norms from the professional communities are basic requirements, not trust for firms. Most interestingly, the structural social capital obtained from the personal political ties make the negative effects more severe. The personal connections between government officials and firm's top management can be considered as the structural social capital in the firm's daily operations. However, the social capital becomes a burden and debt when the firm is experiencing environmental incidents.

Our study has several limitations. First, because the Chinese government does not have a common platform for reporting environmental incidents, we have to rely on the database developed by IPE to identify different incidents. Although IPE currently provides the most comprehensive database for environmental incidents in China, we cannot dismiss the possibility that some environmental incidents that are critical may be missing. Second, the main sample firms are only Chinese listed firms, and thus, the findings may differ in other emerging markets (e.g., India). Third, we did not provide any weighting of the CSR awards in our records, despite some awards being presented at the national level and others at the provincial level. Also, We did not assign a weighting to each award because our evaluation of the award's significance might differ from that of investors. No objective approach exists for evaluating the importance of each award. Therefore, we decided to simply count the number of awards presented to the firm. Finally, the same size of overseas customers is small compare to the sample of manufacturing firms, future studies may consider obtaining more data to enlarge the sample size.

Our findings have crucial implications for Chinese manufacturing firms, their overseas customers, multinationals, policymakers, NGOs, investors, and researchers in creating additional "carrots and sticks" for alleviating environmental incidents.

Implications for Manufacturers. Our results challenged the commonplace notion that investors in emerging markets were less concerned with environmental issues (e.g., Saleh et al. 2011). Instead, our findings in China are consistent with a finding from India that weak environmental performance (measured by environmental rating) leads to negative abnormal stock returns (Gupta and Goldar 2005). Therefore, manufacturers in China should exert efforts to comply with environmental regulations especially when it is evident that the market will react significantly negative to environmental incidents. Moreover, the manufacturers could gain social recognition through the delivery of their corporate social responsibility (CSR) commitments and performance to resonate with the public. Also, our finding reveals that overseas customers will also suffer when their suppliers in China violate certain environmental regulations. To avoid losing their overseas customers due to environmental incidents, manufacturers in China should perform proactively in managing their environmental performance.

Implications for Policymakers. Our analysis revealed that overseas customer firms' market value could be negatively affected by the Chinese suppliers' environmental incidents. In this connection, the Chinese government should consider improving transparency and public access to information about Chinese firm's environmental performance. By doing so, it helps NGOs and overseas customers to monitor the Chinese manufacturers. On top of strengthening law enforcement on environmental regulations, the Chinese government can provide positive incentives for Chinese firms to devote more resources in improving their social and environmental responsibility. For example, the Chinese government can develop national CSR and different environmental awards to motivate more firms to improve. In particular, our results show that recognition of social responsibility is indeed strategic resources for Chinese firms to be more resilient in the case of environmental incidents.

Implications for NGOs. NGOs can continue to play an independent and critical role as enforcers by exposing Chinese contract manufacturers who violate environmental regulations and by pressuring multinational retailers to take corrective and proactive actions. For example, the Green Choice Alliance (GCA) is a coalition of NGOs (including IPE) that promotes a global green supply chain by pushing large corporations to evaluate the environmental performance of their suppliers in the procurement process. Specifically, such independent coalition conducts independent (environmental performance) audits to different Chinese manufacturing firms who supply products for international brands such as Apple, Gap, and H&M. This coalition will share the findings with these international brands and post these findings along with the corrective actions taken by these brands on the internet. This public information has forced companies such as Apple and Timberland to take corrective actions with their Chinese manufacturing firms to avoid public humiliation (Plambeck et al. 2012). At the same time, NGOs can also play as independent endorsers. They help to develop the firm's environmental legitimacy through awards and recognition, which are the "carrot" to Chinese manufacturers to reduce their environmental risks.

Implications for Investors. Our results revealed that an environmental violation committed by a Chinese supplier had a significantly negative impact on the Chinese supplier and its overseas customers. Therefore, investors should focus more on the environmental performance of the entire supply chain, not that of a particular firm. Moreover, our results revealed that personal political ties generate a stronger negative market reaction toward environmental incidents. Thus, investors should be aware of personal political ties of the listing firm.

Implications for Researchers. Our study clarified the mechanisms by which legitimacy protected firms involved in environmental incidents. We also found evidence showing that the impact of environmental incidents involving upstream suppliers on downstream customers can be significant. These findings can be used as a critical reference for future research on sustainability issues arising from emerging markets. Sustainable supply chain researchers should consider linking with both upstream and downstream members in the research design. For example, an examination of the impact of social misconduct (e.g., sweatshops) run by upstream suppliers on downstream customers is warranted.

Chapter 4. Essay 3: The Long-Term Cost of Random Environmental Monitoring and Environmental Violation in China.

4.1. Introduction

In Chapter Three, we used the short-term event study approach to examine the impact of the Chinese manufacturing firms' environmental incidents on firm and supply chain performance and provided insights to various stakeholders, especially for investors and supply chain partners. Although we have proven that the stock markets penalize firm's environmental violations not only the focal firms but also its supply chain partners in the previous chapter, the operations managers may not be sensitive to detect its adverse effect on the firm's market value on a daily basis. Instead, they prefer better economic and operational firm performance due to the pressures from various stakeholders such as supply chain parties, company owners, competitors and even the governments (Mitchell et al., 1997).

In this chapter, we extended the sample collected by the short-term event study in Chapter Three to examine the long-term effects of Chinese manufacturing firms' environmental violations on firm performance, and the findings will motivate firms to maintain their environmental sustainability. To maintain environmental sustainability not only asks for firms' corporations but also requires government involvements. Thus, we developed a prediction model with the aim of helping the Chinese government to identify high-risk firms before any possible pollution based on the concept of supervised machine learning. In the model, we discovered the significant factors that may lead to more pollution for a firm. By understanding the factors, firms can develop more effective mechanisms to improve their environmental performance, and governments can seek an efficient and effective way to conduct environmental enforcement.

We focus more on firms and governments because they are the stakeholders directly involving in the process of maintaining environmental sustainability. In summary, we examine the following three research questions (RQs):

RQ1: Can a firm maintain its economic benefits of violating environmental rules in the long run?

RQ2: What are the financial and operational factors that can predict a firm's pollution?

RQ3: What is (are) the right prediction model(s) of the firm's environmental violation in China?

The knowledge of short- and long-term impacts of environmental violations will contribute to the merging trend of both environmental management practice and green supply chain management clusters mentioned in essay one. We will elaborate each question in the following part.

4.2. Literature and Research Questions

4.2.1. Environmental Performance vs. Economic Benefits

The debates on the link between environmental performance and financial performance have lasted for decades (Wagner, 2001). Scholars have commonly agreed on the importance of environmental management (Arlow & Gannon, 1982), while the empirical outcomes of the relationships between environmental performance and financial performance are mixed (Horváthová, 2010). By using the short-term event study, Klassen and McLaughlin (1996) found a positive relationship associated with environmental award and firm's market performance. Conversely, they found a negative relationship between environmental crisis and firm's market performance. In the same vein, Jacobs et al., (2010) examined firms' announcements about corporate environmental initiatives and certifications and found that announcements of "philanthropic gifts for environmental causes" and "ISO 14001 certifications" are positively related to firm's market performance, whereas "voluntary emission reductions" announcements are negatively related to firm's market performance. In the long-term, King and Lenox (2002) found that waste prevention and pollution reduction leads to financial gain. Also, Waddock & Graves (1997) demonstrated that the relationship between a firm's environmental performance and financial performance are positive and forms a mutual reinforcement. Corbett and Klassen (2006) contributed to this point of "virtuous cycle" by stating "any operating system that has minimized inefficiencies is also more environmentally sustainable." Horváthová (2010) has summarised a list of empirical studies in his meta-analysis on the relationships between environmental performance and financial performance, such as positive relationship (e.g., King & Lenox, 2001; Konar & Cohen, 2001; Russo & Fouts, 1997), negative relationship (e.g., Cordeiro & Sarkis, 1997; Jaggi & Freedman, 1992; Stanwick & Stanwick 1998), and inconclusive relationship (e.g., Cohen et al., 1997; Earnhart & Lízal, 2007; Wagner, 2005).

In many cases, environmental issues affect both costs and income of a firm and hence have a direct or indirect influence on the firm's economic success (Schaltegger & Synnestvedt, 2002). However, the literature above studied the relationship between firm's environmental performance and financial performance either on a single point of view (i.e., positive or negative) or by a single time setting (i.e., short-term benefit or long-term benefit). In our research, we try to study the relationship from multiple points of view and time settings by asking RQ1.

The opinions from traditional economic and strategy literature argue that the goal of environmental enhancement is always subordinate to other corporate goals as most businesses are profit driven (Arlow & Gannon, 1982). Committing to environmental regulation requires firms to improve their environmental performance, which imposes an additional cost for firms, such as investment and introduction of clean techniques (Claver et al., 2007; Palmer et al., 1995). These environmental improvements will increase firms' fixed costs (Claver et al., 2007) and decrease marginal net benefits (Horváthová, 2010), consequently, lead to economic disadvantage (McGuire et al., 1988). So, from a pure trade-off view, if a firm strongly focuses on short-term profit, it would choose to ignore the environmental performance and violate regulation (Schaltegger & Synnestvedt, 2002).

McGuire et al. (1988) argued that improvement on environmental performance could generate other benefits, which offset the cost of its implementation. Admitting new environmental regulation may not only mitigate the environmental impact of firm's production and services (Bacallan, 2000; Rao & Holt, 2005) but also improve firm's bottom line (Cohen et al., 1995), push firm's innovation (Porter & van Der Linde, 1995), and increase operational and economic efficiency (Horváthová, 2010; Porter, 1991). Also, firms will receive a positive reputation and trust from varies stakeholder, such as government and customers, for their commitment to environmental regulation (Iwata & Okada, 2011). The trust from government represents less government intervention on the firm's business, while the reputation of customers leads to more market share. Thus, better environmental performance signals reduction on the firm's environmental risk and production costs, and increase on economic benefits in the long term.

In summary, in RQ1 we examine when a firm is violating environmental regulation in exchange for a short-term benefit, whether it will lose the aforementioned long-term benefit and therefore lead to a decrease in economic benefit. It is suitable for our empirical setting in China market because many Chinese manufacturing firms are polluting for the sake of survival in the global competition. They are eager to know whether it is worth to jeopardize the environment to pursuit benefit.

4.2.2. Environmental Monitoring by Government Inspection

Government inspection is a coercive resolution to enforce firm's regulation compliance, which is widely used in various circumstances, such as ensuring product quality (Ball et al., 2017), corporate social performance (Tong et al., 2018), and financial services (Pasiouras, 2016). Economic scholars and policy-makers generally think that environmental monitoring by government inspection is the top one motivator for many firms' environmental compliance, which dramatically improved environmental quality in the past few decades in developed countries (Gray & Shimshack, 2011; Kagan et al., 2003). Gray and Shimshack (2011) reviewed the existing literature about "the impacts of environmental monitoring and enforcement on subsequent pollution discharges and compliance behavior" and concluded that government inspection could significantly reduce hazardous waste emissions and regulation non-compliance. Doonan et al. (2005) found that managers in the Canadian pulp and paper industry perceived the government inspection as the most critical sources of pressure on improving their environmental performance.

Conducting environmental monitoring could be costly for governments in both developed and developing countries. According to United States Environmental Protection Agency (EPA)'s budget summary in the past seven years, the government budgets for Office of Enforcement and Compliance

Assurance (OECA) activities in EPA are stable at the range of 793 to 841 million, while the full-time equivalents (FTEs) are stable at the range from 3,329 to 3,914. Figure 4-1 shows the distribution of budgets and FTEs for OECA from 2011 to 2017.

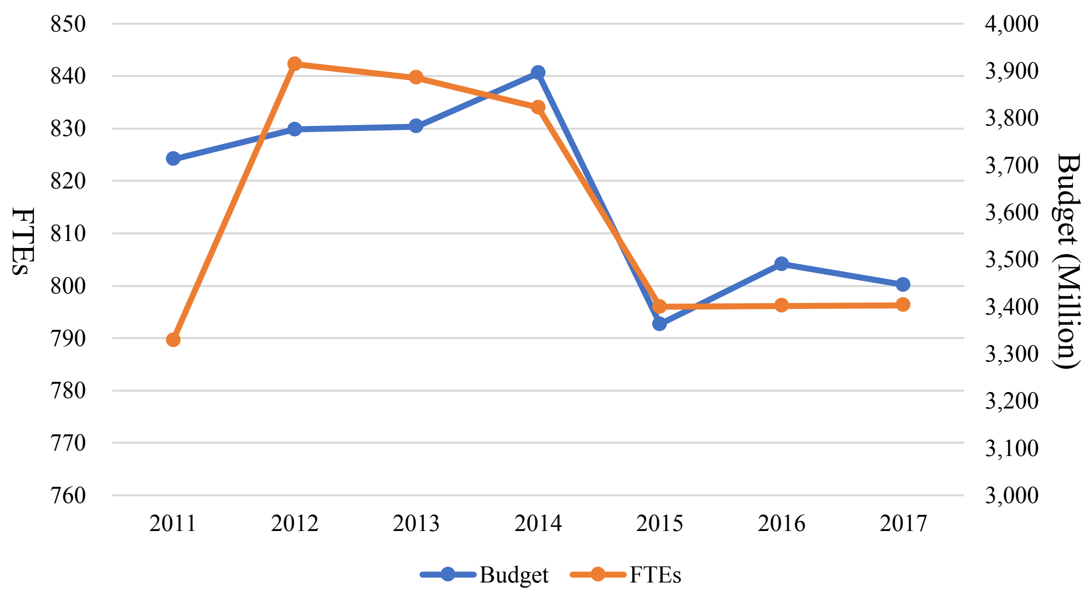


Figure 4-1. Distribution of budgets and FTEs for OECA from 2011 to 2017.

According to EPA's report (2017), the budget for OECA activities is USD 800 million in 2017, which is approximately 10% of the EPA's total budget. The staffing level is 3,403 FTEs for OECA, which is around 22% of EPA's. These figures show that EPA has invested a lot of money and time to conduct the monitoring and enforcement activities. Although the developed countries usually have a long history of conducting environmental protection, the cost of government's environmental monitoring and enforcement is still very high as it requires a continuous investment of not only the money but also the workforce and time (Gary & Shimshack, 2011). The investment for environmental monitoring could be higher for developing countries such as China because the government may not have the experience to conduct government inspection and the environmental damage has been last for decades. The Chinese government promised to "spend heavily to improve its environmental monitoring system" over the 2016 to 2020 period (Reuters, 2016). The below section 4.2.2 descript the current status of government inspection in China and identify its emerging needs of conducting effective and efficient environmental monitoring.

4.2.3. Current Status of Government Inspection in China

To monitor the environmental performance of the public manufacturing firms, the China Government launched both long-term and temporary inspection programs to show their ambitious initiatives on environmental improvement. First, firms can choose to self-report their pollution data in real-time or periodically. After the local governments collect the self-report pollution data, they publish them online and take inspection of the pollution cases[2]. The three common issues in this self-reporting system are "messy data that lacks logic," "underreporting," and "delay reports" (Brombal, 2017; Kotska, 2016). That is because the firms are responsible for reporting the pollution data, and the decisions on what and when to report are depended on various institutional pressures and stakeholder's interests (Delmas & Toffel, 2004). For instance, Stafford (2003) studied 8000 facilities' hazardous waste regulations compliance in United States and found that "strict liability rules," "state environmental spending," and "allocating a higher percentage of employees to regional offices" decreased pollution-related violations but increased record-keeping violations,

[2] Example: Self-report real-time air emissions and water discharges system in Shandong Province. Please refer to http://58.56.98.78:8801/wryfb/MapMainT.html and http://58.56.98.78:8405

which indicated that the coercive pressure from government affect the integrality and accuracy of self-report violations (Gray & Shimshack, 2011). In China, as the institutional environment is different from that of in the US, the firms' motivation for reporting accurate environmental data is smaller, and thus make the self-report environmental data less reliable (Brombal, 2017). Besides, the inspectors of the self-report system are local governments (e.g., city government or provincial government), so the execution and coverage of the system vary between regions. Some local government, such as Shandong province, is responsive to deal with the firms that reported pollution problems, while others were slammed for inaction and neglect (IPE, 2016). In their report, IPE (2016) stated that the local governments only inspect into 35.5% of the violation cases reported by the public manufacturing firms.

Second, the central government takes random inspection on firms' environmental performance (Ministry of Ecology and Environmental of the People's Republic of China [MEEPRC], 2018). They categorize the firms into three inspection groups such as the *general pollution group*, *key pollution group*, and *special supervision group* and randomly monitor the firms in each group by different frequencies. They inspect the firms in the special supervision group most frequently at the rate of 1.39 times per year, and the inspection frequency for the moderate pollution group and key pollution group are 0.48 and 1.17, respectively (MEEPRC, 2018).

The random inspection is an effective way to enforce firms' environmental compliance, but the efficacy and efficiency highly depend on the government investment. According to the MEEPRC's report (2108), they have assigned 4.68 thousand inspectors to conduct the random pollution inspection in 2017, but the random inspection found only 6% of violation cases. Although the central government has invested 2.17 trillion RMB in the period of China's 12th five-year (2011-2015) plan, it was still much less than the total environmental investment demand of 3.4 trillion RMB (Wu et al., 2016). Therefore, the efficiency and efficacy of using the environmental investment are more critical than ever before. Besides that, the central government does not disclose the algorithm to categorize the firms, the accuracy of the categorization may arouse suspicions as "the credibility of Chinese environmental data has been long questioned by domestic and foreign observers" (Brombal, 2017).

Third, the environmental protection department would inspect firm performance after receiving a public complaint. There are more than eighty-thousand pollution cases reported by the public in the first quarter of 2017 (xinhua.net, 2017). Although the public complaints are a source of low-cost information, the efficiency of the system is still questionable (Dasgupta and Wheeler, 1997), as it is very costly for the government to deal with the authenticity and repeatability of the complaints. Besides, the inspection after a public complaint means the pollution had already harmed public health and life.

In conclusion, the government inspection in China may have limited coverage and efficiency, and the algorithm for categorizing firms is not transparent. This problem is also common in other developing countries with a large number of manufacturing plants, yet limited resources to conduct effective environmental monitoring. Based on the current situation, through the lens of operations management, we propose a “simple” and “transparent” but more “accurate” model to help the government to conduct environmental monitoring. First, we raise the RQ2: What financial and operational factors lead to more pollution for a firm? Based on the findings in the RQ2, we test whether various firm’s financial and operational performance indicators are significant to predict the likelihood of a firm to have an environmental violation in the future. We used the most widely available financial data from the firms’ annual financial report as the input because they are audited by professional third parties and easily accessed by the public and government. Based on the significant factors, we ask the RQ3: What is (are) the right prediction model(s) of the firm’s environmental violation in China? We compare the accuracy and efficacy of our model to the random inspection approach of current government practices.

4.3. Sample and Data Collection

We conducted this research in the Chinese context because of the following reasons. China, since its market reform by 1978, has experienced rapid industrialization; the GDP growth rate was average 10% a year during the past few decades of the market reform (World Bank, 2018). In exchanging of the rapid economic growth, China has jeopardized its environment and people health. For instance, the Carbon dioxide emissions per capita increased by 2.82 times in the last 20 years (World Bank, 2014). According to the latest report from the Health Effects Institute (2018), more than 1.5 million people died directly or indirectly because of air pollution in China in 2016. Industrial waste has poisoned more than 10% of the arable land in China, which may have the potential to cause food shortage in the future (Du, 2010). Chinese manufacturers, as the world's factory, receive tons of orders from international brands every day. The Economist (2015) reported that "China produces about 80% of the world's air-conditioners, 70% of its mobile phones and 60% of its shoes." However, facing the situation of increasing labor and production cost in China, the manufacturers face the threats from manufacturers in other emerging markets, as international brands accelerate LCCS. Thus, the results from Chinese context can be used as a reference for those developing countries who are experiencing or will face the industrialization.

Recently, China's 13th National People's Congress has proven the institutional restructuring of the State Council and built up Ministry of Ecology and Environmental of the People's Republic of China (xinhua.net, 2018). This institutional reform tends to improve the government's effort in developing environmental sustainability. Environmental monitoring is one of the duties of this newly reformed Ministry of Ecology and Environmental of the People's Republic of China (xinhua.net, 2018). It forces companies to stick to environmental rules, and thus improve environmental performance. The Chinese government requires fifteen thousand factories to report real-time air emissions and water discharges figures to the public since 2014 (Albert and Xu, 2016; Denyer, 2014). The government also depends on public complaints or random check to conduct the environmental monitoring, which might not be an effective and efficient way (Dasgupta and Wheeler, 1997).

We extended the sample collected by the short-term event study in Chapter three. First, we sampled all the public manufacturing firms that listed on the Shanghai and Shenzhen A-share stock markets. There were 1,312 public manufacturing firms in these markets by 2014, which compose 9955 firm-year observations. Second, we searched their environmental violations announcements between 2004 and 2013 from the Institute of Public and Environmental Affairs (IPE) database and identified 1600 environmental violations that indicate in which year a firm had misconducts. 439 firms committed these 1600 violations, which compose 1131 firm-year observations. Third, we collected their financial data from the Thomson Reuters Eikon database and firm's basic information (i.e., government ownership, firm age, and listed year) from the GTA's China Stock Market & Accounting Research (CSMAR) database. After deleting the samples with missing data, we got total 8522 firm-year observations for prediction model and Propensity Score Matching (PSM) in our later analysis. The 12.70% of them (1082 out of 8522 firm-year observations) have environmental violations, which is used as the sample in the long-horizon event study for testing RQ1. We used the remaining 87.30% (7440 firm-year observations without environmental violations) as the control firms to match the sample firms in PSM. Table 4-1 shows the basic statistics of our sample.

Table 4-1. Descriptive statistics of the firm-year observations

	Total assets (RMB 000,000)	Sales (RMB 000,000)	Net income (RMB 000,000)	Number of employees (000)	ROA	Financial leverage	Operational leverage
All firm-year observations (*n* = 8522)							
Mean	5,146.03	4,373.85	264.18	4.31	0.05	0.51	1.32
Median	1,923.99	1,222.63	76.96	2.09	0.05	0.48	1.05
Std. error	14,004.59	14,228.10	1,178.08	8.08	0.09	0.70	14.53
Maximum	318,633.18	480,979.67	42,028.16	177.62	0.75	43.08	1,281.06
Minimum	14.77	0.00	-9,092.06	0.00	-4.95	0.00	-177.62
Firm-year observations with environmental violations (*n* = 1082)							
Mean	11,661.05	10,376.56	620.99	8.28	0.05	0.54	2.37
Median	3,677.83	2,661.19	133.92	3.51	0.05	0.54	1.08
Std. error	25,337.10	26,060.86	2,259.74	14.71	0.07	0.27	38.99
Maximum	318,633.18	434,803.95	42,028.16	177.62	0.52	4.46	1,281.06
Minimum	39.63	0.00	-9,092.06	0.02	-0.32	0.03	-27.15
Firm-year observations without environmental violations (*n* = 7440)							
Mean	4,198.55	3,500.88	212.29	3.73	0.05	0.51	1.16
Median	1,777.49	1,127.18	71.53	1.95	0.05	0.47	1.04
Std. error	11,148.82	11,277.71	909.11	6.38	0.10	0.74	4.55
Maximum	317,203.00	480,979.67	40,156.36	89.79	0.75	43.08	163.97
Minimum	14.77	0.40	-5,320.00	0.00	-4.95	0.00	-177.62
Final firm-year observations with environmental violations (*n* = 721, final sample firms in the observation years)							
Mean	9,701.23	8,024.07	493.76	7.41	0.05	0.54	1.24
Median	3,766.37	2,614.23	130.64	3.57	0.05	0.55	1.11
Std. error	19,347.04	16,766.22	1,418.12	12.35	0.06	0.31	2.55
Maximum	176,969.16	162,325.57	19,204.29	166.41	0.50	4.46	21.64
Minimum	266.87	47.59	-3,281.00	0.02	-0.30	0.07	-27.15
Final firm-year observations without environmental violations (*n* = 721, final matched firms in the observation years)							
Mean	8,524.98	7,227.70	423.84	6.14	0.06	0.53	0.86
Median	3,445.24	2,421.10	124.48	3.29	0.05	0.54	1.11
Std. error	18,817.33	16,760.65	1,286.08	9.35	0.06	0.20	7.63
Maximum	220,875.84	200,638.01	15,652.19	89.79	0.51	2.00	25.10
Minimum	326.05	82.93	-5,320.00	0.03	-0.12	0.01	-177.62

Note. All the factors are based on the fiscal year ending before the observation year

4.4. Analysis and Results

4.4.1. Effect of Environmental Violations on Long-term Firm Performance

To answer the RQ 1, we introduce a long-horizon event study approach to test the causal effect of environmental violations on the firm's performance. The main idea of the method is to detect abnormal performance by comparing the performance of sample firms (firms with violations) to that of the control firms (firm without violations). We used propensity score matching (PSM) to match each 1082 firm-year observation with a control sample from the 7440 firm-year observations that face similar risk to having violations (Please refer to the section 4.2.1 for the details). We define the event year (Year 0) as the year when the firm committed violation(s). The Year 0 is also the base year that used to investigate the firm's pre- and post- event abnormal performance. We set the pre-event period as the three years before the event (i.e., Year -3, Year -2, Year -1) and post-event period as the five years after the event (i.e., Year 1, Year 2, Year 3, Year 4, Year 5). The eight-year period is the most prolonged period we could investigate since the extension of the period will decrease the sample size dramatically. As previous long-term event studies usually investigate a four-year period (see Hendricks and Singhal, 2005; Lo et al., 2014; Liu et al., 2014), we believe our eight-year period is long enough to show up the causal relationship between environmental violations and firm's long-term performance.

We calculated a firm's abnormal performance based on the difference between actual performance with environmental violations and expected performance without violations. We obtained the expected performance by adding the control firm's performance change during the observation period to the sample firm's actual performance at the beginning of observation. The formulas are as follows:

$$AP_{t+j} = SP_{t+j} - EP_{t+j} \tag{E.4-3}$$

$$EP_{t+j} = SP_{t+i} + \left(CP_{t+j} - CP_{t+i}\right) \tag{E.4-4}$$

where *AP* is the abnormal performance, *SP* is the sample firm's actual performance, *EP* is the sample firm's expected performance, *CP* is the control firm's actual performance, *t* is the base year, *i* the starting year of the observation period (*i* = -3, -2,…,+4), *j* is the ending year of the observation period (*j* = -2, -1,…,+5). We conducted the t-test and Wilcoxon sign-rank (WSR) test to test whether the mean and median abnormal performance is significant from zero. We also conduct the binomial sign test to see whether the percentage of abnormal performance is significantly higher than 50%.

4.4.1.1. Propensity Score Matching

The long-horizon event study that we used in this research is a quasi-experiment method, which matches sample firms with control firms to compare the treatment results (i.e., effects of the environmental violations). Selecting the control firms with a similar risk of having violation(s) as the sample firms in a given year could be biased such as self-selection bias, and sometimes the selection is based on the researcher's systematic judgment (Dehejia and Sadek Wahba, 2002). Previous research usually used dimension-to-dimension matching approach proposed by Barber and Lyon (1997) to select control firms. They matched sample firms to control firms by a similar group of dimensions. However, it may also have an issue called the "curse of dimensionality," which refer to the difficulties to match every dimension of the sample unit to control unit (Ho et al., 2017). In many cases, researchers need to enlarge the similarity standard when selecting control firms, which may decrease matching quality. To eliminate the effects produced by these problems, we use the propensity score matching (PSM) in our study. It was first introduced by Rosenbaum and Rubin (1983) and widely used in observational studies to reduce the selection bias in the operations literature (Ho et al., 2017), economics literature (Dehejia and Sadek Wahba, 2002) and healthcare literature (Crown, 2014; Oh et al., 2017).

In our study, the propensity score is the firm's risk (estimated probability) of experiencing environmental violation(s) in an observation year. We used the program Propensity Score Matching for SPSS, Version 3.0.4 (Thoemmes, 2012) to calculate the propensity score for each 8522 firm-year observation. In our calculation, we considered observation year *(j)*, industry that a firm belongs to, firm's age by observation year *(j)*. Also, we included lagged independent variables that represent firms' operational and financial characters in year *(j-1)*, such as firm's revenue (in natural logarithm), total assets (in natural logarithm), industry-adjusted ROA*,* the percentage of government ownership, operational leverage and financial leverage. We did not include violation history in the PSM because this value is significantly different between sample and control, that may increase the selection bias and decrease the matching quality (Caliendo & Kopeinig, 2008).

After calculating the propensity scores of the 8522 firm-year observations, we use the nearest neighborhood as the matching algorithm to match each 1082 firm-year observation (a manufacturer with violations in a given year) with a control sample from the 7440 firm-year observations (manufacturer without violations in a given year). Thus, we matched each sample firm with a control firm that has the closest propensity score in the observation year.

4.4.1.2. Matching Quality Between Sample Firms and Control Firms

We ensure the matched firms are facing a similar risk of having environmental violations in a given year as the sample firms as follows: First, sample firms and control firms are in the same industry to make sure that they are facing the same law and norms. Second, we set a caliper to 0.2 standard deviations and delete the matched samples with the caliper higher than the number (Austin, 2011). The caliper represents the probability difference between the sample and the matched firm of having a violation in a given year (Lunt, 2013). If the probability difference is small, the matched firms are facing a similar risk as the sample firms. 41 samples are removed.

Third, we delete the samples that the matched firm's revenue and total assets are not within a range of 95-105% of the sample firm's (Quesnel-Vallee et al., 2010). This 10% cut-off point ensured the firm size of the matched group does not deviate from the sample group. 128 samples are removed. Forth, we further eliminate 186 firm-year observations that include regular government report and improvement report on firms' environmental performance because they did not indicate a specific incident on a specific date, while our interests are the impact of a specific violation. Thus, our sample only consists of violations that have specific details of the pollution condition. We then remove 1% outliers (6 samples) of the abnormal performance for each observation period.

After all the above trimming, our final sample consists of 721 firm-year observations for testing RQ3. We conducted an independent sample t-test to test the mean differences of all the factors between the sample firms and matched firms. None of the factors are significantly different at 10% level which shows that the matched firms have similar risk and characters as sample firms.

4.4.1.3. Effect of Environmental Violations on Long-term Firm Performance

We examine the abnormal ROA performance in different pre-event periods (i.e. year -3 to 0, year -2 to 0, and year -1 to 0) and post-event periods (i.e. year 0 to 1, year 0 to 2, year 0 to 3, year 0 to 4 and year 0 to 5). Table 4-6 shows the result of the cumulative abnormal ROA performance.

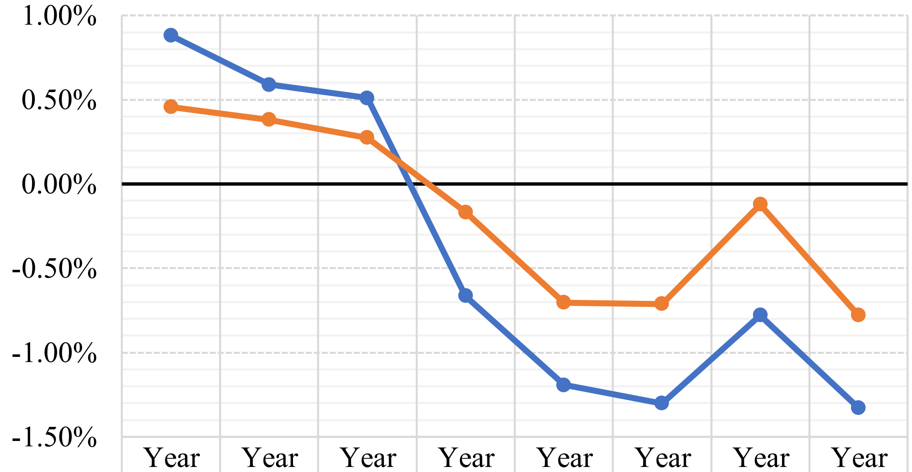
Table 4-6. Cumulative abnormal ROA for the firms with violations

	Year -3 to 0	Year -2 to 0	Year -1 to 0	Year 0 to 1	Year 0 to 2	Year 0 to 3	Year 0 to 4	Year 0 to 5
n	719	721	721	721	719	716	638	541
Mean abnormal returns	0.88%	0.59%	0.51%	-0.66%	-1.19%	-1.30%	-0.78%	-1.33%
t -statistic	2.49^{**}	1.80^{*}	2.18^{*}	-2.53^{**}	-4.10^{**}	-3.91^{**}	-2.15^{*}	-3.13^{**}
Median abnormal returns	0.46%	0.38%	0.28%	-0.17%	-0.70%	-0.71%	-0.12%	-0.78%
Wilcoxon signed-rank Z-statistic	2.16^{*}	1.58^{+}	1.75^{*}	-1.93^{*}	-3.58^{**}	-3.54^{**}	-1.83^{*}	-3.19^{**}
% abnormal returns negative	47.4%	47.4%	48.1%	52.1%	56.2%	55.4%	51.4%	54.2%
Binomial sign test Z-statistic	1.34^{+}	1.34^{+}	0.97	-1.12	-3.28^{**}	-2.88^{**}	-0.67	-1.89^{*}

Note: $^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$ (all tests are one-tailed).

Our result shows that the sample firms abnormal ROA performance is significantly better than that of the control firms in all the pre-event periods. For instance, the mean (median) abnormal ROA in the period year -3 to 0 are 0.88% (0.46%) and significantly larger than zero ($p < 0.01$ for the mean and $p < 0.05$ for the median), and 47.4% of abnormal ROA are negative and significantly less than 50% ($p < 0.10$). Similarly, the mean (median) abnormal ROA for period -2 to 0 are positively at 0.59% (0.38%) and significantly larger than zero ($p < 0.05$ and $p < 0.10$ for the mean and median, respectively), and 47.4% of abnormal ROA are negative and significantly less than 50% ($p < 0.10$). The mean (median) abnormal ROA for the year -1 to 0 are 0.51% (0.28%) and significantly larger than zero ($p < 0.05$ for both mean and median), and 48.1% of abnormal ROA are negative but not significantly less than 50%. A firm has a better abnormal financial performance before the event suggests that it is boosting the profit either by earning more revenue or reducing more cost. We have calculated the abnormal revenue and sales growth for our sample firms, and they are not significantly increase during the pre-event period, which suggests that the firms are more aggressive in cutting corners to boost profit by reducing cost. However, after they were caught by the government, they have to take corrective action, and their financial performance deteriorates.

Examining the impact over the post-event periods reveals that the increasing trend of abnormal ROA in the pre-event period did not remain as the sample firms abnormal ROA performance is significantly worse than that of the control firms in all the post-event periods. The mean (median) abnormal ROA in the year 0 to 1 are −0.66% (−0.17%) and significantly less than zero ($p < 0.01$ for the mean and $p < 0.05$ for the median), and 52.1% of abnormal ROA are negative but not significantly higher than 50%. Similarly, the mean (median) abnormal ROA in the year 0 to 2 and year 0 to 3 are −1.19% (−0.70%) and -1.30% (-0.71%), respectively. They all significantly less than zero at $p < 0.01$. 56.2% and 55.4% of abnormal ROA are negative and significantly higher than 50% (both at $p < 0.01$) for the year 0 to 2 and 0 to 3 period. For the year 0 to 4 period, the mean (median) abnormal ROA is also -0.78% (-0.12%) and significantly less than zero (both at $p < 0.05$). 51.4% of abnormal ROA are negative but not significantly higher than 50%. Lastly, the mean (median) abnormal ROA in the year 0 to 5 are -1.33% (-0.78%) and significantly less than zero (both at $p < 0.05$) and 54.2% of abnormal ROA are negative and significantly higher than 50% at 0.05 significant level. We plotted the mean and median abnormal ROAs in each period and visualized the changes in Figure 4-6.



	Year -3 to 0	Year -2 to 0	Year -1 to 0	Year 0 to 1	Year 0 to 2	Year 0 to 3	Year 0 to 4	Year 0 to 5
Mean	0.88%	0.59%	0.51%	-0.66%	-1.19%	-1.30%	-0.78%	-1.33%
Median	0.46%	0.38%	0.28%	-0.17%	-0.70%	-0.71%	-0.12%	-0.78%

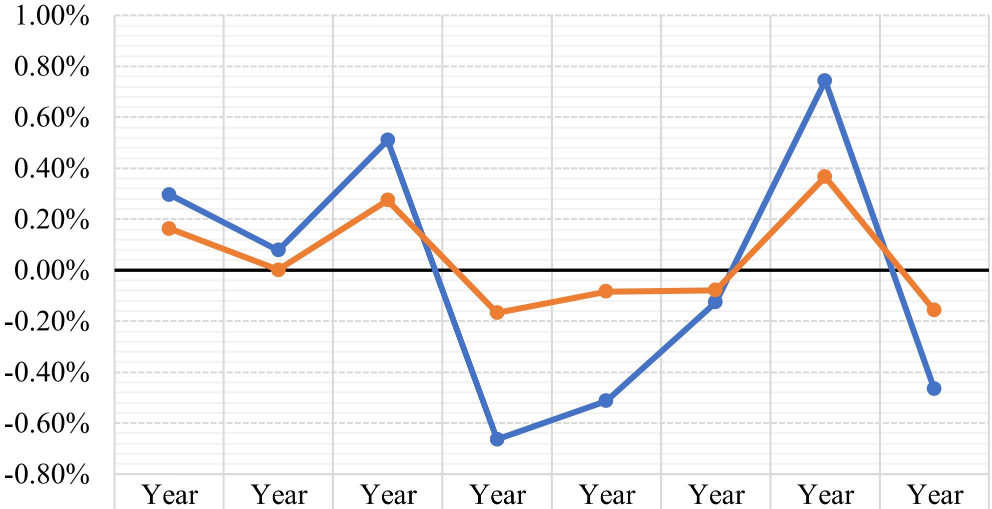
Figure 4-6. Mean and median abnormal ROAs in each period for the firms with violations

Table 4-7. Year-to-year abnormal ROA for the firms with violations

	Year -3 to -2	Year -2 to -1	Year -1 to 0	Year 0 to 1	Year 1 to 2	Year 2 to 3	Year 3 to 4	Year 4 to 5
n	719	721	721	721	719	716	638	541
Mean abnormal returns	0.30%	0.08%	0.51%	-0.66%	-0.51%	-0.13%	0.74%	-0.47%
t -statistic	1.11	0.30	2.18*	-2.53**	-1.94*	-0.52	2.78	-1.58+
Median abnormal returns	0.16%	0.00%	0.28%	-0.17%	-0.08%	-0.08%	0.37%	-0.16%
Wilcoxon signed-rank *Z*-statistic	1.36+	0.27	1.75*	-1.93*	-1.82*	-0.73	2.23	-1.68*
% abnormal returns negative	48.1%	49.9%	48.1%	52.1%	50.9%	51.4%	46.6%	51.8%
Binomial sign test *Z*-statistic	0.97	0.00	0.97	-1.12	-0.45	-0.71	1.70	-0.77

Note: + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$ (all tests are one-tailed).

The year-to-year abnormal ROA performance (Table 4-7) also support our argument. Examining the impact over the year-to-year periods reveals that the abnormal ROA fluctuate most significantly during the year -1 to 2. For the period year -1 to 0, the mean (median) abnormal ROA is 0.51% (0.28%) and significantly larger than zero (both at p < 0.05) and 48.1% of abnormal ROA are negative but not significantly. On the contrary, the mean (median) abnormal ROA for the year 0 to 1 is -0.66% (-0.17%) and significantly less than zero (p < 0.01 for the mean and p < 0.05 for the median). 52.1% of abnormal ROA are negative but not significantly greater than 50%. For the year 1 to 2, the mean (median) abnormal ROA for year 0 to 1 is -0.51% (-0.08%) and significantly less than zero (both at p < 0.05), 50.9% of abnormal ROA are negative but not significantly greater than 50%. These show that the fluctuation of abnormal ROA happened close to the event year. We recorded an increase in mean and median abnormal ROA in the year 3 to 4 period, but they are not significant. The decreasing trend remains in the year 4 to 5 period. The mean (median) abnormal ROA is -0.47% (-0.16%) and significantly less than zero (p < 0.10 for the mean and $p < 0.05$ for the median), and 51.8% of abnormal ROA are negative but not significantly greater than 50%. Figure 4-7 visualizes the mean and median abnormal ROA changes in each year-to-year period.



	Year -3 to -2	Year -2 to -1	Year -1 to 0	Year 0 to 1	Year 1 to 2	Year 2 to 3	Year 3 to 4	Year 4 to 5
Mean	0.30%	0.08%	0.51%	-0.66%	-0.51%	-0.13%	0.74%	-0.47%
Median	0.16%	0.00%	0.28%	-0.17%	-0.08%	-0.08%	0.37%	-0.16%

Figure 4-7. Mean and median abnormal ROA changes in each year-to-year period for the firms with violations

In conclusion, our result shows that violating environmental rules will bring short-term economic benefit to firms, but such benefit cannot be maintained in the long run. Polluting firms need to pay back the benefit gained from violating the rules, and their performance are even worst after environmental violations.

4.4.2. Prediction of Firm's Environmental Violations

We used the concept of supervised machine learning to predict whether a firm will violate environmental laws and regulations in the future or not. Figure 4-2 shows the necessary steps of how it works.

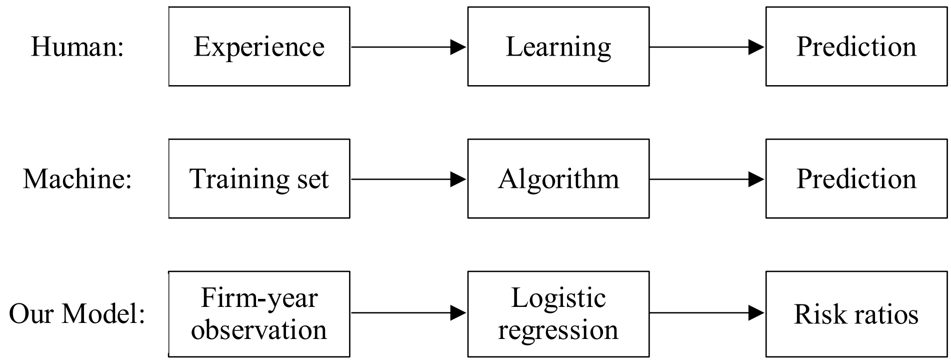


Figure 4-2. Steps of supervised machine learning

Supervised machine learning simulates the process that human beings learn from past scenarios and make predictions about future instances. The "Experience" for the machine is a training set that includes data with input-output pairs. The "Learning" process is usually a statistical algorithm that handles the training set data. After that, the machine is cable of making a prediction based on different instances.

In our research, we use 7306 firm-year observations in the period of 2004-2012 as the training set. The remaining 1216 firm-year observations in 2013 are used to check the prediction accuracy and verify the model efficacy. Table 4-2 shows the sample firms by year.

Table 4-2. Number of sample firms by years

Year	Total number of firms	Number of firms with violations	% (Firms with violations)
2004	516	26	5%
2005	605	47	8%
2006	668	90	13%
2007	732	115	16%
2008	811	135	17%
2009	798	118	15%
2010	902	131	15%
2011	1,092	164	15%
2012	1,182	156	13%
2013	1,216	100	8%
Total	8,522	1,082	13%

In the robustness tests, we used different input-output training sets to test our model accuracy and efficacy. We randomly selected 6855 firm-year observations (80% of 8522 observations) as a training set to predict the remaining 1677 observations. We also used 6124 firm-year observations in the 2004-2011 period as a training set to predict the remaining 2398 observations in the 2012-2013 period. The results are similar.

We chose the logistic regression[3] as the learning algorithm because it has some advantages than other machine learning methods, such as decision tree, Naïve Bayes classifier, and artificial neural networks (ANNs). First, the input-output pairs training set is the firm-year observations, which is a suitable setting for logistic regression. The dependent variable (output) is whether a firm has environmental violation(s) in a given year (i.e., 1 = no violations in a given year, otherwise 0). The independent variables (input) are the factors that may affect the output. Second, logistics regression is superior to the decision tree for classification for sample smaller than 10,000 (Perlich et al., 2003) while our sample size is 8522. Third, the logistic regression model can indicate a possible causal relationship between the dependent variable and independent variables within a reasonable computing time. Naïve Bayes classifier and ANNs need additional steps to identify the relationship, and it is difficult to interpret the weights generated in these methods (Moon et al., 2012; Tu, 1996). In summary, other methods require additional time and procedures to have the similar

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[3] The PSM (in section 4.4.1.1.) is intended to identify control firms with similar risk than those sample firms in the "same" year. For this reason, it is less suitable than our logistics regression model that uses data based on all "historical" years to predict each firm's likelihood for violating environmental regulations in future years.

outcomes without improving the model accuracy and efficacy (Dreiseitl and Ohno-Machado, 2002; Manel et al., 1999).

Our purpose is to help the environment regulator or inspectors to identify as many violations as we can by consuming fewer resources (i.e., number of inspections), so all the variables in our regression model are publicly available and can be easily obtained and calculated from the firms' financial reports. We include the firms' common operational and financial variables that may affect firm's environmental performance, such as industry (dummy variable), firm age, revenue (natural logarithm), total assets (natural logarithm), industry-adjusted ROA, the percentage of government ownership. Government ownership is an essential factor in China, as the government asserts their influence on public listed firms through the form of ownership, as some firms used to be state-owned enterprise (SOE), which serve strategic and social purposes for the government. We also include operational leverage (i.e., operating income/net income) and financial leverage (i.e., total liability/total assets) to estimate the operational risks of the firms.

We have also tried other market-related factors such as debt-to-equity ratio, price-to-book ratio, gross margin, market share but they are not significant and do not improve the figures in model fit (i.e., 2 log likelihood, Cox & Snell R Square, Nagelkerke R Square) and decrease the sample size significantly (around 5%). So we did not include them in our model (Please see Appendix B). We further refined the model for prediction purpose by controlling the firm's past performance (i.e., violation history). We calculated the violation history by a firm's total number of environmental violations since 2004 (the first observation year) divided by the number of observation years. It may affect the firm's future performance (Russo and Fouts, 1997). Thus, our logistic regression model is as follows:

$$EV_{ij} = \beta_0 + \beta_1 Violation\_history_{ij} + \beta_2 Industry_{ij} + \beta_3 firm\_age_{ij} + \beta_4 Revenue_{i(j-1)} + \beta_5 Total\_assets_{i(j-1)} + \beta_6 ROA_{i(j-1)} + \beta_7 Goverment\_ownership_{i(j-1)} + \beta_8 Operational\_leverage_{i(j-1)} + \beta_9 Financial\_leverage_{i(j-1)} \quad \text{(E.4-1)}$$

where EV_{ij} represents whether the firm *i* has violation(s) in the year *j* (i.e., 1 = no violations in the year *j*, otherwise 0), We used the value of violation history, industry and firm age in the year *j*. The revenue (natural logarithm), total assets (natural logarithm), ROA (industry-adjusted), the percentage of government ownership, operational leverage and financial leverage is the value in the previous year *j-1* (the fiscal year ending before the observation year).

4.4.2.1. Identification of the Key Predictors (RQ2)

After we input the 7306 firm-year observations into the logistic regression model, it identified the significant factors (key predictors) and their parameters that can affect the likelihood of having environmental violation(s) in a given year. Table 4-3 shows the logistics regression result.

Table 4-3. Estimated Coefficients (z-Statistics in Parentheses) from Logistics Regressions of 7306 firm-year observations from the period of 2004-2012

Independent variables	Training set	
Intercept	-8.68	(61.22)**
Industry dummy	-	
Firm age	0.02	(3.63)+
Firm size (Total assets)	0.17	(4.00)*
Percentage of government ownership	0.38	(4.93)*
Industry-adjusted ROA	-0.83	(3.86)*
Operational leverage	0.00	(0.67)
Revenue	0.23	(10.23)**
Financial leverage	0.01	(0.01)
violation history	2.33	(311.50)**
n	7,306	
-2 Log likelihood	4,604.70	
Cox & Snell R Square	14.71%	
Nagelkerke R Square	26.95%	

Note: All tests are two-tailed: +p ≤ 0.10; *p ≤ 0.05; **p ≤ 0.01; Industry is categorical dummy variable of 26 industries, and we did not show it in the table to save space.

The result shows that revenue and violation history is positively related to the emergence of environmental violations (both at $p<0.01$), so the firms with more considerable revenue and more violation history have a high probability of having violations. Some other significant predictors are the percentage of government ownership, total assets, and industry-adjusted ROA (all at $p<0.05$). The result shows that firms with higher government ownership, larger total assets, and lower ROA are more likely to violate environmental rules in the future. Also, the firm age also matters (at $p<0.10$). The older firms are more likely to have environmental violations.

4.4.2.2. Prediction of the Risk Ratios (RQ3)

With the estimated coefficients from the logistic regression model, we can calculate each firm's probability of violating in the future. The formula is

$$\Pr(V)_{ij} = 1 \Big/ 1 + e^{-\left(\begin{array}{c}\beta_0 + \beta_1 violation\_history_{ij} + \beta_2 Industry_{ij} + \beta_3 firm_{age_{ij}} + \beta_4 Revenue_{i(j-1)} + \\ \beta_5 Total\_assets_{i(j-1)} + \beta_6 ROA_{i(j-1)} + \beta_7 Goverment\_owenrship_{i(j-1)} + \\ \beta_8 Operational\_leverage_{i(j-1)} + \beta_9 Financial\_leverage_{i(j-1)}\end{array}\right)}$$

(E.4-2)

where $\Pr(V)_{ij}$ is the probability of having violation(s) for each firm *i* in the year *j* (i.e., *j* = 2013). The value in the brackets will be calculated based on the significant factors and the estimated coefficients in the equation (1) by using the 7306 firm-year observations in the period of 2004-2012. The estimated coefficients of insignificant factors will be set to zero.

The $\Pr(V)_{ij}$ can be considered as a risk ratio to indicate the firm *i*'s probability of having environmental violation(s) in the year *j*. We calculated each firm's risk ratio for all 1216 firms in the year 2013. The firms with higher risk ratios are riskier of committing environmental violations than those with lower ratios. We can set decision boundaries to decide at which levels the firm will violate the rules in 2013. Table 4-4 shows the number of firms with violations by industry when we set the decision boundary to 50%.

Table 4-4 shows that the industry categories, such as chemical products and metal and non-metallic mineral products are the high-risk categories with 22 firms with risk ratio larger than 50% in each. The raw chemical materials and chemical products industry (C26) is the high-risk industry with 17 firms with risk ratio larger than 50%.

Table 4-4. Distribution of firms with violations by industry (decision boundary = 50%)

Industry category	Industry code	Industry	Number of firms with violations
Chemical products (C26-29, except C27)	C26	Raw Chemical Materials and Chemical Products	17
	C28	Chemical Fibre Manufacturing	4
	C29	Rubber and plastic product industry	1
	Sub-total		22
Metal and non-metallic mineral products (C30 - 33)	C30	Non-metallic Mineral Products	9
	C32	Smelting and Pressing of Nonferrous Metals	7
	C31	Smelting and Pressing of Ferrous Metals	4
	C33	Metal Products	2
	Sub-total		22
Others (all other not included)	C14	Food Manufacturing	4
	C15	Wine, drinks and refined tea manufacturing	4
	C13	Farm Products Processing	2
	C25	Petroleum Processing, Coking and Nuclear Fuel Processing	2
	Sub-total		12
Textiles and paper products (C17-18, C20, C22)	C22	Papermaking and Paper Products	7
	C17	Textile	2
	C18	Textiles, Garments and Apparel industry	1
	Sub-total		10
General equipment manufacturing (C34 - 41)	C36	Automobile Manufacturing	4
	C37	Railway, shipbuilding, aerospace and other transportation equipment manufacturing	3
	C34	General Equipment Manufacturing	1
	C39	Computer, communication and other electronical device manufacturing	1
	Sub-total		9
Pharmaceutical manufacturing (C27)	C27	Pharmaceutical manufacturing	7
	Sub-total		7
Total			82

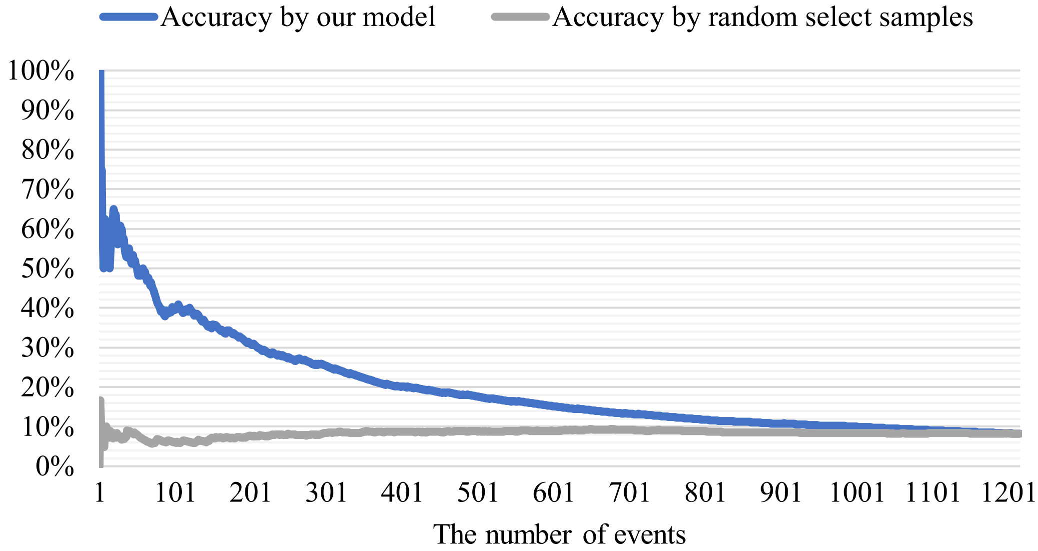
We then compare our prediction accuracy to the actual number of firms (i.e., 100 firms) with violations in 2013. Table 4-5 summarizes the accuracy and coverage of our prediction in different risk ratio categories.

Table 4-5. Distribution of the prediction accuracy and coverage in different risk ratio categories.

Category of risk ratio	No. of firms (1)	%	Accumula-tive %	Actual no. of firms with violations (2)	%	Accumula-tive %	Accuracy ratio = (2) / (1)	Accumulative accuracy ratio
90% - 100%	13	1.07%	1.07%	7	7.00%	7.00%	53.85%	53.85%
80% - 90%	10	0.82%	1.89%	7	7.00%	14.00%	70.00%	60.87%
70% - 80%	15	1.23%	3.13%	6	6.00%	20.00%	40.00%	52.63%
60% - 70%	21	1.73%	4.85%	9	9.00%	29.00%	42.86%	49.15%
50% - 60%	23	1.89%	6.74%	3	3.00%	32.00%	13.04%	39.02%
40% - 50%	30	2.47%	9.21%	12	12.00%	44.00%	40.00%	39.29%
30% - 40%	57	4.69%	13.90%	14	14.00%	58.00%	24.56%	34.32%
20% - 30%	93	7.65%	21.55%	13	13.00%	71.00%	13.98%	27.10%
10% - 20%	322	26.48%	48.03%	20	20.00%	91.00%	6.21%	15.58%
0% - 10%	632	51.97%	100.00%	9	9.00%	100.00%	1.42%	8.22%
Total	1216	100.00%	-	100	100.00%	-	-	-

If we set the decision boundary at 90% risk ratio, we can identify 13 firms that will have violations in 2013 because their risk ratios are larger than 90%. The actual number of firms with a violation of the 13 firms is seven. Therefore, our prediction accuracy is 53.85%. If we set the decision boundary at 80%, we will have 23 firms and the prediction accuracy is 60.86%. When we lower the decision boundary, we can identify more violating firms, but the accuracy will drop. Figure 4-3 visualizes the prediction accuracy compare to the random sampling technique when we extend the investigation to all 1216 firms in 2013.

Figure 4-3. Predicting events in 2013 based on samples in 2004-2012



We used the data from 2004 to 2012 to predict which firms will violate the environmental rules in 2013. We first selected the firm with the highest risk ratio (99.93%) among the 1216 firms. The firm actually had a violation in 2013, so our prediction accuracy is 100%. If we choose one more firm, we will select the second risky firm with 99.69% risk ratio. Our prediction accuracy is still 100%. To find out more firms with environmental violations, we need to investigate the lower risk firms. Although the accuracy rate of our model will decrease when we increase the numbers of firms to investigate, we only need to investigate a small number of firms to find out a significant proportion of environmental violations. Based on the above illustration, it shows that our prediction accuracy is robust, and it is much better than that of the random sampling (average 8.3% accuracy). Figure 4-4 compares the efficacy of our model and random sampling.

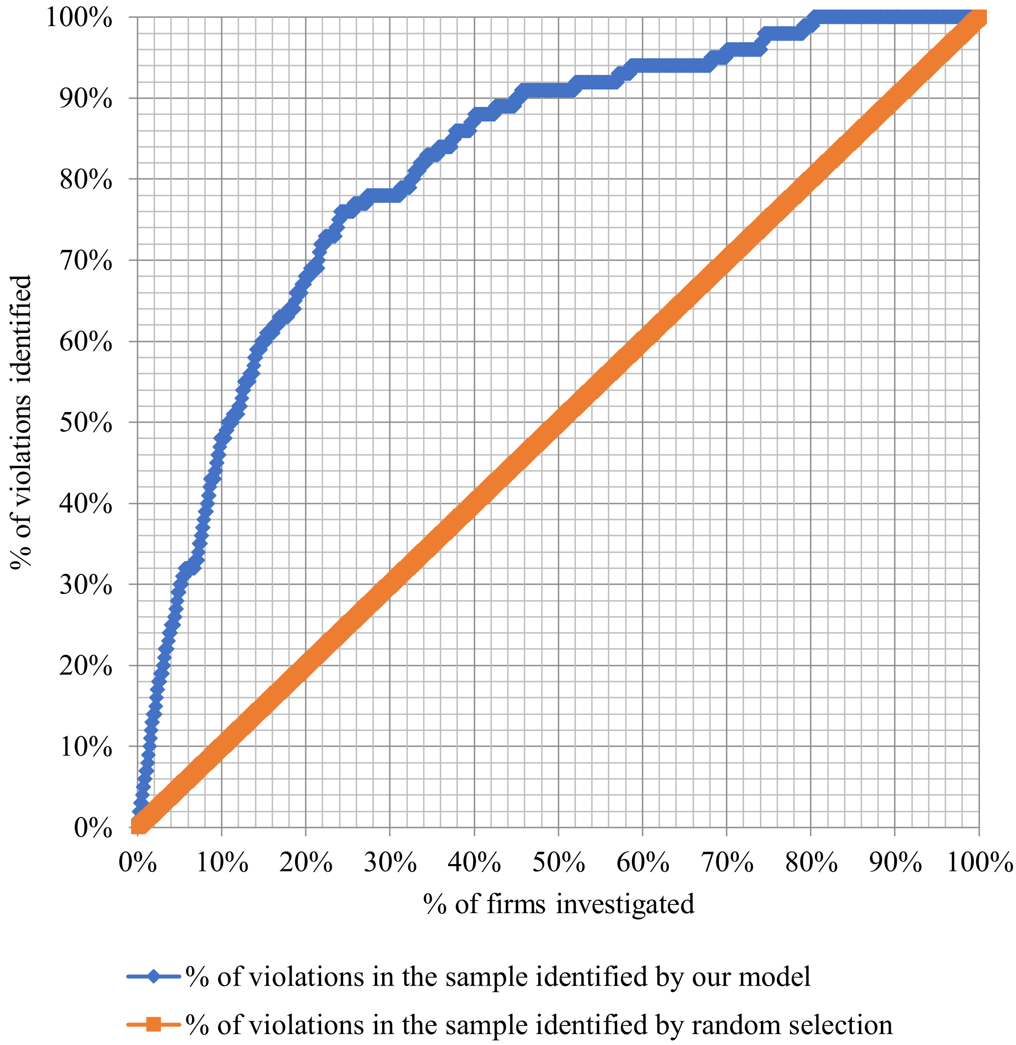


Figure 4-4. Efficacy Comparison between our model and random sampling

On the contrary, the traditional approach of random sampling, to catch 80% of the environmental violations, the environmental inspectors need to cover 80% of the whole population. Our model can do better than random selection, by using 0.10 significant level, we can rank the firms according to their risk ratio. The higher the score, the more likely the firm will violate in 2013. We only need to investigate 32.4% of the population to pick up 80% of the environmental violations. Consider the government often only randomly inspect a small proportion of the whole population in a given year, a large number of violations get unnoticed until it pollutes the environment.

In 2017, the Chinese government sorted out 80.95 thousand polluters and categorized them into *special supervision group* (2.05%), *key pollution group* (9.54%), and *general pollution group* (88.41%) based on their pollution records (MEEPRC, 2018). The government conducts a random inspection within groups with more focus on the firms in *special supervision group* and *key pollution group* mentioned in section 2.2. We applied the method that the Chinese government conducted an inspection to our sample, and categorized our 1216 firms into three pollution groups based on their pollution records. Following the same proportion that the Chinese government set to the three groups, we include 25 firms (1216 firms x 2.05%) in the *special supervision group,* 116 firms (1216 firms x 9.54%) in the *key pollution group*, and 1075 firms (1216 firms x 88.41%) in the *general pollution group*. We then conducted inspection randomly within each group started from the firms in *special supervision group* to the one in *general pollution group*. We also divided our 1216 samples into the three groups based on the industry pollution history. We compared the two methods to our model and basic random selection model in Figure 4-5.

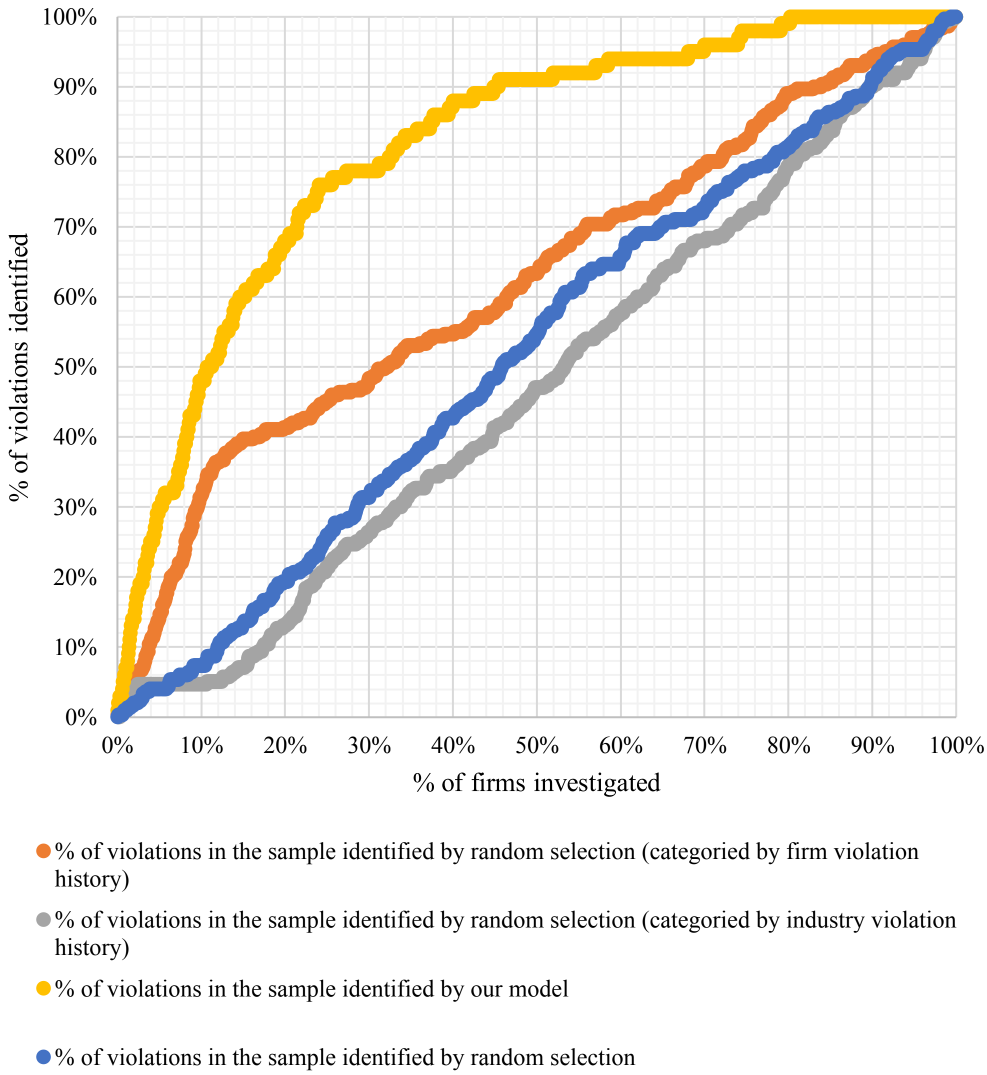


Figure 4-5. Efficacy Comparison between different samples

The performance of our model (yellow line) is always better than those of our models. Although the efficacy of the government's current practice (orange line) is better than those of the other two models, it still worse than that of our model. From 0 to 10% firms' coverage, our model can predict the maximum 17% more violations than the government model. The gap becomes significantly larger after 10% coverage. Overall, our model is much better than random sampling and the Chinese government's current practice regarding accuracy and efficacy.

We estimated the inspection cost that could be saved by our model. The Chinese government conducted 63.26 thousand inspections for the 80.95 thousand polluters (MEEPRC, 2018). If we assumed they inspected each company one time, the coverage of the polluter population is 78.15%. They found 3.79 thousand environmental violations. If average 13% of the firms had environmental violations (according to Table 2), 36.01% of the violations [3.79 thousand / (80.95 thousand x 13%)] were found. The Chinese government invested RMB 2.42 billion in conducting environmental monitoring and inspection (MEEPRC, 2017). So, the average cost per inspection is 2.42 billion divided by 63.26 thousand times, which equals to RMB 3,830. If the government wants to cover 80% of the violations by using their current practice, it needs to invest RMB 2.48 billion (RMB 3,830 x 80.95 thousand firms x 80%). By our model, the government needs to invest RMB 1.00 billion (RMB 3,830 x 80.95 thousand firms x 32.4%) to cover 80% of the violations. The total saving for government inspection is RMB 1.48 billion.

4.5. Discussion

This study proposed an environmental risk prediction model to improve environmental inspection efficiency and efficacy. The model can significantly reduce the inspection costs and mitigate environmental pollution. The model provides a new avenue for maintaining supply chain sustainability in China. Also, knowing the short-term benefits of violating environmental regulation for rapid production would eventually hurt the company in the long run, firms would have more motives to reduce their pollution activities.

We proposed our predictive model based on the concept of supervised machine learning. Thus, our model could self-improve continuously. Compared to random sample inspection, we used the financial and operational indicators that are publicly available in our model could build a significantly more accurate model to identify polluting firms in China. As we input more data on the operational and financial factors or more variables into our model, the prediction accuracy will be continuously improved. However, our research has some limitations. First, we used the data from public companies, the significant factors that affect the prediction results may be different from involving private company data. Future research could consider adding the data from private companies to the model. Second, we used the data in the current year to predict next year's environmental violations. We did not use yearly averaged performance (for 3-5 years) to leverage the fluctuation of the company performance due to the data availability. Using yearly averaged data will decrease our sample size dramatically. Our research has some several limitations. First, the current government inspection practices are not transparent. So, the total savings and comparisons are based on the best available data we have. There might be some government hidden practices which may affect the inspection costs and results. Second, our analysis is based on the listed manufacturing firms, which are larger firms compare to private firms. We do not include the pollution caused by private firms because we build up our models based on the public available financial data. Further studies may consider adding private firms in the analysis.

Our findings provide implications to various stakeholders as follows.

Implications for Policymaker and Inspectors. This study proved that the monitoring strategy could be more predictive, rather than responsive. Government inspectors could make use of the data they have to enhance the prediction accuracy and efficacy by the model. For instance, with the recent advancement of safety monitoring system in China, many additional data can be used to enhance the models further, such as traffic data (represents the level of activities of the plants), employment data (represents the frequency of labor turnover, and their education level), etc. These additional data could serve as a proxy for the firm's operational performance and contribute to the likelihood of an environmental violation.

Policymaker should continue to improve the data transparency of polluting firms, so that their long-term cost of polluting the environment is higher until it reaches a tipping point that is not worthy of risking it for short-term benefits. Meanwhile, the data transparency can be benefited through the collaboration with NGOs, such as IPE, would help to bring up the costs of pollution, as the overseas consumers can also access these data without a barrier.

Implications for Operations Managers. RQ1 showed that the firms need to pay back the environmental violation in the long run. The short-term surge of economic benefits does not last. Operations managers should consider the strategies from a longer-term perspective to improve their operations to reduce the likelihood of environmental violation incidents. For example, our model shows that operating and financial leverages indeed do not lead to a higher risk of environmental violations. Rather than cutting corners in the first place, the managers can consider making use of these leverages to resolve their problems. Also, operations managers could also use our prediction model to estimate the firm's pollution probabilities in the future and facilitate an effective and efficient environmental monitoring process for preventive and/or remedial purposes, thus, help the managers to adjust their future manufacturing plans.

Implications for NGOs. NGOs should further develop the data transparency of environmental issue. Thus, various stakeholders could use our prediction model to monitor firms' pollution problems. These monitoring activities may generate pressures on the firms and force them to maintain their environmental sustainability. It would be even better if the NGOs in China could extend their monitoring to employee workplace health and safety (or other social aspects misconducts), which could enhance the factories' overall sustainability in the long run. Workplace safety and performance is also directly linked to firms' financial performance in developed countries (Lo et al., 2014), so it is reasonable to predict that this relationship would grow stronger in China as if what we observed on environmental aspects.

Implications for international brands and sourcing agents. Sourcing agents can use our models to identify risky supplier through the financial and operational indicators. It proves that even if the environmental pollution records in some countries are not so well established, the sourcing decision can rely on other indicators to predict the risk of environmental violation of the suppliers. International brands can also estimate the environmental risks of their suppliers from a holistic and operational perspective and predict if the risk would surge after a large order is placed on the selected suppliers.

Chapter 5. Conclusions

This thesis was motivated by the crucial challenge of maintaining environmental sustainability in emerging markets. At first, I conducted a citation network analysis to review the relevant researches in this area in operations management fields in essay one. I identified four research domains, namely green supply chain management, environmental management practice, supplier evaluation and green extended supply chain. I used main path analysis to identify the knowledge structures and future research trends in each domain. The results showed that there is a merging trend of two research domains, namely green supply chain management and environmental management, with increasing interest in researching the environmental management practice in emerging markets from supply chain perspectives.

To contribute the literature with the ultimate goal of halting the environmental pollution and maintaining environmental sustainability in developing countries, I provided a comprehensive understanding on the impacts of environmental violations on firm and supply chain performance through various stakeholders, such as investors, firms, governments, supply chain partners in two empirical studies.

The first empirical study (essay two) examined the short-term impact of the environmental incidents through the supply chain. Specifically, I examined the impact of environmental incidents on a firm's stock returns in China, and how a Chinese manufacturer's environmental incidents led to negative abnormal returns for its overseas customers. I found that the recognition of social responsibility and government share reduced the negative impact of an environmental incident on the market value of firms, whereas personal political ties with government officials amplified the negative impact. Our results implied that the senior management teams of firms operating in emerging markets should develop organizational-level legitimacy with critical stakeholders (e.g., the Chinese government and NGOs) and secure legitimacy from external bodies. Our findings also indicated that multinational firms should not underestimate the negative impact of environmental incidents on their upstream suppliers, and they should develop a strategic plan proactively to prevent environmental incidents and mitigate associated risks (regarding the likelihood of occurrence and impact).

One primary purpose of this study (essay two) was to examine how social capital, legitimacy and political ties moderate the negative impact of environmental incidents in the Chinese context. Specifically, we focused on the recognition of social responsibility, government share of ownership, and personal political ties. We found that the accumulated number of recognition of social responsibility can serve as a buffer to mitigate the adverse effect of the environmental incidents in China. With the emphasis of corporate social responsibility (CSR) by the government and the typical expectations of Chinese society, social responsibility recognition is likely to be critical for sociopolitical legitimacy, which serves as a crucial strategic resource that protects a firm in case of environmental incidents. We adopted a broader view of social responsibility by covering all the related awards before the environmental incidents, showing how such awards can be accumulated over time and valuable to firms. We also found that government support through its direct-share ownership is likely to provide investors with confidence that mitigates their adverse reactions toward environmental incidents. Nevertheless, connecting to government officials through personal ties can lead to greater skepticism in cases of environmental incidents. This study is the first to identify the role of government shares and personal political ties following an environmental incident. This finding not only provides critical implications for firms in emerging markets but also offers recommendations for future research wishing to explore these moderating effects in developed markets.

Institutional theorists have stated that the development of an organizational policy is not solely grounded in its technical efficiency but also on its social influence and legitimacy. Organizations require efficiency to succeed, but they also require legitimacy and endorsements to survive (e.g., Tolbert and Zucker 1999). However, the legitimacy secured through personal political ties in China might be critical to firms before any environmental incidents, but such a legitimacy could immediately become a liability to the firm in case of environmental incidents. The value of personal political ties is fragile, and its actual value is questionable in the long term. Our findings corroborate those reported in studies conducted in a similar context. For example, Fan et al. (2007) found that some newly listed firms in China with CEOs who held political positions in certain governmental units were more likely to appoint other bureaucrats to become the board of directors, rather than directors from relevant professional backgrounds. The post-IPO performance of these firms is approximately 18% in underperforming compared to those of their counterparts in the market. Our findings were consistent with this finding: We found empirical evidence indicating that the personal political ties have limited contributions to a firm's survival.

The second empirical study (essay three) examined the long-term impact of the environmental violation on a firm's performance. Specifically, I examined a firm's abnormal ROA performance before and after they violated an environmental regulation, and I found that the firm's abnormal ROA increased before the violation was exposed, which suggested that violating environmental regulation would bring short-term benefit to the firm. However, the result of decreasing abnormal ROA after the violation was exposed indicated that the company would pay back the short-term benefits of violating environmental regulation and the firm performance would be even worse in the long run. Together with the essay three, it showed that violating environmental regulation would hurt the firms both in the short and long run. Knowing that violating activities could not benefit firms while the market would penalize such activities, firms would have fewer motives to violate environmental rules. Besides, to examine the impacts of environmental violations, the essay three studied the current government environmental enforcement practices. They depended on the actual environmental violations, which had already caused damages to the environment and people's health. Based on supervised machine learning concept, I proposed a predictive model to predict high-risk pollution firms. The model could help governments to conduct environmental enforcement proactively and improve the efficiency and efficacy of the monitoring process compare to the current government practices. Also, the agencies and firms could make use of the model and facilitate an effective and efficient environmental monitoring process for preventive and/or remedial purposes.

Although the main event in our studies was associated with different environmental violations, our model and analysis can apply to other social responsibility issues (e.g., product safety and safety violations in the production process; Tang and Babich 2014). With growing concerns about ethical standards in supply chains, customers and investors are more aware of the risks of operational safety performance (Lo et al. 2014). A safety incident is likely to have a negative impact on a firm's performance both in the short and long run, and the government share and recognition in social responsibility are likely to have a similar mitigating effect. Finally, our findings are based on China market, but it is useful for those developing countries, which are seeking a balance between economic growth and environmental performance during or after their industrialization.

Appendices

Appendix A. Research Clusters in Each Research Domain (full references are provided in the references list).

Research Domain	Articles	
Green Supply Chain Management	Ates, 2012	Mitra, 2014
	Bergenwall, 2012	Pagell, 2007
	Blome, 2014	Pagell, 2009
	Bowen, 2001	Pagell, 2009
	Cantor, 2015	Pil, 2003
	Ding, 2016	Pullman, 2009
	Dubey, 2015	Reuter, 2010
	Esfahbodi, 2016	Rothenberg, 2001
	Fahimnia, 2015	Schaltenbrand, 2015
	Figge, 2012	Schrettle, 2014
	Galeazzo, 2014	Simpson, 2007
	Geffen, 2000	Simpson, 2010
	Gimenez, 2012	Simpson, 2012
	Golini, 2014	Tachizawa, 2015
	Graham, 2015	Touboulic, 2014
	Grekova, 2014	Trentin, 2015
	Hayami, 2015	Vachon, 2006
	Hollos, 2012	Vachon, 2007
	Hsu, 2013	Vachon, 2008
	King, 2001	Wong, 2012
	Klassen, 2001	Wu, 2012
	Klassen, 2003	Yang, 2010
	Kusi-Sarpong, 2016	Zhu, 2004
	Lee, 2008	Zhu, 2005
	Li, 2016	Zhu, 2007
	Longoni, 2014	Zhu, 2008
	Mena, 2014	Zhu, 2012
Environmental Management Practice	Chan, 2016	Narasimhan, 2012
	Curkovic, 2007	Narasimhan, 2015
	Delmas, 2001	Nath, 2016
	De Giovanni, 2012	Rao, 2004
	Hartmann, 2015	Rao,2005
	Hofer, 2012	Schoenherr, 2012
	Graham, 2016	Sroufe, 2003
	Jacobs, 2010	Thoumy, 2012

	Jacobs, 2016	Ubeda, 2011
	Kassinis, 2003	Wiengarten, 2012
	Klassen, 1996	Wong, 2013
	Klassen, 1999	Wu, 2011
	Lai, 2015	Yang, 2011
	Lucas, 2016	Yu, 2015
	Montabon, 2007	
Supplier Evaluation	Awasthi, 2010	Humphreys, 2006
	Azadnia, 2015	Ji, 2015
	Buyukozkan, 2012	Liou, 2016
	Chithambaranathan, 2015	Lu, 2007
	Dai, 2012	Mirhedayatian, 2014
	Genovese, 2013	
Green Extended Supply Chain	Corbett, 2001	Pang, 2015
	Drake, 2013	Subramanian, 2007
	Jacobs, 2012	Subramanian, 2009
	Konur, 2014	Subramanian, 2012

Appendix B. An Expanded Logistics Regression Model.

Our expanded model includes: market-related factors such as debt-to-equity ratio, price-to-book ratio, gross margin, and market share. Adding these factors decreased sample size by 4.2% (304 observations) and did not improve the figures in model fit (i.e., -2 log likelihood, Cox & Snell R Square, Nagelkerke R Square) significantly. So, we did not include them in our model.

Table B1. Estimated Coefficients (z-Statistics in Parentheses) from Logistics Regressions of 7002 firm-year observations from the period of 2004-2012

Independent variables	Training set	
Intercept	-9.58	(52.83)**
Industry	-	
Incident history	2.34	(302.17)**
Firm age	0.02	(2.61)
Revenue	0.31	(13.08)**
Total assets	0.10	(1.17)
Industry-adjusted ROA	-1.22	(2.06)
Percentage of government ownership	0.36	(4.16)*
Debt ratio	0.07	(0.07)
Financial leverage	0.00	(0.62)
Price-to-book ratio	0.00	(0.06)
Debt-to-equity ratio	0.00	(0.06)
Gross Margin	-0.11	(0.06)
Market Share	-0.01	(0.12)
n	7,002	
-2 Log likelihood	4,414.36	
Cox & Snell R Square	15.09%	
Nagelkerke R Square	27.54%	

Note. All tests are two-tailed: *$p < 0.05$; **$p < 0.01$; Industry is categorical dummy variable, and we did not show it in the table to save space.

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