ANTECEDENTS AND PERFORMANCE OUTCOMES OF GREEN INNOVATION ADOPTION: AN EMPIRICAL STUDY OF THE SHIPPING INDUSTRY

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Ph.D

The Hong Kong Polytechnic University

2018

The Hong Kong Polytechnic University

Department of Logistics and Maritime Studies

Antecedents and Performance Outcomes of Green Innovation Adoption: An Empirical Study of the Shipping Industry

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A thesis submitted in partial fulfillment of the requirements for

the degree of Doctor of Philosophy

August 2017

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Certificate of Originality

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NG Man Kit Michael

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To my Lord and Saviour, Jesus Christ

To my parents, Marion and Norman

Abstract

The shipping industry has been placing increasing emphasis on greening issues. Over the past decade, shipping researchers have devoted considerable research efforts into exploring diverse topics relevant to green shipping. The concept of green innovation (GI), however, has been largely ignored. As a result, our understanding of the conceptualization, measurement, and performance implications of GI adoption for shipping remains particularly limited. Therefore, this study aims to: (1) develop a theoretical framework to identify the different dimensions of GI adoption, (2) develop and validate measurement instruments of GI, (3) identify the antecedents of GI and examine their impacts on GI adoption, and (4) investigate the implications on organizational performance with GI adoption.

To achieve these research objectives, this study uses a mixed-method research approach that comprises a qualitative study (i.e., exploratory case study) and two quantitative studies (i.e., a participatory survey study and a secondary data analysis). First, an exploratory case study of a Danish mega-carrier, Maersk Line, is conducted to evaluate the adoption and features of GI in the shipping industry. Second, a participatory survey study is conducted. A sample of 226 shipping firms that are operating in the Pearl River Delta (PRD) region of China is surveyed to validate the measurements of GI and examine the relationships among the antecedents, GI adoption, and organizational performance outcomes. Third, to improve the generalizability of the research findings and for triangulation purposes, a secondary data analysis is conducted with data on the financial position of 129 shipping firms listed on the major stock markets worldwide.

The results reveal that first, GI consists of four sub-dimensions; namely, green management, service, process, and technological innovations. Second, stakeholder pressures (i.e., regulatory, competitive, and customer pressures) and environmental governance mechanisms (i.e., contractual, relational, and organizational governance) are positively related to the GI adoption of shipping firms. Third, GI and its sub-dimensions are positively related to the organizational performance of shipping firms (i.e., environmental, innovation, and economic performances). Lastly, environmental uncertainty moderated the positive impact of GI on organizational performance.

By systematically and empirically examining the relationships among the antecedents, GI adoption, and organizational performance outcomes, this study provides

a comprehensive picture of GI adoption. The findings of this study are expected to advance knowledge on environmental and innovation management and bridge the significant gap between green shipping and GI research. Particularly, this study not only provides practical knowledge on factors that might contribute to the successful adoption of GI, but also sheds new light on the crucial role of GI adoption as a viable means of improving the competitiveness and organizational performance of shipping firms.

Publications arising from this dissertation

Ng, M., Lun, Y.H.V., Lai, K.H., Cheng, T.C.E., "Green Innovation and Firm Performance: A Case Study of the Liner Shipping Industry"
Working paper.

Ng, M., Lun, Y.H.V., Lai, K.H., Cheng, T.C.E., "The Contingent Role of Environmental Uncertainty on Green Innovation and Organizational Performance"
Working paper.

Ng, M., Lun, Y.H.V., Lai, K.H., Cheng, T.C.E., "Is Environmental Governance an Antecedent in the Green Innovation Adoption? An Empirical Study"
Working paper.

Acknowledgements

I am thankful to my Lord for giving me the gift and love of learning. Without His abundant grace and blessings, this dream would have never come true.

I would like to thank my supervisors Dr. Venus Lun, Prof. Mike Lai, and Prof. Edwin Cheng for their advice, inspiration and intellectual guidance and support in the past few years. It has been a privilege to work with them and I have learned very much from them professionally. I am particularly grateful to Dr. Venus Lun, who was not just my supervisor, but more importantly, my mentor during my years in the doctoral programme and also when I was her research assistant.

Lastly, I would like to sincerely thank my parents Marion and Norman, and my sister Pollyanna for their understanding, love, and support. The positive values and beliefs of my parents have made me what I am today. I developed my love for learning and my drive for achievement because of them. I am deeply grateful for all that they have given me, especially their love. I am deeply indebted to my family for their many sacrifices during the past few years.

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AVE	Average variance extracted
CCWG	Clean Cargo Working Group
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CITC	Corrected-item-total-correlation
CMV	Common method variance
CO_2	Carbon dioxide
COP	Competitive pressure
CR	Composite reliability
CRS	Constant return to scale
CTM	Contractual governance
CUP	Customer pressure
DEA	Data envelopment analysis
DMU	Decision-making unit
ECP	Economic performance
EEDI	Energy Efficiency Design Index
EFA	Exploratory factor analysis
ENP	Environmental performance
EPEA	Environmental Protection Encouragement Agency
EU	Environmental uncertainty
FFE	Forty-foot equivalent unit
GHG	Greenhouse gas
GMI	Green management innovation
GPI	Green process innovation
GRI	Global Reporting Initiative
GSI	Green service innovation
GTI	Green technological innovation
IFI	Incremental fit index
IMO	International Maritime Organization
INP	Innovation performance
KPIs	Key performance indicators
MARPOL	International Convention for the Prevention of Pollution from Ships
NO_x	Nitrogen oxide
NRBV	Natural resource-based view of the firm
OP	Organizational performance
ORM	Organizational governance
PM	Particulate matter
PRD	Pearl River Delta
RBV	Resource-based view of the firm
RLM	Relational governance
RMSEA	Root mean square error of approximation
RPI	Regulatory pressure
SEEMP	Ship Energy Efficiency Management Plan
SEM	Structural equation modelling
SO_x	Sulfur oxide
SRMR	Standardized root mean square residual
TEU	Twenty-foot equivalent unit
UNCTAD	United Nations Conference on Trade and Development
VOCs	Volatile organic compounds
WSC	World Shipping Council

1. Introduction

1.1. Motivation for this study

1.1.1. Shipping and the environment

Global warming and climate change have been increasingly issues of public concern since their emergence a couple of decades ago. As a globalized industry, shipping plays a vital role in facilitating international trade through the transportation of cargo at a low cost and in a timely manner (Lun et al., 2016). Shipping (i.e., the movement of cargo by maritime transport) handles as much as 90% of the international trade by cargo volume but accounts for only 10% of the emissions of the transport sector (Crist, 2009). However, according to the United Nations Conference on Trade and Development (UNCTAD), the international seaborne trade volume more than tripled from 2,605 million tons to 10,047 million tons from 1970 to 2015. Particularly, the international container trade volume has drastically increased by about 16 times from 102 million tons to 1,687 million tons (United Nations Conference on Trade and Development, 2016). Given the significant jump in seaborne trade volume, the total greenhouse gas (GHG) emissions from the shipping industry are expected to exacerbate in the years ahead. If business continues as usual, maritime carbon dioxide (CO_2) emissions are projected to increase by 50% to 250% over the period of 2012 to 2050 (Smith et al., 2014). Containerships are generally considered as the largest maritime CO_2 emitters (Psaraftis and Kontovas, 2010). Moreover, stringent regulations that govern GHG emissions, maritime pollution (e.g., ballast water discharge, oil spills, etc.), and ship design have prodded the shipping industry into finding ways to enhance its eco-efficiency and environmental performance. Table 1 summarizes the environmental problems caused by shipping operations, their causes and impacts, relevant environmental standards and regulations for addressing the problem, and the initiatives adopted by shipping firms to mitigate the problem. As shown in Table 1, the major environmental problems caused by shipping operations include GHG (e.g., CO_2, nitrogen oxide (NO_x), sulphur oxide (SO_x), and particulate matter (PM)) emissions; transfer of invasive species caused by ballast water discharge of vessels, release of biocides and organotin compounds from anti-fouling paint applied on ship hulls, oil spills, discharge of black and gray water, etc. To facilitate compliance with environmental regulations and improve eco-efficiency, shipping firms have implemented diverse technologies and environmental management systems on their vessels (e.g., green engines, and waste-heat recovery, ballast water treatment, and sewage treatment systems, etc.). In addition, stringent environmental regulations motivate shipping firms to routinely advance their current technologies, operating processes, or even vessel design, so as to meet the latest environmental standards. These regulations offer shipping firms tremendous potential for the introduction of new or significantly refined shipping processes, services, and technologies, or in other words, for "green innovation (GI)" adoption to mitigate the adverse environmental impacts of shipping operations.

Table 1. Environmental issues caused by shipping industry

Pollution Problem	Cause(s)	Environmental Impacts	Regulations	Initiatives Adopted by Shipping Industry
GHG emissions (e.g., CO_2, NO_x, SO_x, and PM)	CO_2 is produced as ships use petroleum-based fuels to power both main and auxiliary engines. NOx, SOx, and PM are by-products of combustion associated with engines used and heavily influenced by the sulphur content of fuel used.	Anthropogenic GHG emissions are directly linked to climate change and global warming (Corbett and Winebrake, 2009), creating radiative forcing, which changes the energy balance of the earth and leads to a variety of climatic problems (Intergovernmental Panel on Climate Change, 2007).	International standards that limit NOx, SOx, and PM emissions from ships are established and enforced through the MARPOL Annex VI, International Convention for the Prevention of Pollution from Ships. A revised Annex VI with tightened emissions limits was adopted in October 2008 which entered into force in July 2010. In addition, the International Maritime Organization (IMO) adopted a mandatory technical and operational energy efficiency measure, the Energy Efficiency Design Index (EEDI), applicable to newly-built ships. Mandatory measures (EEDI/ Ship Energy Efficiency Management Plan (SEEMP)) entered into force in January 2013.	Shipping firms have adopted various initiatives to improve the eco-efficiency of vessels and reduce GHG emissions, such as introducing larger and energy-efficient vessels, implementing slow steaming and retrofitting existing vessels to lower emissions and transportation costs. According to the World Shipping Council (WSC), the majority of new ships built by their member companies since 2013 are approximately 30-40% more carbon efficient than the ships that they replaced.
Transfer of invasive species	Transferred through ballast water discharge	Ballast water transports invasive organisms into new ecosystems under favorable conditions (Carlton, 1985; Williams et al., 1988). Invasive aquatic species can result in ecosystem changes and disruptions of ecosystem services (Vilà et al., 2010). The introduction of invasive species into new marine environments has been identified as one of the greatest threats to the ocean, and a key factor in 54% of all known species extinction as documented in the Red List database maintained by the International Union for Conservation of Nature (Clavero and Garcia-Berthou, 2005).	The ballast water discharge of ships is regulated through the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). It adopted by the IMO in February 2004 and enacted in September 2017. Two different protective ballast water management standards are provided in the BWM Convention for the shipping industry to follow. 1. Ballast Water Exchange Standard (Regulation D-1) which requires ships to exchange a minimum volume of 95% ballast water at least 50 nautical miles from the nearest shore and in waters of 200 m depth or more. 2. Ballast Water Performance Standard (Regulation D-2), which requires that discharged ballast water contains viable organisms only in numbers below specified limits (Werschkun et al., 2014).	Shipping firms have installed different ballast water treatment technologies on their ships, however, according to Werschkun et al. (2014), none of these technologies are capable of achieving the treatment level required by the BWM Convention D-2 standard without modification. Therefore, it provides an important driving force for the development of ballast water treatment technology (David and Gollasch, 2008).

Cont. Table 1. Environmental issues caused by shipping industry

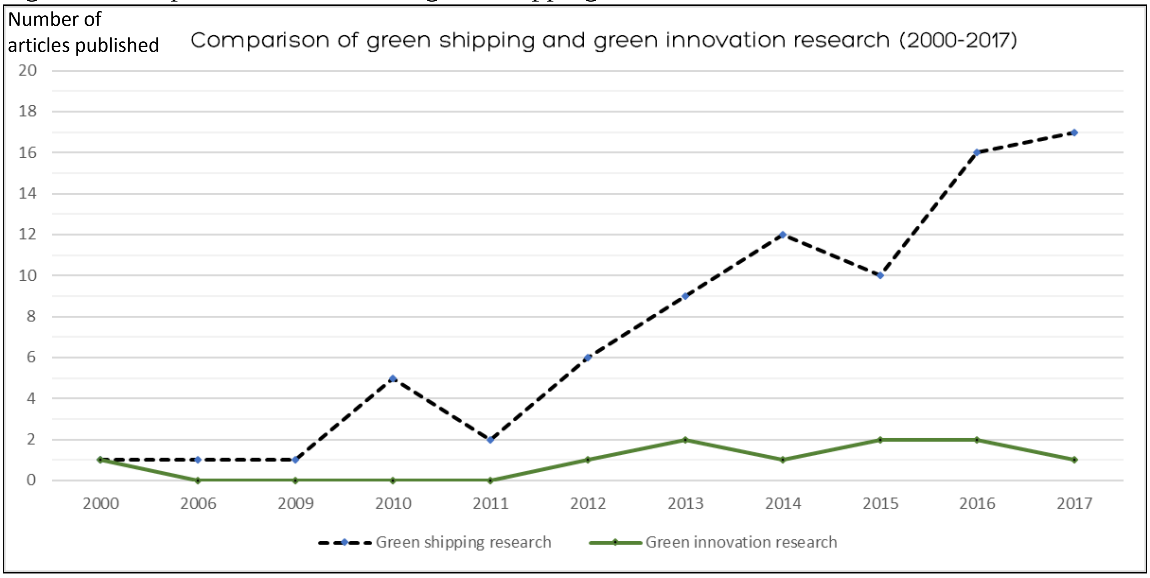
Pollution Problem	Cause(s)	Environmental Impacts	Regulations	Initiatives Adopted by Shipping Industry
Release of biocides and organotin compounds	Toxic chemicals and organotin compounds (e.g., tributyltin (TBT)) are released through the use of antifouling paint on ship hulls to prevent the attachment of marine organisms to the hulls (Gipperth, 2009).	Organotin compounds are highly toxic to various aquatic organisms. They affect marine organisms such as bacteria, shellfish, and algae, which cling to the ship hulls. TBT is also found to bioaccumulate in fish and other sea mammals, causing sterility and even death (Strand and Jacobsen, 2005). They may also have harmful health effects on shipyard workers when washing, scraping, and repainting ship hulls (Wilson et al., 2004).	The International Convention for the Control of Harmful Anti-Fouling Systems on Ships (AFS Treaty) which was enacted in 2008, prohibits the use of harmful organotins (e.g., TBT) in anti-fouling marine paints and the potential future use of other harmful substances in anti-fouling systems.	To facilitate regulatory compliance and marine environment protection, many shipping firms (e.g., Hapag-Lloyd, MSC, and Maersk Line) apply TBT free biocidal antifouling paint and biocide free coatings to their ships.
Oil Spills	Can be accidental or deliberate. Ships may illegally discharge bilge oil (a mixture of water, oil, lubricants, and other pollutants) before entering a port; or due to accidents and negligence (e.g., collisions, fires, groundings, environmental conditions, technical malfunctions, etc.) (Hassler, 2016; Troisi et al., 2016).	Direct and immediate effects of oil spills include suffering and death of seabirds and mammals, loss of habitat (e.g., wetlands), loss of economic activities (e.g., tourism, commercial fishing), etc. (Hassler, 2016).	Oil pollution is regulated through MARPOL Annex I for the prevention of pollution by oil, and the International Convention on Oil Pollution, Preparedness, Response, and Cooperation (OPRC) and its protocol that covers pollution by hazardous and noxious substances (HPRC).	To comply with the requirements of MARPOL Annex I and mitigate oil pollution problems, shipping firms have improved the design of new ships that have an aggregate oil fuel capacity of 600 cubic meters or more to locate the fuel tanks inside the double hull for preventing oil spills in case of collision or grounding.
Black and gray water discharges	Black and gray water is generated and discharged in the course of ship operations	Black and gray water consist of non-sewage wastewater, including drainage from showers, laundry, galleys, and washbasins. It contains pollutants such as fecal coliform, food waste, oil and grease, detergent, pesticides, heavy metals, etc. (Environmental Protection Agency, 1999) These ingredients contain inorganic compounds and harmful substances such as nitrogen and phosphorous, which deplete the dissolved oxygen in water necessary to support marine ecology.	Discharge of black and gray water is regulated through MARPOL Annex IV, International Convention for the Prevention of Pollution from Ships. Discharge of black water is prohibited except for specific conditions stipulated under the Annex. In addition to MARPOL Annex IV, some jurisdictions also regulate sewage discharge. For example, in the US, specific waters are designated as no discharge zones, where black water discharge is prohibited.	To comply with the requirements of MARPOL Annex IV, different sewage treatment systems have been developed and installed on ships. For example, some of the containerships of Maersk Line are equipped with three-phase biological sewage treatment systems to ensure the effective treatment of sewage prior to its discharge.

Sources: International Maritime Organization (IMO), World Shipping Council (WSC), World Wildlife Fund (WWF)

1.1.2. Need for GI research

To address the adverse environmental impacts of shipping operations and improve their eco- and operating efficiencies, the shipping industry has been placing increasing emphasis on greening issues. Green shipping has thus received considerable attention from researchers and policy makers. Green shipping research identifies various environmental issues caused by maritime transport and evaluates environmental policies and shipping practices that seek to cope with particular environmental issues such as global warming (Ng et al., 2013). To identify and demonstrate the current lack of GI research in the shipping industry, a cursory search is conducted. Green shipping and GI research papers are identified from the *Web of Knowledge* database provided by Thomson Reuters between 2000 and 2017. The search is refined by focusing on topics of (‘green’ OR ‘environmental management’) AND (‘shipping’ OR ‘maritime’ OR ‘seaport’) for green shipping research, and (‘green innovation’ OR ‘environmental innovation’ OR ‘eco-innovation’) AND (‘shipping’ OR ‘maritime’ OR ‘seaport’) for GI research under the categories of ‘transportation’ and ‘management’. From 2000 to 2017, 80 green shipping articles have been published. However, only 10 GI articles that focus on the shipping industry are published in the same period. A comparison of the number of green shipping and GI research works from 2000 to 2017 is shown in Figure 1.

Figure 1. Comparison of number of green shipping and GI research works



1.1.2.1. Review of green shipping research

The extant research on green shipping has largely focused on the discussion of four related topics of green shipping, including the environmental impacts of shipping, determinants of green shipping operations, green technologies and practices, and performance impacts of green shipping.

To examine the environmental impacts of shipping operations, Lee et al. (2010) developed a model to calculate the external costs of domestic container transportation in Taiwan, and suggested that the external costs of short sea shipping are significantly lower than those of truck transport and is a viable alternative to current domestic container transportation. A study by Acciaro and McKinnon (2015) reported the results of an analysis of a fuel consumption database collected by the Clean Cargo Working Group (CCWG) which comprised 2,300 container ship voyages. They examined the effect of technical and operational parameters on the fuel consumption and emission of these vessels and revealed significant differences among carriers in terms of energy efficiency and carbon intensity.

Regarding the determinants of green shipping operations, Adland et al. (2017) investigated whether the introduction of regional environmental regulations (for the North Sea which is designated as an Emission Control Area (ECA)) can impact the speed of vessels. They found no support for the contention that the introduction of stricter regulation on sulphur oxide emission inside the ECA affects vessel speeds in any economic sense. The vessel speeds are not determined by fuel prices or freight rates but rather by voyage-specific variables such as ports of call. Lun et al. (2015) proposed and empirically validated an integrated model that examined how various environmental governance mechanisms are enacted by shipping firms and their impacts on the environmental performance of these shipping firms. The results showed that environmental governance mechanisms are positively related to the environmental performance of shipping firms, thus suggesting that environmental governance mechanisms are a viable means of mitigating environmental risk by adopting green operations and reducing environmental damage during shipping activities.

Some studies on green shipping have discussed the technologies and practices adopted by shipping firms. For example, Schinas and Stefanakos (2014) discussed the limitations of the financial assessment of technologies that assist with the compliance of the regulations on sulphur emissions in the MARPOL Annex VI. Lam and Notteboom (2014) investigated the port management tools that port/public authorities use to enforce or encourage green port development. It was found that ports mainly apply standard environmental regulations for green port development. Lai et al. (2013) developed and tested a measurement scale on six dimensions of green shipping to evaluate the adoption of green shipping practices in the shipping industry. Lun et al. (2014) examined the relationships between green shipping practices and greening capability of shipping firms. They found that shipping firms are relatively weak in practicing shipper cooperation and designing shipping equipment.

Lastly, the majority of green shipping research has studied the performance implications of green shipping. Yang et al. (2013) examined the relationships among internal and external green integration, green performance, and firm competitiveness in the container shipping context. The results verified that internal and external green collaborations have positive impacts on green performance. Lirn et al. (2014) investigated green shipping management capability and its impact on firm performance. They found that greener policies are positively related to greener ships and suppliers, and greener ships and suppliers are positively related to financial performance through environmental performance. Lun (2011) examined the elements of green management practices and their influences on firm performance, and showed that three elements of green management practices, which include cooperation with supply chain partners, environmentally friendly operation, and internal management support, are positively related to the performance of container terminals. Cheon et al. (2017) utilized insights from the resource-based view of the firms, examining the relationship between environmental and economic performances of the top 10 U.S. seaports. They suggested that the environmental performance of a port is positively related to its economic performance. The capabilities of ports to carry out strategic capital investment, collaborative inter-organizational processes, and performance monitoring are essential for achieving environmental and economic goals.

Based on the brief review of the literature on green shipping above, it is evident that green shipping has received tremendous attention from researchers. The topics that involve different determinants, practices, and performance outcomes have been largely explored, and thus the topic of green shipping has started to mature. In contrast, as shown in Figure 1, there are only 10 GI articles which focus on the shipping industry that were published from 2000 to 2017, and only six of those are specifically relevant to GI and the shipping industry. Table 2 shows the details of six GI articles that focus on the shipping industry. The results of the cursory search indicated that the concept of GI has received little conceptual and empirical attention from shipping researchers. As a result, the current understanding of the conceptualization, measurement, and performance implications of GI adoption in shipping remains extremely limited. Hence, it is timely to conduct an empirical study that systematically investigates the antecedents, adoption, and organizational performance (OP) outcomes of GI in the shipping context.

Table 2. GI research that focuses on shipping industry (2000 - 2017)

Title	Author(s)	Journal	Research objectives and findings
Atmospheric Emissions from Shipping: The Need for Regulation and Approaches to Compliance	Cullinane and Cullinane (2013)	*Transport Reviews*	To review the evidence on atmospheric emissions of shipping, proposing that the objective of profiting has prompted the pursuit of greater fuel efficiency within the sector, but that reliance on market forces alone is insufficient to deliver on the environmental imperative. Findings: The shipping industry has been slow to improve its environmental credentials; a combination of regulation and technological innovation provides significant potential to reduce its environmental impacts.
Environmental innovation and the role of stakeholder collaboration in West Coast port gateways	Hall et al. (2013)	*Research in Transportation Economics*	To explore the role of stakeholder collaboration in the adoption of innovations as part of the environmental and sustainability agenda of port gateways. Findings: Successful innovation requires conscious involvement and collaboration of stakeholders.
Environmental sustainability in seaports a framework for successful innovation	Acciaro et al. (2014)	*Maritime Policy & Management*	To investigate successful innovations that improve the environmental sustainability of seaports. Findings: The success of innovations requires a dynamic fit with the demands of port actors and the port institutional environment.
Sustainable shipping green innovation for the marine industry	Cogliolo (2015)	*Rendiconti Lincei - Scienze Fisiche e Naturali*	To discuss the significant aspects of the environmental regulations in the maritime field, such as requirements on NOx, SOx, and CO_2 in MARPOL Annex VI; requirements of the Ballast Water Management Convention; and the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, etc. Findings: The international measures to protect the marine environment will affect the way to design and operate new and existing ships in the marine industry. Technological innovation is necessary to cope with the international environmental requirements in a sustainable way.
Innovation in product and services in the shipping retrofit industry: a case study of ballast water treatment systems	Rivas-Hermann et al. (2015)	*Journal of Cleaner Production*	To develop a conceptual framework that examines how a specific type of business model (product-service systems) could be applied to the context of the maritime industry. Findings: Port-based systems have the highest potential for eco-efficient value creation and a product-service system can be designed for port-based systems.
Eco-Innovation Drivers in Value-Creating Networks: A Case Study of Ship Retrofitting Services	Hermann and Wigger (2017)	*Sustainability*	To conduct a case study to discuss how eco-innovation drivers, such as regulation, market pull, and technology, interact and affect processes in value-creating networks in the maritime industry. Findings: Value-creating network is a platform for the development of more radical eco-innovations if actors in the network are able to align their value creation and capture objectives.

1.2. Issues arising from the extant research

There have been numerous research work on innovation and environmental management that have attempted to discuss the different aspects of GI, including the determinants (e.g., Horbach, 2008; Horbach et al., 2012; Berrone et al., 2013; Cuerva et al., 2013; Triguero et al., 2013); success factors (e.g., Wong, 2012; Forsman et al., 2013); measurements (Cheng and Shiu, 2012); performance impacts (e.g., Theyel, 2000; Cheng et al., 2014a; Doran and Ryan, 2016); its relationship with competitive advantage (e.g., Chen et al., 2006; Chang, 2011; Chiou et al., 2011), etc. However, to the best of my knowledge, none of the studies have systematically examined the antecedents, dimensions of GI, and OP implications in the shipping context. Specifically, a number of issues are found in these extant studies on GI such as the lack of an integral framework and consensual measurements for GI, under-researched antecedents, and inconsistent results on the performance outcomes of GI adoption.

1.2.1. Lack of measurements and integral framework for GI

Although the extant research has considered different aspects of GI adoption, the understanding of the components and features of GI is limited (Rehfeld et al., 2007; Costantini and Mazzanti, 2012; Kesidou and Demirel, 2012), and thus has prevented the development of a widely applicable framework that would characterize and categorize the GI activities of firms (Tseng et al., 2013). Moreover, the majority of empirical studies mainly use a single dimension to measure GI and have failed to discriminate between its different dimensions (Qi et al., 2013). It is not clear whether different variables may have a different explanatory role depending on the dimension of the GI adopted (Naranjo-Gil, 2009). Therefore, to understand the interrelationship between the dimensions of GI, studies on GI should approach GI with a holistic view (Hallstedt et al., 2013; Lozano, 2015), and based on an integral framework (Henriques and Sadorsky, 2007; Frondel et al., 2008). Furthermore, previous research has repeatedly highlighted the need for instruments to measure the implementation of GI (e.g., Arundel and Kemp, 2009; Morgan et al., 2009; Cheng and Shiu, 2012; Tseng et al., 2013). Developing and adapting measurement items in the shipping context are thus particularly important in this emerging topic of study. Accordingly, the issues of the extant research have motivated this study to identify and examine the different dimensions of GI, their features, and measurements, and integrate them into an integral framework to examine the implications for OP.

1.2.2. Under-researched antecedents

Environmental governance mechanisms have been identified as one of the important antecedents of firm innovation (Wang et al., 2011). These mechanisms involve contractual, relational, and organizational governance, which all play an essential role in facilitating the adoption of green shipping operations (Lun et al., 2015). However, the impacts of contractual, relational, organizational governance on GI adoption are still under-investigated. Particularly, there is paucity of research on the impacts of relational governance on inter-firm innovation (Cheng et al., 2014b), and little empirical evidence has been found that shows how the effectiveness of contractual governance affects firm innovation (Wang et al., 2011) and how environmental governance could enhance environmental performance in shipping operations (Lun et al., 2015). Moreover, the literature has discussed the interaction between relational and contractual governance mechanisms (e.g. Liu et al., 2009; Li et al., 2010; Cao and Lumineau, 2015; Huo et al., 2016), however, the interaction between these governance mechanisms is still a subject of controversy (Wang et al., 2011).

Furthermore, while there is no lack of research work on how stakeholder pressures impact the environmental decisions of firms (e.g., Sarkis et al., 2010; Garcés-Ayerbe et al., 2012; Ferrón-Vílchez et al., 2017), nevertheless its impacts on GI adoption is still under-researched. Berrone et al. (2013) highlighted a particular issue that has not been addressed in the extant literature. While firms similarly perceive pressure from stakeholders, why do some firms engage in more GI than others? In that case, what are the conditions that facilitate firms to pursue GI? Similarly, inconclusive empirical results on the influence of regulatory pressure on GI adoption have also been found in prior studies (e.g., Kammerer, 2009). Accordingly, these unresolved issues have motivated this study to examine stakeholder pressures and environmental governance mechanisms as antecedents of GI adoption, investigating how and the extent that they can drive and direct a shipping firm to adopt GI.

1.2.3. Inconsistent results on performance outcomes of GI adoption

Previous research work on GI has examined the different dimensions of GI and the implications on different performances. For example, examining green process and technological innovations on operational performance (Kemp and Horbach, 2007), and GI on environmental performance (e.g., Carrión-Flores and Innes, 2010; Chiou et al., 2011), financial performance (e.g., Rennings and Zwick, 2012; Dong et al., 2014; Li, 2014), and innovation performance (e.g., Fraj-Andrés et al., 2009). However, no consensus has been found on the relationships among GI, environmental performance, and economic performance or competitiveness (Boons and Wagner, 2009; Ambec et al., 2013; Forsman, 2013). Moreover, there are calls for researchers to use different performance criteria to reflect the multidimensionality of GI (e.g., Chiou et al., 2011; Tseng et al., 2013; Wu, 2013; Cheng et al., 2014a). Given that each dimension of GI has its own attributes and contribution to firm performance (Damanpour et al., 2009), research efforts that specifically focus on the individual dimensions of GI are required (Cheng and Shiu, 2012). Accordingly, these issues have motivated this study to advance the extant literature by empirically examining and elucidating the individual dimensions of GI and their implications on OP in terms of environmental, innovation, and economic impacts, in order to provide a comprehensive picture of the relationship between adoption of GI and firm performance.

1.2.4. Neglect of influence of environmental uncertainty

Environmental uncertainties are the result of inaccurately predicting the effects of environmental changes on operational efficiency (Duncan, 1972), which include demand, supply, and technology (Paulraj and Chen, 2007). In the literature on innovation (e.g., Li and Atuahene-Gima, 2001; Jansen et al., 2006) and operations management (e.g., Flynn et al., 2010; Wong et al., 2011), environmental uncertainty has been used as a moderator to influence the relationship between innovative strategies and performance outcomes of firms. However, given the inherent uncertainty of innovation (von Krogh et al., 2000), previous studies on GI have not recognized the influence of environmental uncertainty (e.g., Verghese and Lewis, 2007; Nidumolu et al., 2009; Wu, 2013). Qi et al. (2013) stressed that there is a lack of research that explores how the business environment influences GI adoption and examines how environmental conditions affect the effectiveness of innovative strategies that enhance innovation performance, and consequently the financial performance of firms (Oke et al., 2012). Accordingly, by focusing on the shipping industry, this study is motivated by these issues to examine how the relationships between GI and OP is moderated by environmental uncertainty.

1.3. Research focus

This study specifically focuses on the context of the shipping industry. To establish a boundary for identifying GI in the shipping industry, in light of Lun et al.'s (2010) identification of shipping systems and relevant actors in the shipping business, this study focuses on: (1) GI adopted in shipping services which consists of a number of activities, such as the provision of infrastructure (e.g., ports or terminals), operation of ships, and management of organizational systems, and (2) GI adopted by actors in the shipping business such as terminal operators and transport operators (e.g., liner carriers and third-party intermediaries, such as intermodal transport operators, non-vessel-operating common carriers (NVOCC), and ship agents, etc.). Terminal operators are the companies that operate a seaport or terminal, and responsible for the handling, warehousing, or forwarding of cargoes inside the physical limits of a seaport or terminal (Ioannou, 2008). Liner carriers are the transport operators that provide liner shipping services by which cargo-carrying ships are operated between scheduled, advertised ports of loading and discharge on a regular basis (Lu et al., 2007). Third-party intermediaries are the companies that represent the shippers and are responsible for the transport management associated with the movement of cargoes. Intermodal transport operators are the companies that provide intermodal transport services for the door-to-door movement of cargoes. NVOCC are the transport operators that have no operating vessels but coordinate the provision of shipping services. Ship agents are the companies that work on behalf of the shipowners to engage in the routine business related to arrival, departure, and operations of ships (Lun et al., 2010). The sample in this study includes all the relevant key stakeholders of the shipping industry, such as terminal operators (e.g., port or terminal operators), transport operators (e.g., liner carriers, barge operators), and third-party intermediaries (e.g., freight forwarders, ship and freight agents). The research problems, questions, objectives, and framework that will be discussed in the following sections are primarily applicable to the shipping industry.

1.4. Research problems

Although there are many studies on innovation, and environmental and operations management that discuss various topics in relation to GI adoption, there is still a serious lack of empirical research that comprehensively examines GI adoption in the shipping industry. As discussed above, numerous issues have been identified in the extant research. First, due to the lack of a widely accepted framework for characterizing and conceptualizing the GI activities of firms, there is the need to develop an integrated framework that incorporates the multi-dimensionality of GI. Second, as there is lack of instruments for measuring the GI activities of shipping firms, it is therefore necessary to develop and adapt measurement items for the shipping context. Third, as the results of the antecedents and adoption of GI and OP outcomes of GI remain inconclusive and under-researched, conducting an in-depth examination of the relationships among these elements can provide valuable insights for shipping researchers and managers to gain a better understanding on the factors that may drive shipping firms to adopt GI and how shipping firms can achieve better OP through GI adoption. Fourth, due to the neglect of the influence of environmental uncertainty on the relationship between the innovative strategies and performance outcomes of firms in previous research, investigating the moderating role of environmental uncertainty would provide valuable theoretical and managerial implications on how shipping firms can achieve the most improvement in OP under different environmental situations. In the following section, research questions will be provided to address these problems, which contribute to the development of the research objectives.

1.5. Research questions

As discussed above, little or inconclusive information is available to shipping researchers to recognize the antecedents, dimensions, and implications of GI adoption. Therefore, a comprehensive examination of GI adoption is timely from the perspective of green shipping, which has produced the following research questions:

1) What is GI to shipping firms? What are the theoretical dimensions that underpin the GI adoption of shipping firms? How do shipping firms adopt GI?
2) What are the antecedent factors that compel shipping firms to adopt GI? What are the relationships among these driving factors? How do these factors impact the extent of GI adoption by shipping firms?
3) What are the relationships among the different dimensions of GI?
4) Does GI adoption instigate improved organizational performance of shipping firms?
5) Does environmental uncertainty have a moderating role in the relationship between GI and organizational performance?

1.6. Research objectives

By empirically testing the relationships among the antecedents and adoption of GI and performance outcomes of GI, this study will contribute to the current understanding of related issues with theoretical and practical relevance. A mixed-methods research approach that comprises qualitative (case studies) and quantitative (survey research and secondary data analysis) research are used to accomplish the following objectives:

1) To develop a theoretical framework that would identify the different dimensions and the role of shipping firms in GI adoption;
2) To develop, adapt, and validate measurement scales that would examine the extent of GI adoption by shipping firms;
3) To develop and test hypotheses on the relationship between the antecedents and the performance outcomes of GI adoption; and
4) To provide managerial insights into how GI adoption facilitates improvements in environmental, innovation, and economic performances.

1.7. Structure of the dissertation

This dissertation consists of nine chapters. The motivation for the study, research problems, questions, and objectives have been discussed already in Chapter 1. In Chapter 2, a literature review will be provided which explores and examines previous research work that is relevant to GI adoption. In Chapter 3, the conceptualization of GI, research framework and hypotheses will be discussed. The research design of this study will be discussed in Chapter 4. In Chapter 5, an exploratory case study and its data analysis will be presented. A quantitative survey study will be presented in Chapter 6 and the research method, development of the questionnaire, and relevant issues regarding data sampling and collection will be discussed. The data analysis and research findings from the quantitative survey study will be discussed in Chapter 7. To improve the generalizability of the research findings and for triangulation purposes, a post-hoc analysis with secondary data is conducted and will be presented in Chapter 8. Chapter 9 is a discussion of the research findings, theoretical, managerial and policy implications, and provides the concluding remarks.

2. Literature review

2.1. GI adoption

To address the environmental concerns of customers, the public, and the government, firms have developed and adopted various environmental strategies, programmes, and products (e.g. green technologies and eco-design) (Hoffmann, 2007; Zhu et al., 2008) in response. It can be seen that firms prioritize increasing their environmental awareness to meet the demands of their customers and suppliers for green products and services that do not adversely impact the environment.

In general, GI is defined as “new or modified processes, techniques, practices, systems, and products to avoid or reduce environmental harms” (Kemp and Arundel, 1998; Beise and Rennings, 2005; Rennings and Zwick, 2012). A summary of the different definitions of GI is provided in Table 3. In the field of environmental management, GI improves products or processes to save energy, prevent pollution, and recycle waste, and by designing green products and through corporate environmental management (Chen et al., 2006; Chen, 2008). GI also exemplifies the incorporation of the concept of environmental protection into product design and packaging to enhance their differentiation advantages (Hart, 1995; Shrivastava, 1995; Chen et al., 2006). Chen et al. (2006) noted that GI is the best means of improving environmental performance to meet environmental regulatory requirements. Firms that proactively adopt GI would lead to the use of a new business model which would generate business opportunities (Gladwin et al., 1995).

The impact of GI on the environmental performance of firms has been empirically analyzed in previous studies. Carrión-Flores and Innes (2010) argued that GI is a key driver for the reduction of pollutants and toxic emissions. By adopting GI, firms can simultaneously save on costs, improve productivity and product quality, meet government pollution targets and customer demands, as well as enhance their environmental performance (Carrión-Flores and Innes, 2010; Chiou et al., 2011). Huang and Wu (2010) suggested that factors such as environmental benchmarking, environmental commitment, research and development (R&D), and cross-functional integration can improve the environmental performance of firms.

Table 3. Summary of definitions of GI

Green Innovation is
- “The process of developing new products, processes or services which provide customer and business value but significantly decrease environmental impact” (Fussler and James, 1996).
- “New and modified processes, equipment, products, techniques, and management systems that avoid or reduce harmful environmental impacts” (Kemp and Arundel, 1998).
- “The creation of new market space, products, and services or processes driven by social, environmental or sustainability issues” (Little, 2005).
- “The implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations” (Organisation for Economic Co-operation and Development, 2005).
- “The creation of novel and competitively priced goods, processes, systems, services, and procedures designed to satisfy human needs and provide a better quality of life for all, with a life-cycle minimal use of natural resources (materials including energy, and surface area) per unit output, and a minimal release of toxic substances” (Europa INNOVA, 2006).
- “A process where sustainability considerations (environmental, social, and financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialization. This applies to products, services, and technologies, as well as new business and organization models” (Charter and Clark, 2007).
- “Any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy” (European Commission, 2007).
- “The production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)” (European Commission, 2008).
- “The production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives” (Kemp and Pearson, 2008).
- “Defined as innovations that consist of new or modified processes, practices, systems, and products which benefit the environment and so contribute to environmental sustainability” (Oltra and Saint Jean, 2009).

2.2. Antecedents of GI adoption

The extant literature on environmental management has identified various factors that drive the adoption of GI. Bossle et al. (2016) conducted an extensive and systematic review on the drivers for the adoption of GI and broadly categorized them into “external factors” and “internal factors”. External factors are mostly related to pressure from stakeholders and institutions, such as regulatory (coercive) pressure, competitive (mimetic) pressure, and customer (normative) pressure. Internal factors are mostly related to the specific organizational and environmental capabilities and strategies, such as the company strategies for the adoption of GI and the integration of innovation and sustainability. A summary of the selected relevant drivers for the adoption of GI is shown in Table 4. In this study, I identify the pressure from stakeholders to shipping firms and their environmental governance mechanisms as the external and internal drivers for the adoption of GI respectively.

2.2.1. External drivers – Stakeholder pressures

Stakeholder pressures are the most important factor that motivates the implementation of environmental practices of a firm (Buysse and Verbeke, 2003; Sharma and Henriques, 2005; González-Benito and González-Benito, 2006). According to the stakeholder theory, a stakeholder is "any group or individual who can affect or is affected by the achievement of an organization's objectives" (Freeman, 2010, p.32). They play a prominent role in the organizational environment and have been discussed in environmental research (Etzion, 2007). The extant studies have also identified and classified different types of green stakeholders, which may influence the decisions made by firm in their environmental strategy (Garcés-Ayerbe et al., 2012). Different researchers have proposed different types of classifications to group green stakeholders in accordance with their relationship with firms (e.g. Clarkson, 1995; Henriques and Sadorsky, 1999; Buysse and Verbeke, 2003; Murillo-Luna et al., 2008; Darnall et al., 2010). A summary of the classifications of green stakeholders is provided in Table 4.

Clarkson (1995) classified stakeholders into primary and secondary stakeholders. The former are those who are essential for the survival of a firm (e.g. customers, the government). The latter are those who influence or are influenced by the firm, but are not engaged in transactions with the firm and not essential for its survival (e.g. the media, special interest groups that are able to mobilize public opinion in favor of, or in opposition to the performance of a firm, for instance, non-governmental organizations (NGOs)). Henriques and Sadorsky (1999) proposed four different important pressure groups that compel firms to implement green practices namely, regulatory, organizational and community stakeholders, and the media. Buysse and Verbeke (2003) identified four broad groups of influential stakeholders, namely, regulators, internal and external primary stakeholders, and secondary stakeholders. Based on previous studies (Henriques and Sadorsky, 1999; Buysse and Verbeke, 2003), Murillo-Luna et al. (2008) proposed 14 types of stakeholders who are able to influence the environmental behaviors of a firm and classified them into five groups; namely, regulatory (e.g., environmental legislation); corporate government (e.g., managers, shareholders); internal economic (e.g., employees);

external economic (e.g., suppliers, competitors); and social external (e.g., the media, NGOs) stakeholders.

Table 4. Classifications of green stakeholders

Clarkson (1995)

Primary stakeholders	Secondary stakeholders
• Shareholders and investors • Employees • Customers • Suppliers • Public stakeholder groups: governments and communities	• The media • Special interest groups

Henriques and Sadorsky (1999)

Regulatory stakeholders	Organizational stakeholders	Community stakeholders	The media
• Governments • Trade associations • Informal networks • Competitors	• Customers • Suppliers • Employees • Shareholders	• Community groups • Environmental organizations • Potential lobbyists	• The media

Buysse and Verbeke (2003)

Regulators	Internal primary stakeholders	External primary stakeholders	Secondary stakeholders
• National (and regional) governments • Local public agencies	• Employees • Shareholders • Financial institutions	• Domestic customers • International customers • Domestic suppliers • International suppliers	• International rivals • Domestic rivals • International agreements • Environmental NGOs • The press

Murillo-Luna et al. (2008)

Regulatory stakeholders	Corporate government stakeholders	Internal economic stakeholders	External economic stakeholders	External social stakeholders
• Environmental legislation • Administration control	• Managers • Shareholders/owners	• Employees • Labour unions	• Suppliers • Financial institutions • Insurance companies • Competitors	• Media • Citizens/ communities • Ecologist organizations

Darnall et al. (2010)

Primary stakeholders	Secondary stakeholders
• Value chain participants • Internal stakeholders	• Societal stakeholders • Environmental regulators

Darnall et al. (2010) identified two groups of stakeholders based on their direct or indirect involvement in the economic transactions of a firm: primary and secondary stakeholders. The former are those who have a direct economic stake in the firm, such as value chain participants (e.g., buyers, suppliers, consumers) and internal stakeholders (e.g., managers, employees). The latter are those who are indirectly involved in the economic transactions of a firm, such as societal stakeholders and environmental regulators.

Although the extant stakeholder literature has proposed different classifications of green stakeholders, Buysse and Verbeke (2003) argued that they are not equally important in influencing the decision of firms on implementing green strategies. Regulatory, competitive and customer pressures are foremost among the driving factors of GI (Porter and van der Linde, 1995; Montalvo, 2008; Yalabik and Fairchild, 2011). In summarizing the extant stakeholder literature, I identified three main types of stakeholder pressure that compel firms to implement GI activities, namely, regulatory, competitive, and customer pressures.

2.2.1.1. Regulatory pressure

Environmental regulators are individuals within the government who have the authority to create environmental requirements and inspect the compliance of firms with those requirements (Carmin et al., 2003; Darnall et al., 2010). Environmental regulators are typically linked to coercive pressure (Sarkis et al., 2010) and play an important role in influencing firms to adopt green practices (Christmann, 2004; Backer, 2007; Etzion, 2007; Zhu and Sarkis, 2007; Darnall et al., 2009). Regulatory pressure arises from threats of penalties and fines for non-compliance, or requirements to publicly disclose information that concern the environmental impacts of a firm (Konar and Cohen, 1997; Testa and Iraldo, 2010). Firms must comply with environmental regulations or face legal action, penalties and fines by regulators. Failure to meet environmental regulations not only leads to penalties, fines, lawsuits or even the loss of an operating permit (Kassinis and Vafeas, 2006) but also damages corporate image and customer relations (Sarkis et al., 2010). As a result, firms may commit resources to control their environmental impacts in their operations in response to environmental regulations. The extant GI literature suggests that firms implement various types of GI (see for e.g., Rennings and Zwick, 2002; Brunnermeier and Cohen, 2003; Frondel et al., 2007; Triguero et al., 2013), green product innovations (see for e.g., Green et al., 1994; Cleff and Rennings, 1999; Rehfeld et al., 2007; Horbach, 2008), green process innovations (see for e.g., Darnall, 2006; Johnstone and Labonne, 2009), and green technologies (see for e.g., del Rio Gonzalez, 2005; Darnall et al., 2008; Darnall, 2009) to reduce environmental impacts, respond to environmental regulations, and avoid disciplinary action and higher taxes.

Moreover, government support can motivate firms to adopt GI. Firms gain government support when they align their business strategies with government expectations and regulations (Li and Atuahene-Gima 2001). Governments can increase the number of firms that adopt GI by providing incentives, such as subsidies, technical resources, or tax incentives for alternative energy technologies, bank financing at lower rates for green technologies, and lower insurance premiums for lower environmental risks (Aragón-Correa and Sharma, 2003; Rothenberg and Zyglidopoulos, 2007; Lin and Ho, 2011). Many researchers have reported a positive relationship between the influence of government support and the GI activities of various firms (e.g., Kemp and Anderson, 2004; Lee, 2008; Doran and Ryan, 2012).

2.2.1.2. Competitive pressure

The activities of competitors can affect the decision of a firm on the adoption of GI (Sharma, 2000). When competitors adopt new green practices, firms in the same industry will be under competitive pressure to re-evaluate their current status on environmental responsibility, so that they increase the level of adoption or refine their current practices (Christmann, 2004; Hsu et al., 2013). With increasing market competition, firms are more likely to be “greener” than their competitors by using new products and management methods, which could lead to an improved financial performance (Lin et al., 2014). Moreover, firms can use GI as a principal differentiation tool to enhance efficiency, product/service quality, and green image to achieve a competitive advantage (Bernauer et al., 2007; Hojnik and Ruzzier, 2016b). While successful firms in the industry gain benefits from adopting GI, other firms are under pressure or compelled to implement similar types of GI in order to maintain competitiveness and avoid a disadvantaged market position. The institutional theory (DiMaggio and Powell, 1983) describes mimetic isomorphism as firms that will follow the green actions of successful firms in the industry; those that are considered particularly innovative or legitimate in their business practices. The adoption of GI thus enables firms to achieve greater legitimacy and better strategic positioning. Furthermore, previous studies in GI have also indicated that competitive pressure is a determinant factor that can encourage the adoption of GI by firms (e.g., Cai and Zhou, 2014; Li, 2014; Hojnik and Ruzzier, 2016a).

2.2.1.3. Customer pressure

Customer demands and their increasing environmental expectations form the core normative pressure for firms to implement green initiatives (Liu et al., 2012; Hsu et al., 2013; Zhu et al., 2013). Customer pressure is a key driver in the decision of firms to adopt innovations (Hashem and Tann, 2007) and can motivate them to incorporate green initiatives to improve their environmental performance (Kagan et al. 2003; Lee and Klassen, 2008). Customers may refuse to purchase products/services that damage the environment (Qi et al., 2010). Therefore, firms that choose not to conform to the green demands of their customers may suffer market share losses which lead to a declining financial performance (Gualandris and Kalchschmidt, 2014). Therefore, firms have implemented various green initiatives and innovations, such as environmental management systems (e.g., Melnyk et al., 2003; Delmas and Montiel, 2007), green technologies (e.g., Klassen and Whybark, 1999; Zailani et al., 2014), green packaging and green design initiatives (e.g., Zhu et al., 2013), and reverse logistics innovation (Huang and Yang, 2014) in response to the environmental demands of their customers. Moreover, the extant literature on GI has discussed the positive impacts of customer pressure on the adoption of GI (e.g., Qi et al., 2013; Li, 2014; Doran and Ryan, 2016; Huang et al., 2016).

2.2.2. Internal drivers – Environmental governance mechanisms

2.2.2.1. Contractual governance

Contractual mechanism (contractual governance), also known as “formal contract”, “explicit contract” or “contractual safeguards” (Lui and Ngo, 2004; Li et al., 2010; Zhou and Poppo, 2010; Cao and Lumineau, 2015), refers to the use of a formalized, legally-binding agreement, or a contract to govern inter-organizational relationships. Contractual mechanism explicitly prescribes roles and obligations to be performed, determines the outcomes to be delivered, and specifies the procedures for resolving unforeseeable problems and monitoring and penalties for non-compliance (Poppo and Zenger, 2002; Argyres and Mayer, 2007). In this study, contractual mechanism is defined as the formal agreement between shipping firms and their business partners that incorporate each party's roles, responsibilities, and obligations in the development of GI. Contracting parties (i.e. shipping firms and their business partners) can use a contract to formalize the agreed environmental specifications of GI, specify the roles, rights, and obligations of each party, specify the clauses (e.g., required input of assets and resources, access right of required technologies), and expected performance outcomes of GI.

The extant studies suggest that contracts can be exercised as a form of formal control which promotes cooperation and inhibits opportunistic behaviors (e.g., Carson et al., 2006; Li et al., 2010; Zhang and Zhou, 2013). While developing GI in shipping requires a significant commitment in terms of technology, expertise, financial input, etc., contracts are useful and important for shipping firms and their business partners for mitigating and controlling potential risks and uncertainties in the development of green shipping technologies and introduction of green shipping services/processes. According to MacNeil (1978), contracts represent a promise to perform particular actions in the future. They are a legally-bound, institutional framework in which the rights, duties, and responsibilities of the contracting parties are specified (Luo, 2002). Detailed descriptions of the development of GI activities or projects can be incorporated into contracts that the contracting parties need to comply.

For example, in a contract for the green shipping technology project (e.g., waste heat recovery systems or voyage optimization systems) between a shipping firm and its partner, a number of items could be documented in detail (e.g., "purpose of project", "liabilities of the parties", "technologies or material transfer obligations", "environmental or technical standards requirements", "ownership of technologies", "access rights to parties for completing the project", "termination clauses", "dispute resolution", "relevant intellectual property", "compliance with environmental regulations" etc.), so that both parties will have clear guidelines and a standardized reference source that is utilized for the effective and successful completion of the project. Therefore, contractual mechanism is important to promote inter-organizational innovations and its positive impacts on GI adoption has also been discussed in previous studies (e.g., Nielsen, 2010; Wang et al., 2011; de Reuver and Bouwman, 2012; Vázquez-Casielles et al., 2013).

However, the previous literature (e.g., Johnson and Andersson, 2016) also considered contracts to be one of the barriers to realizing energy efficiency in a shipping firm due to the fragmentation of responsibilities and actions that concern energy use in contracts between different firms. In the shipping context, the extant literature (e.g., Brown, 2001; Graus and Worrel, 2008; Vernon and Meier, 2012; Agnolucci et al., 2014) have discussed the problem of split incentives (also known as principal-agent or tenant-landlord problems) in the contractual relationship between two parties. Split incentives refer to the potential difficulties that arise when two parties engaged in a contract have different goals and different levels of information (International Energy Agency, 2007). Conflict occurs when the costs and benefits of energy efficiency are accrued to different parties (Howarth and Winslow, 1994). The split incentives problem is the most common barrier to the implementation of energy efficiency measures (Rehmatulla and Smith, 2015).

For example, split incentives occur in a time charter market because there are different types of charters as well as shared responsibility for fuel costs between shipowners and charterers. On the one hand, shipowners who invest in energy efficiency measures (e.g., fuel-saving technologies) are unable to recoup their investment unless they operate their own ships or have long-term contracts with charterers, as the charter rates and second-hand price of ships do not justify the economic benefits of energy efficiency measures (Faber et al., 2009, 2011). On the other hand, charterers are unlikely to pay a premium for energy efficiency due to the difficulties in verifying the actual amount of fuel saved that shipowners indicate in the time charter contract (Wang et al., 2010; Veenstra and Dalen, 2011). Alternatively, Johnson and Andersson (2016) suggested that the issue of energy efficiency can be more effectively addressed by applying best practices and standards (e.g., standard operating procedures in organizational governance) in shipping operations.

2.2.2.2. Relational governance

Relational mechanism, which is also known as "relational governance" (Jayaraman et al., 2013; Cao and Lumineau, 2015), refers to the extent in which inter-organizational exchanges are coordinated through social relations and shared norms (Poppo and Zenger, 2002; Poppo et al., 2008; Zhou and Xu, 2012). In this study, relational mechanism is defined as the shared values or mutual understandings among shipping operators concerning appropriate behavior and obligations that maintain and improves inter-organizational relationship over the course of GI development.

In contrast to contractual mechanism that relies on formal control, relational mechanism relies on informal structures to govern exchanges and self-enforcement of each exchange party to control opportunistic behaviors and mitigate adaptation problems (Lusch and Brown, 1996; Malhotra and Murnighan, 2002; Zhou et al., 2008). It features a bilateral relationship that creates a "mini-society with a vast array of norms" (MacNeil, 1978: p.901) to govern the behavior of the exchange parties. Earlier studies have identified a number of components that are involved in relational mechanism, such as relational norms, trust, personal ties, previous experience etc. (e.g. Zhou and Poppo, 2010). Amongst these components, relational norms and trust are two of the most accepted and discussed components of relational mechanism (Cao and Lumineau, 2015).

Relational norms are the shared expectations and values that concern the behaviors of each party in an exchange relationship (Heide and John, 1992; Cao and Lumineau, 2015). They specify permissible limits on the behavior of each party and guide reciprocal exchanges, which in turn provides safeguarding against the opportunistic behaviors of each party (Brown et al., 2000; Griffith and Myers, 2005). In earlier studies, three dimensions of relational norms that are widely emphasized and significant for safeguarding opportunism are *flexibility*, *information exchange*, and *solidarity* (Heide and John, 1992; Zhang et al., 2003; Lumineau and Henderson, 2012; Zhou and Xu, 2012).

- *Flexibility* is the bilateral expectation of willingness to make adjustments in response to circumstantial changes (Heide and John, 1992). The exchange relationship between a shipping firm and its business partner is subject to adjustment if the prescribed practice proves detrimental to one or both parties under changed circumstances (Zhang et al., 2003). If there is substantial flexibility, both parties can jointly search for solutions and adapt smoothly to unforeseen events (Poppo and Zenger, 2002).
- *Information exchange* is the expectation that business partners will proactively provide useful information to each other (Heide and John, 1992). It enables both firms and their partners to have symmetric information through communication, which not only facilitates effective decision making because of a better understanding of the mutual needs, goals, and requirements (Lado et al., 2008; Zhou and Xu, 2012), but also promotes harmonization of conflicting opinions and encourages honesty within an exchange relationship (Liu et al., 2009).
- *Solidarity* is the expectation that the exchange parties strive for mutual benefits and highly value the exchange relationship (Heide and John, 1992; Antia and Frazier 2001). It facilitates the creation of joint value rather than individual value claiming (Ghosh and John 1999; Rokkan et al., 2003). Developing solidarity norms enhances exchange efficiency because a shipping firm and its partner are expected to perform in ways that aim for mutual benefits, participate in joint problem solving, and coordinate actions toward shared objectives (Heide and John, 1992; Lumineau and Henderson, 2012).

While relational norms have been used as a feasible mechanism for governing and mitigating the opportunistic behavior of business partners, trust also has a similar effect. Trust refers to the reliance on, and confidence in the goodwill, reliability, and benevolence of the partners in an exchange relationship (Zaheer and Venkatraman, 1995; Zaheer et al., 1998). High levels of trust mean that a shipping firm and its business partner share mutual confidence in that each will perform according to common agreements and cooperate in good faith, rather than take non-cooperative actions and exploit the vulnerabilities of the other party (Dyer and Chu, 2003; Inkpen and Currall, 2004; Wang et al., 2008). A reduction in the perceived risk allows the establishment of a long-term and committed relationship between the partners (Yeung et al., 2009), which in turn facilitates mutual learning, joint problem solving and increased knowledge transfer (Lee and Cavusgil, 2006; Zhang and Zhou, 2013). Hence, relational norms and trust are recommended as useful mechanisms for governing exchange relationships and reducing opportunism by developing a congenial and socially constructed environment that promotes and nourishes exchanges (Liu et al., 2009).

In the shipping context, relational mechanism (i.e., relational norms and trust) can be developed through more involvement of suppliers. For example, a shipping firm can regularly provide trends and innovation workshops to its suppliers and customers. Such workshops create effective and informal channels for the firm and its business partners to communicate and understand the needs and goals of each other (e.g., environmental targets of shipping operations or technologies), share the latest environmental trends and information (e.g., industry best practices in green operations, latest trends in green shipping technologies, etc.) and jointly engage in generating ideas for new green shipping technologies, services, or processes (e.g., jointly implement R&D activities with suppliers/customers and research institutions). Both parties will consequently gain deeper insight into each other's needs, capabilities, and limitations, which in turn, promote a trusting relationship and shared expectations and objectives between the shipping firm and its partners for flexible adaptation to contingencies in shipping operations, as well as the effective development of green shipping innovations.

2.2.2.3. Organizational governance

Organization governance, which is also known as "organizational control", refers to "any process by which managers direct attention, motivate, and encourage organizational members to act in desired ways to meet the firm's objectives" (Cardinal, 2001). Previous studies have identified different forms of organizational control, such as behavior/process, input, output, and social (Cardinal, 2001; Chen et al., 2009; Kang et al., 2012; Kreutzer et al., 2014). Of these, behavior/process control has been frequently examined in the literature on GI (e.g., Turner and Makhija, 2006; Rijsdijk and van den Ende, 2011; Roy and Sivakumar, 2012; Schultz et al., 2013). Therefore, this study adopts the view that behavior/process control acts as a mechanism of organizational governance and seeks to understand its impact on the GI activities of shipping firms.

In this study, organizational governance is defined as the business process formulated within a shipping firm to direct the attention and motivation of organizational members to effectively develop and implement GI activities. It clearly specifies the appropriate behaviors and processes which organizational members must take into consideration so as to ensure that the organizational goals are achieved (Kirsch et al., 2002; Turner and Makhija, 2006). Firms may employ various control measures such as highly formalized standard operating procedures, rules and routines, rigorous approval processes and reporting protocols to govern organizational routines and goal-oriented activities (Cardinal et al., 2004; Chen et al., 2009). Employing such measures assist firms in developing a surveillance method that controls the operation processes, and formulate rules and norms for the behavior of the organizational members (Turner and Makhija, 2006). Moreover, organizational governance can be used to establish a solid frame of reference for the business partners to examine appropriate operations, which in turn facilitates the development of mutual understanding between the business partners in relational governance and improves the effectiveness of environmental governance as a whole (Lun et al., 2015). Similarly, it is suggested that organizational governance is an important means of achieving organizational goals by developing and maintaining inter-firm and intra-firm collaboration relationships (Kang et al., 2014).

In the shipping industry, shipping firms exercise organizational governance through the implementation of various measures to guide the adoption of green practices and improvement of environmental performance (Lun et al., 2015). For example, shipping firms employ environmental management systems (e.g., ISO14001) to identify environmental impacts for continuous improvement of their environmental performance. They also develop company policies to guide the adoption of green practices (e.g., reduce resources used to lower production costs, and recycle waste as a means of using environmental resources); and publish environmental reports to share their experiences of adopting green practices with business partners and customers. Therefore, by implementing organizational governance through formalized standard operating procedures, cross-departmental collaboration in GI activities, and environmental reporting, shipping managers can receive the most recent environmental/technological information and trends that assist with the timely identification of environmental problems, non-conformance, and improvement opportunities in shipping processes, which in turn enable them to provide sufficient guidance and support to their organizational members to continuously improve on the operational and environmental performances of shipping processes. Such continuous operational and environmental improvements are particularly important for generating incremental innovation (e.g. fleet optimization, strategic routing and scheduling) in green shipping processes and technologies.

2.3. Performance outcomes of GI adoption

The subject of performance has received increasing interest from both academics and practitioners (Panayides and Lun, 2009). Previous studies in the literature have reported a correlation between the adoption of innovation and OP (e.g., Lööf and Heshmati, 2006). In comparison with non-innovative firms, innovative firms have a competitive advantage when they develop innovative products and processes. However, there are two opposing views on the impact of adopting GI on OP. Li (2014) denied that there is a positive relationship between GI adoption and the financial performance of a firm due to the high initial capital required and lengthy payback period. Similarly, Dong et al., (2014) argued that environmental performance improvements achieved by GI (e.g., end-of-pipe innovation) may come at the cost of financial losses, which are caused by the high amounts of capital investment in pollution prevention and control technologies. The majority of the studies, however, tend to support a positive relationship between the adoption of GI and OP (e.g., Chen et al., 2006; Chiou et al., 2011; Lin et al., 2013). Chen et al. (2006) demonstrated that firms with a focus on GI enjoy first-mover advantage which improves their OP. GI adoption not only positively affects competitiveness and the market recognition of firms (Dong et al., 2014), but also allows them to enjoy advantages such as better financial performance, cost reduction, and improved corporate image and market share through product differentiation (Tien et al., 2005; Rennings and Zwick, 2012). Green processes and technological innovation can improve eco- and operational efficiencies, thus yielding cost savings (Kemp and Horbach, 2007). Moreover, the impact of GI on the environmental performance of a firm has been empirically analyzed in previous studies. Arundel and Kemp (2009) suggested that GI could benefit both economic and environmental performances. Carrión-Flores and Innes (2010) argued that GI is a key driver of reduction of pollutants and toxic emissions. By adopting GI, firms can simultaneously save on costs, improve their productivity and product quality, meet government and customer pollution targets, as well as improve their environmental performance (Carrión-Flores and Innes, 2010; Chiou et al., 2011). Huang and Wu (2010) suggested that factors such as environmental benchmarking, environmental commitment, R&D capability, and cross-functional integration can improve environmental performance.

The extant literature on shipping suggests that shipping firms can improve their environmental performance, profitability, and operation effectiveness by implementing GI, such as the use of environmental management systems, eco-designs, green information systems, etc. (see for e.g., Green et al., 2012; Perotti et al., 2012). However, the development of GI incurs significant start-up costs and initial capital investment for shipping firms, particularly in the short run. These include, for instance, R&D expenditure for green engines and green ships, costs to retrofit vessels or acquire expertise from various professionals (e.g., marine consultants, mechanical and chemical engineers), and costs related to the risk of shipping process improvements in terms of consumer acceptance and service quality. Moreover, the lengthy period of payback of investment in green products and process innovations (e.g., retrofitting, investment in mega vessels for slow steaming or cold ironing technologies) may not benefit economic performance in the short run. The implementation of GI for energy and resource saving in shipping operations, on the one hand, may lead to an increased turnover by reducing the bunker costs, and improving the eco- and operational efficiencies of shipping operations. On the other hand, the implementation of GI involves significant managerial and operational costs, and risks that the economic benefits may not be able to offset in the short run, thus leading to a reduction in turnover.

2.4. Review of related organizational theories

2.4.1. Natural resource-based view (NRBV) of the firm

The resource-based view (RBV) of the firm is one of the most accepted theories to explain performance differences across firms (Barney, 1991; Newbert, 2007). The RBV focuses on the internal resources and capabilities of a firm that lead to sustained competitive advantages. A resource is anything that a firm owns such as financial assets and employee skills. In contrast, capability refers to the capacity for a bundle of resources to perform tasks (Grant, 1991). Taking into consideration the natural environment, Hart (1995) extended the RBV to the natural-resource-based view (NRBV) of the firm, arguing that firms can utilize their resources to develop capabilities that will help them not only to develop environmental strategies but also achieve competitive advantages. In the NRBV perspective, firm resources have to be “rare, valuable, indispensable and difficult to imitate” (Hart, 1995) to achieve sustained competitive advantages.

In the early stage of theory development, Hart (1995) outlined three stages of proactive environmental strategies, namely, *pollution prevention*, *product stewardship* and *sustainable development*, and discussed their impacts on OP. However, due to the difficulties of defining sustainable development in a business context, the academic literature has failed to provide linkages between sustainable development strategies and OP (Hart and Milstein, 2003). In the literature that followed, Hart (2007) and Hart and Dowell (2011) separated corporate sustainable development strategies into two areas: those that involved *clean technology* or the concept of the *base of the pyramid*. The base of the pyramid focuses on the role of firms in alleviating the poverty of the poorest world citizens (Hart and Dowell, 2011) and therefore, is not in the focus of this study. Instead, the discussion will be centered on pollution prevention, product stewardship, and clean technology.

Pollution prevention is the capability of a firm to reduce emission and waste by implementing process innovations rather than traditional pollution control measures such as 'end-of-pipe' solutions. In doing so, this reduces pollution during the production process of goods and services (Russo and Fouts, 1997). The concept of pollution prevention capability is closely related to process innovation but incorporates an environmental objective (Hart, 1995). Therefore, in this study, the development of green process innovations by shipping firms can be viewed as a pollution prevention capability.

Product stewardship is the capability of a firm to enhance the environmental friendliness of the entire value chain from accessing raw material to the production processes and disposing used products (Chen et al. 2009). Product stewardship refers to practices that aim to reduce the entire life cycle cost of a product (Shrivastava and Hart, 1995). Product stewardship focuses on the development of new or redesigning of existing products that minimize the environmental burden across the entire life cycle of a product or service, i.e. during production, use, reuse and recycling (Shrivastava, 1995). This capability involves the capacity to conduct an environmental analysis on all resources, parts, and components of a product or service, as well as seek potential reuse or recycle opportunities. Hence, the development of green service/product innovations by shipping firms can be viewed as the capability of product stewardship.

Clean technology is the capability of a firm to reduce material and energy consumption by pursuing clean technologies (Meurig Thomas and Raja, 2005). Through the adoption of clean technology, firms are able to develop new competencies and obtain competitive advantages as their industry evolves (Hart and Dowell, 2011). The successful implementation of clean technologies requires firms to focus on innovation (Hart, 2007) and have capability to deal with areas that are uncertain, constantly evolving, and dramatically complex (Hart and Sharma, 2004). Hence, the introduction of green technological innovation to shipping firms can be viewed as a clean technology strategy for achieving sustainable development and competitive advantages. The development of green management innovation can be regarded as building organizational capability to foster and direct the pursuit of clean technologies.

The NRBV perspective allows researchers to differentiate the resources and capabilities of a firm and recognize their performance outcomes with the adoption of environmental management initiatives. However, a good understanding of the relationship between environmental management and performance outcomes is still lacking (Aragón-Correa and Sharma, 2003). It is therefore recommended that researchers further explore the implications of the relationship between environmental management and business performance by applying the NRBV perspective. Particularly, Aragón-Correa et al. (2008) highlighted the lack of empirical examination of external pressures on corporate strategy in the NRBV literature. Hoffman (2001) suggested that corporate strategy is impacted by the relationship between internal and external factors. While the NRBV perspective is used to consider the internal factors that affect the GI adoption of shipping firms, another well-established organizational theory, the *institutional theory,* will be used to explain the external factors that influence the adoption of GI by shipping firms.

2.4.2. Institutional theory

According to Scott (1995), the institutional theory examines how external pressures influence firm strategies. By addressing the institutional requirements, firms can better adapt to the external environment (Orlitzky et al., 2003). ‘Institution’ refers to the regulatory complex that consists of political and social agencies which dominate other firms through the enforcement of laws, rules, and norms (DiMaggio and Powell, 1983; Scott, 1995). Institutional pressures on the environmental management of a firm increase the constraints of business operations. Firms inevitably have to allocate resources for green initiatives and measures to improve their environmental performance, as well as to address institutional pressures. Failure to conform to institutional pressures can threaten their legitimacy, resources, and survival (DiMaggio and Powell, 1983; Scott, 1995).

The institutional theory is relevant to GI adoption since the adoption of GI by shipping firms can be reflected as the mandates of the institutional environment in which they operate, in order to pursue legitimacy (Oliver, 1997; DiMaggio and Powell, 1983). Legitimacy is “a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions” (Suchman, 1995). According to DiMaggio and Powell (1983), three specific types of pressure, namely coercive, normative, and mimetic, transfer the influence of the institutional environment to firms.

Coercive pressure is the main factor that drives shipping firms to adopt GI. Government agencies are an example of powerful groups that impact the actions of an organization (Rivera, 2004). In this study, regulatory pressure is a form of coercive pressure that drives shipping firms to adopt GI to improve their environmental performance. With increasing pollution problems that affect air, noise, and marine environment by shipping operations such as sea transport, distribution, and port operations, the Hong Kong government has introduced various rigorous environmental regulations that shipping firms need to comply, for example, the Water Pollution Control Ordinance, and Merchant Shipping (Prevention of Air Pollution) Regulation. Besides, the international environmental regulations and policies also force shipping firms to adopt relevant greening measures for improving environmental management. For example, in order to eliminate maritime pollution due to the leaking of oil and other harmful substances, vessels flagged under countries that are signatories to the International Convention for the Prevention of Pollution from Ships (MARPOL) are subjected to its requirements. Such local and international policies create substantial pressure for shipping firms not only to devote efforts to greening to fulfill the environmental expectations and targets of institutions, but also to comply with the laws and regulations.

Normative pressure stems from professionalism that is associated with the norms of formal education and professional societies (DiMaggio and Powell, 1983). According to Lai et al. (2006), firms are subjected to the norms, standards, and expectations of their external stakeholders. Customer demands form a core normative pressure and are an important driver for the implementation of green initiatives (Bansal and Roth, 2000; Hall, 2000; Álvarez-Gil et al., 2007). Customer pressure comes from both customers and downstream supply chain partners (Lewis and Harvey, 2001). In the context of the shipping industry, Lai et al. (2011) observed that some shippers such as IKEA and Wal-Mart require their logistics service provider to demonstrate their environmental commitment in shipping operations, for example, reduced carbon emissions, and indicate their fuel use and standards for utilizing facilities and equipment to reduce environmental degradation.

Mimetic pressure arises from the rational desire of firms to imitate the behaviour of other firms because they perceive that the imitated behaviour is legitimate or has technical value. Zhu et al. (2013) defined such imitative behaviours as competitive benchmarking. The rationale is merely to follow the successful path of their competitors, and avoid losing business and investment risks in developing novel greening efforts. For instance, most shipping firms have implemented carbon analysis services as a means for their external customers to gauge the environmental impacts of their shipping operations. Shipping firms without compatible technologies and service can be considered to have a competitive disadvantage and thus, may choose to imitate the core functions of the systems of their competitors to maintain competitiveness by offering similar carbon analysis services.

2.4.3. Synthesis of NRBV and institutional theory

According to Prajogo et al. (2012), the NRBV and institutional theories can be used as complementary theoretical lenses to comprehensively explain the drivers and performance implications of the adoption of green initiatives. While the institutional theory examines the impact of external pressures on firms and takes into consideration the adoption of technologies, practices, or management structure among firms that seek to achieve institutional legitimacy (DiMaggio and Powell, 1983; Scott and Christensen, 1995; Oliver, 1997), the NRBV considers such adoption as strategic means for firms to develop green capabilities by extending the RBV to include the different ways that safeguard natural resources, such as pollution prevention, product stewardship, and clean technology, which in turn, lead to sustainable competitive advantages (Hart, 1995).

Moreover, although the institutional theory emphasizes the role of external pressures imposed onto firms which impacts organizational practices and structures (Scott, 1995), it fails to explain for why firms in the same industry or sector adopt different strategies or practices under the same institutional pressures (Delmas and Toffel, 2004). The NRBV on the other hand points to the internal resources and capabilities of firms and recognizes their performance outcomes with the adoption of green initiatives. For example, firms may adopt similar GI strategies in response to institutional pressures, but the economic performance outcomes may differ significantly. Whether a firm can achieve superior performance outcomes in comparison to their competitors depends on how well and effectively they utilize their internal resources.

The theoretical lenses of the institutional theory and NRBV suggest that there are implications from both external and internal factors. External pressures drive firms to demonstrate legitimacy by adopting GI, while internal drivers motivate firms to develop new competencies and sustain competitive advantages by adopting GI. Moreover, the extant literature has suggested that combining both the NRBV and institutional theories provide greater clarity on hypothesized relationships (Blome et al., 2014), and a thorough and complete explanation of the motivations of a firm toward sustainability (Darnall et al., 2008).

Synthesizing the NRBV and institutional theory, the research framework of this study identified, on the one hand, three types of stakeholder pressure (i.e., regulatory, competitive, customer pressures) which refer to the coercive, mimetic, and normative isomorphisms in institutional theory as external factors that drive firms to achieve institutional legitimacy by GI adoption. On the other hand, the conceptualized components of GI (i.e., green management, service, process, and technological innovations) which refer to the environmental strategies of pollution prevention, product stewardship, and clean technology in the NRBV, as internal drivers encouraging firms to develop new capabilities that lead to superior organizational performance and sustained competitive advantages. This research recognizes the effect from institutional theory as an external driver of the GI adoption of a firm, but also suggests that GI adoption from the NRBV perspective has an important role in transforming institutional drivers into actual organizational performance outcomes.

3. Conceptual framework and hypothesis development

3.1. Conceptualization of GI

To address the environmental concerns of customers and the government, firms can develop a variety of environmental strategies, programmes, and products (e.g., green technologies, eco-designs, etc.) (Zhu et al., 2008). It is important for them to increase their environmental awareness so as to meet the requirements of their customers and suppliers for green products and services that are friendly to the environment. Shipping firms regularly introduce new green shipping products (e.g., advanced eco-containers, retrofitted containerships etc.) and services (e.g., GHG emission tracking, green optimization/consulting services, etc.) to their customers with the aims of easing the environmental burden of their shipping operations and demonstrating their environmental commitment and regulatory compliance. In general, GI can be "any form of innovation aiming at making significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy" (European Commission, 2007). GI comprises new and significantly modified processes, equipment, products, techniques, and management systems that avoid or reduce harmful environmental impacts (Beise and Rennings, 2005; Rennings and Zwick, 2012). GI is a process where environmental consideration is integrated into an organizational system from idea generation through to R&D and commercialization (Charter and Clark, 2007). Firms that proactively adopt GI would generate new business models as well as business opportunities (Gladwin et al., 1995).

In environmental management, GI improves products or processes in regard to energy saving, pollution prevention, waste recycling, green product design, and corporate environmental management (Chen et al., 2006; Chen, 2008). GI exemplifies the incorporation of environmental protection into product/service design and packaging to improve the differentiation advantage of firms (Hart, 1995; Shrivastava, 1995). Chen et al. (2006) suggested that GI is the best way to improve environmental performance by meeting environmental regulatory requirements. In recent years, increased regulations for the shipping industry have prompted shipping firms to broaden their scope and improve the quality of their shipping services (Cheng and Choy, 2007). In the shipping industry firms are required to conform to MARPOL. In its provisions, MARPOL addresses pollution issues from ships in the form of oil (Annex I); noxious liquid substances carried in bulk (Annex II); harmful substances carried by sea in package form (Annex III); sewage

(Annex IV); and garbage (Annex V), and also the prevention of air pollution from ships (Annex VI). Driven by MARPOL, shipping firms have proactively adopted innovative means to meet these regulatory requirements. For instance, the International Convention on the Control of Harmful Anti-Fouling Systems on Ships, which was enacted in 2008, prohibits the use of harmful organotins in anti-fouling marine paints and the potential future use of other harmful substances in anti-fouling systems. To facilitate regulatory compliance and environmental protection, Hapag-Lloyd has applied an innovative biocide-free silicon coating to its ships. The innovative coating requires less than half of the material to apply the coating than with conventional paint. Moreover, the silicon coating beneath the water line of the ship not only protects sensitive marine flora and fauna but also reduces the resistance of the ship to water, which, in turn, reduces fuel consumption up to six per cent. Furthermore, the International Maritime Organization (IMO) adopted the amendments to MARPOL Annex VI in 2011, which includes a set of mandatory technical and operations measures to reduce GHG emissions in international shipping, with the aim of improving the energy efficiency of new ships through improved design and propulsion technologies. With a view to meet the regulatory requirements (i.e., MARPOL), CMA CGM collaborated with DSME Shipyards and certification agency Bureau Veritas to initiate the "green ship concept", which applies cutting-edge innovations to reduce the environmental impacts from ships. A series of the latest green technologies have been installed in three innovative vessels, namely, the CMA CGM Marco Polo, CMA CGM Alexander Von Humboldt, and CMA CGM Jules Verne, which include an "exhaust gas bypass" system that improves the energy efficiency of the vessel when slow steaming; a "pre-swirl stator" and a twisted leading edge rudder that improves and optimizes the hydrodynamics of the vessel, which, in turn, reduces two to four per cent of energy consumption and atmospheric emissions; an optimized hull design that significantly improves the propulsion of the vessel; a novel pollution prevention technology known as the "fast oil recovery system" that enables hydrocarbons in the fuel bunkers to be rapidly recovered; and a new ultraviolet (UV) lamp filtering system for ballast water treatment. Equipped with such technological innovations, the containerships can achieve an environmental performance improvement of 36 g of CO_2 emissions per km/twenty-foot equivalent unit (TEU), which is 12% less than the ships in the class of 13,800 TEU.

GI in the shipping context can be considered from different perspectives (e.g., organizational management, technology management, shipping operations, and customer-driven, etc.). In this study, GI is defined as the implementation of novel or significantly improved organizational management practices, products/services, processes, and technologies deployed by shipping firms to combat the environmental harms caused by shipping operations. Based on this conceptualization, four underlying components of GI in shipping are identified, namely *green management*, *green service/product*, *green process*, and *green technological innovations*. The conceptualization of GI is shown in Figure 2.

Figure 2. Conceptualization of GI

- **Green management innovation** is the ability of a firm to formulate green management systems and programmes that would refine its current operations or production processes with the view to saving resources, reducing waste and pollutants, improving operational efficiency, and re-designing and improving products and services so as to meet new environmental criteria or directives (Zhu et al., 2010). The implementation of green management systems is suggested as a complement to GI, which positively impacts firm performance (Arranz and De Arroyabe, 2012; Amores-Salvadó et al., 2015). In the shipping context, green management innovation is an organization-oriented innovation, which plays an important role in assisting the development of green technological, process, and service innovations. Green management innovation refers to the implementation of novel organizational management methods in business practices, the workplace or external relations of a shipping firm (e.g., Business for Social Responsibility) to initiate new green shipping service or R&D partnership with universities to invent new green shipping equipment) to facilitate operational efficiency improvement, energy saving, pollution prevention, and waste and material recycling or reuse. It also aims to enhance the OP of a firm by reducing operating costs, improving staff productivity, as well as obtaining non-tradable assets (e.g., external knowledge about environmental protection). Examples of green management innovation in the shipping industry include the implementation of environmental/innovation training and workshops for staff and customers to facilitate knowledge sharing (e.g., DHL – Customer Innovation, Idea Generation, and Trend Workshops), R&D collaboration with universities to invent new green technologies or shipping methods (e.g., Maersk Line - ENERPLAN (Energy Efficient Transport Planning) research project, and Arkas - MINI-CHIP (Minimizing Carbon Footprint in Maritime Shipping Operations) project), and the founding of a dedicated innovation department (e.g., Maersk's innovation department – Maersk Maritime Technology) to assist with GI adoption.

- **Green technological innovation** is the investment or installation of green equipment and advanced green technologies that guide and support the innovation efforts of a firm, e.g., the management of information and documentation, and provision of information on a comprehensive material saving plan (Tseng et al., 2013). Zhu et al. (2008) argued that the installation of technological systems is essential for the implementation of green technological innovations. In the shipping context, green technological innovation is technology-oriented innovation that involves the implementation of novel or significantly refined green technologies, information systems, and shipping and cargo handling equipment to guide and support the introduction of green management, service/product, and process innovations in shipping operations. For instance, contemporary shipping companies have installed green engines with advanced energy saving or pollution control technologies to maximize the eco-efficiency of vessels and minimize GHG emissions. APL has installed and tested an advanced emissions control technology called the "seawater scrubber", which uses seawater to scrub contaminants from the engines and boiler before exiting the exhaust stack of a ship. This innovative technology reduces PM by 85%, volatile organic compounds (VOCs) by 90%, NO_x by 10%, and eliminates all SO_x emissions. Moreover, to enhance the eco-efficiency of their vessels, NYK has introduced a green technological innovation called the "air-lubrication system". This system aims to reduce frictional resistance between the hull and seawater with the use of bubbles that are generated by air released from the bottom of the vessel. This air blower-based system can effectively reduce CO_2 emissions by approximately six per cent on average. Furthermore, electronic data interchange (EDI) solutions and electronic documentation are used as green shipping practices to facilitate data sharing between customers and business partners, which reduces paperwork and the time required for processing paperwork (Lai et al., 2011). In addition to improvements made to data sharing and documentation of data, green technical innovation also facilitates environmental knowledge management in companies (e.g., providing advanced and specialized environmental information to implement comprehensive energy saving plans or carbon footprint analysis). For example, CMA CGM adopted the concept of "Big Data" in 2015 by investing in TRAXENS, an innovative container monitoring, geolocation, and multimodal coordination system that offers high-value solutions and real-time data collection to their customers from any place in the world. With such innovative technology, their customers can acquire real-time information on the position of a container and its temperature, the vibrations that the container will be subjected to, any attempted burglaries, any traces of specific substances in the air, and the regulatory status of the cargo. In 2016, Mediterranean Shipping Company joined CMA CGM in backing TRAXENS. With strong endorsement from leading shipping lines, such innovative container monitoring system has set to become a standard in the shipping industry.

- **Green process innovation** is an operation-oriented innovation that refers to the implementation of novel or significantly improved operating processes, shipping modes and methods, or relevant ancillary support activities for shipping services to facilitate operational efficiency improvement, energy saving, pollution prevention, waste recycling, and material recycling or reuse (Chen et al., 2006; Chiou et al., 2011; Santamaría et al., 2012). Typical examples of green process innovation in the shipping industry include the (re-)design of shipping operations for increased environmental efficiency, innovative transport and distribution modes and methods based on "eco-friendly" parameters, and strategic routing and scheduling. Lun et al. (2013) provided an example of an innovative transport method for a "green shipping network" by using the hub-and-spoke approach and the deployment of mega ships, thus enabling shipping firms to effectively improve their environmental and economic performances, as well as reducing regional carbon emissions. Slow steaming and weather routing are well-known examples of innovative green processes that have been widely adopted by shipping firms. For example, Hapag-Lloyd and Hamburg Süd have introduced weather routing programmes to identify optimal routes. Equipped with the latest navigation and communication technologies, their captains can assess meteorological developments (e.g., storms, waves, currents, and other marine influences) and optimize meteorological navigation (e.g., use of favourable currents or avoiding areas with bad weather). This programme not only enables a ship to optimize its fuel consumption but also reduces CO_2 emissions in the process. Moreover, Hamburg Süd has also introduced slow steaming with the use of speed reduction, considered as one of the most effective ways of reducing emissions from container shipping operations. By reducing the speed of their "Santa" class ships from 20 to 16 knots, approximately 40 per cent of fuel can be saved. Equal levels of reduction in the emissions of CO_2, NO_x, and SO_x are obtainable (Hamburg Süd, 2016).

- **Green service/product innovation** is the ability of a firm to create novel products or services that significantly enhance its basic characteristics and functions, technical specifications or materials for energy saving, pollution prevention, and waste recycling. Green product innovations also include green product design, green packaging design or improvement, and "end-of-life" product recovery and recycling (Chen et al., 2006; Huang and Wu, 2010; Chiou et al., 2011; Santamaría et al., 2012). In the shipping context, green service/product innovation is a customer-oriented innovation, which refers to the introduction of novel shipping services/products or significant improvements to existing shipping services/products with respect to the features, technical specifications or materials for energy saving, pollution prevention, and waste recycling. Examples include the provision of advanced carbon tracking services or carbon-footprint analysis; green optimization/consulting services (e.g., DHL - Green Optimization and DB Schenker - Eco-Consulting services); use of advanced or sustainable materials to develop container floorings (e.g., high tensile steel); and strategic vessel maintenance or disposal (e.g., Maersk - Cradle-to-Cradle Passport and retrofitting) to minimize the risk of environmental harms. Particularly, there is an emphasis that these novel or improved services in the shipping services have considerably different characteristics or intended uses from the services that they will replace (e.g., improved efficiency, reduced carbon emissions, enhanced service quality, etc.). For example, Hapag-Lloyd uses steel floors in their newest containers, which is a good example of green product innovation. This innovative container is made entirely of steel including the flooring and is fully recyclable. The steel-floor containers are lighter, more durable and hygienic in comparison with conventional green containers that use bamboo or Forest Stewardship Council (FSC)-certified wood flooring. Moreover, to continuously promote emission reduction throughout its entire transport chain, Hapag-Lloyd has also developed an advanced emission tracking service called "EcoCalc", which calculates the environmental impact of global freight transport. While similar carbon footprint calculators have long been used by other liner carriers (e.g., APL, CMA CGM, Hamburg Süd, OOCL, and Hanjin), EcoCalc not only evaluates the emissions of CO_2, but also assesses the emissions of NO_x, SO_x, and PM_{10} in order to provide a wide range of environmental information to their customers, business partners, and staff who are interested in green shipping solutions.

3.2. Research framework

3.2.1. External drivers – Stakeholder pressures

3.2.1.1. Regulatory pressure

The institutional theory suggests that the coercive institutional isomorphism stems from pressure exerted on a dependent firm by other organizations and by cultural expectations in the society in which it operates (DiMaggio and Powell, 1983). Government regulations and incentives can drive firms to implement innovative environmental practices (Murphy and Gouldson, 2000; Christmann, 2004; Backer, 2007; Etzion, 2007; Darnall et al., 2009). Government agencies can mandate firms to employ pollution control technology to reduce their environmental impacts (Darnall et al., 2008; Darnall, 2009). Failure to comply with the relevant environmental laws and regulations may lead to penalties, fines, lawsuits or loss of operating permits (Sarkis et al., 2010). Consequently, to avoid financial loss and pursue legitimacy, firms are obliged to adopt GI to address the environmental impacts caused by their business operations.

The environmental management literature considers environmental regulations to be the main determinant of GI adoption (Rennings, 2000; Kassinis and Vafeas, 2006; Frondel et al., 2008; Johnstone and Labonne, 2009). Chen et al. (2006) suggested that GI is the best way to improve environmental performance by meeting environmental regulatory requirements. In the shipping industry, firms are required to conform to international environmental regulations, such as MARPOL, the International Convention for the Control and Management of Ships' Ballast Water and Sediments, and the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, etc. Shipping firms have therefore proactively adopted innovative means to meet these regulatory requirements. For instance, the International Convention on the Control of Harmful Anti-Fouling Systems on Ships, which was enacted in 2008, prohibits the use of harmful organotins in anti-fouling marine paints and the use of other harmful substances in anti-fouling systems. To facilitate regulatory compliance and environmental protection, Hapag-Lloyd has applied an innovative biocide-free silicon coating to its ships.

Furthermore, to meet the requirements of MARPOL Annex VI, the CMA CGM has initiated a "green ship concept" to introduce cutting-edge innovations that reduce the environmental impacts from their ships.

Besides environmental regulations, government agencies also offer various environmental incentives such as tax and duty allowances or exemptions, and capital rebates for replacing or recycling machinery and equipment to encourage shipping firms to implement waste management and recycling programmes, and ensure the conservation of energy (Holt and Ghobadian, 2009; Zailani et al., 2012). According to Ruhnka and Boerstler (1998), regulatory pressure on corporate behaviour is overwhelmingly punitive in their intended effects, while government incentives that encourage voluntary corporate self-regulation are much more positive in their intended effects. Moreover, government incentives can be used as external resources which encourage the adoption of green practices (Aragón-Correa and Sharma, 2003; Rothenberg and Zyglidopoulos, 2007). Governments can provide external resource support (e.g., tax incentives for green fuel and technologies that reduce environmental risks) so that shipping firms are more likely to adopt GI (Lee, 2008; Lin and Ho, 2011). Besides, governments can also provide financial support to firms through export credit agencies (ECAs) which are considered to be substantial financial-aid and risk mitigation instruments in the development of GI projects (Kanda et al., 2016). ECAs encourage GI projects by providing non-concessional loans, investment insurance and guarantees for firms to manage the development and operations risks of GI (Ang and Marchal, 2013; Sen and Ganguly, 2017). The financial support from ECAs is particularly important for industrial projects that are exposed to significant commercial and non-commercial risks, such as technology and transportation systems (Wright, 2011). The extant literature on environmental management has reported that government incentives are a significant factor that influences the adoption of GI (see for e.g., Lee 2008; Lin and Ho 2011; Doran and Ryan, 2012; Chen et al., 2016; Lee et al., 2016).

For example, in Hong Kong, ocean-going vessels (OGVs) (e.g., container ships, dry-bulk carriers, oil tankers, etc.) emit considerable quantities of SO_2, PM, and NO_X. The sulphur dioxide (SO_2) emissions from OGVs at berth account for about 40% of their total SO_2 emissions within Hong Kong waters (Environmental Protection Department, 2015). To improve the air quality of Hong Kong and reduce health risks, the Hong Kong government has enforced IMO standards that regulate the sulphur content of bunker fuel and NO_X emissions from vessel engines through the Merchant Shipping (Prevention of

Air Pollution) Regulation in July 2015. This regulation requires all OGVs that are more than 500 gross register tonnages to switch to low-sulphur fuel (with a sulphur content less than 0.5%) during the periods that the ship is at a berth, excluding the first and last hour of the berthing period. To encourage OGVs to switch to low-sulphur fuel while berthing, the government launched and extended the "Port Facilities and Light Dues Incentive Scheme" to March 2018 which started in July 2015. Under this scheme, all registered OGVs can enjoy a 50% reduction in light facilities and port dues. Moreover, to further reduce emission from OGVs, the government has extended the scope of this scheme to include switching to a compliant fuel (i.e. low-sulphur fuel, liquefied natural gas (LNG) or other approved fuels) or use green technologies that can achieve SO_2 emission reduction as effective as using low-sulphur fuel which started in July 2015. In doing so, this encourages shipping firms to implement different types of GI (e.g., clean fuel technologies or green ship technologies) to achieve the equivalent level of SO_2 emission reduction and minimize the environmental impacts of their shipping operations. According to Mads Stensen, Senior Sustainability Advisor at Maersk Line (2013[1]), "fuel switching in Hong Kong is a local initiative but it is also a part of their global objective of driving down air emissions from their own fleet and for the shipping industry as a whole. This requires them to go beyond regulation in order to drive a development towards a level playing field through regulation or financial incentive schemes. The establishment of a level playing field is crucial in order not to financially punish those companies that actually reduce their environmental impacts". Hence, based on the previous arguments, it is posited that

H1a: Regulatory pressure is positively related to the adoption of GI by a firm

3.2.1.2. Competitive pressure

According to DiMaggio and Powell, (1983), firms may model their behavior on that of other firms when faced with environmental uncertainty. While successful firms have developed effective GI, firms may fear that they will be out-competed if their competitors benefit from such GI (Christmann, 2004). The fear of losing market position and competitive disadvantage create competitive pressure that drives firms to learn from or imitate the environmental management strategies of their competitors thus resulting in mimetic isomorphism (Carter and Carter, 1998). It is suggested that firms are inclined to follow the successful business model of their competitors under high competitive pressure

[1] Maersk Line. 2013. "Skies clearing in Hong Kong". Retrieved from http://maerskstories.maersk.com/post/68360121458/skies-clearing-in-hong-kong

(Wu et al., 2012). The extant research on GI (e.g., Cai and Zhou, 2014; Li, 2014; Hojnik and Ruzzier, 2016a) has indicated that firms that perceive greater competitive pressure are more likely to implement GI. In the shipping industry, given that a highly concentrated liner shipping market is dominated by the carriers of four shipping alliances[2] (i.e., 2M, Ocean Three, G6, CKYHE), the competition in the shipping market is fierce. The adoption of GI allows these carriers to improve their operating efficiency, lower operating costs, meet customer and regulatory requirements and achieve greater legitimacy. Therefore, similar GI can be easily found between carriers, and they inevitably follow the strategies or actions of their competitors or alliance partners to implement similar GI to retain their competitiveness. For instance, slow-steaming has become a trend in the shipping industry as it helps to save costs in bunker and emissions reduction. However, slow-steaming very much relies on green product and technological innovations (e.g., retrofitted vessels for slow-speed sailing, green ship technologies, waste heat systems, etc.). Carriers undoubtedly have to implement or acquire similar innovations or technologies to retrofit their fleet, so as to employ slow-steaming activities with their alliance partners or compete with other carriers. Therefore, similar retrofitting projects can be found in mega-carriers that implement slow-steaming operations, such as the CMA-CGM, Maersk Line, and Hapag-Lloyd, etc. Moreover, while green practices such as traditional EDI solutions are widely employed by carriers, the CMA-CGM has utilized the concept of "Big Data" to implement an innovative container monitoring and multimodal coordination system in order to sustain their competitive advantage by providing high-value solutions and real-time data collection to their customers. It will not be surprising if more carriers follow the steps of CMA-CGM to employ innovative concepts such as "Big Data" or "Cloud Computing" in the development of the next generation of EDI systems. Hence, based on the previous arguments, it is posited that

H1b: Competitive pressure is positively related to the adoption of GI by a firm

3.2.1.3. Customer pressure

The institutional theory states that normative pressure drives firms to address social legitimacy concerns in their organizational activities (Sarkis et al., 2011). This pressure is exerted by customers who have a direct or indirect interest in the firm (Vachon et al., 2009). Pressure from customers for environmentally responsible operations constitutes the

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[2] Four major shipping alliances (i.e., **2M** – Maersk Line, MSC; **Ocean Three** – CMA CGM, UASC, CSCL; **G6** – Hapag-Lloyd, NYK, OOCL, APL, MOL, HMM; and **CKYHE** – Cosco, **"**K"Line, Yang Ming, Hanjin, Evergreen) account for approximately 75% of the market share in the liner shipping market in terms of TEU (United Nations Conference on Trade and Development, 2015).

core normative pressure that influences the implementation of green practices by a firm (Zhu et al., 2013). It is a key determinant of a firm in the adoption of GI (Doran and Ryan, 2016). It can also motivate firms to develop, adapt and employ green innovative products, processes, and management systems (Horte and Halila, 2008).

The extant literature in GI suggests that pressure from customers and their environmental demands can significantly compel firms to adopt GI (e.g., Kesidou and Demirel, 2012; Veugelers, 2012; Qi et al., 2013; Li, 2014). Huang et al. (2016) emphasized, in particular, the positive impact of pressure from customers on the level of R&D investment and formation of collaboration networks of firms. The increase in profits and market share can greatly motivate them to accommodate the green demands of their customers. Moreover, industry clients often given utmost priority to suppliers who can demonstrate their environmental commitments (e.g., providing green training and support, participating in environmental programmes or partnerships, etc.), which facilitate green products and processes (Delmas and Montiel, 2007; Ağan et al., 2013).

In the shipping context, shipper cooperation has been identified as an important green practice used by shipping firms (Lai et al., 2011; Lun et al., 2013). This is the cooperation between industry clients and their suppliers to meet environmental objectives. Extending the line of thought of the previous work in the literature, this study posits that industry clients will exert pressure on their suppliers to adopt GI for environmental protection throughout their cooperation. However, their cooperation actually goes beyond meeting environmental objectives. More importantly, it provides a viable means for customers and suppliers to acquire and disseminate environmental knowledge, techniques, and trends that are essential for GI adoption.

For example, the giant shipper, Dell, has its own green packaging and shipping policy that addresses different areas of shipping activities such as internal processes, transport networks and container optimization, packaging innovations, reverse logistics, etc (Dell, 2018). They rely on a shipping partner who shares their commitment in efficiency and environmental stewardship. Specifically, Dell is a participant of the SmartWay programme of the United States Environmental Protection Agency (EPA), which aims to identify technologies and strategies that reduce the carbon emissions of their freight operations. They explicitly expect their carriers to participate in this programme and seek cooperation with carriers to extend the green shipping programme. As a key carrier partner of Dell and a leading third-party logistics provider, DHL addresses their customer's environmental demands in multiple ways so as to maintain a cooperative business relationship. For instance, DHL is not only a member of the SmartWay programme, but has also been recognized with the Excellence Awards of the programme for their greening efforts in reducing climate change and air pollution emissions from freight supply chains (DHL, 2016c). Moreover, DHL offers innovative green services to Dell, such as "green optimization", which is a customized green solution that analyzes every link of the supply chain in Dell to provide opportunities for optimization that will help to reduce GHG emissions and minimize the environmental impacts of their logistics processes. In recognition of their innovative solutions and transportation capability, DHL was honored with the "Dell EMC Best Global Transport Logistics Partner of the Year" and "Dell EMC Best Global Innovative Partner of the Year" awards in 2016. This example aligns with the suggestion in Weng et al. (2015) that customer experience with a product or interaction with the services of a company affects word of mouth and the company brand and image. Hence, based on the previous arguments, it is posited that

H1c: Customer pressure is positively related to the adoption of GI by a firm

3.2.2. Internal drivers – Environmental governance mechanisms

3.2.2.1. Contractual governance

Contracts are a formal agreement between shipping firms and their business partners that outlines the roles, responsibilities, and obligations of each party in the development of GI. Previous studies have discussed the nature of contracts as a governance mechanism from different perspectives (e.g., Williamson, 1985; Cannon et al., 2000; Fried, 2015). This study follows the recommendation in Rai et al. (2012) and considers that contractual governance consists of three key factors namely, goal expectations (Reuer and Ariño, 2007; Rai et al., 2012), activity expectations (Gundlach and Murphy, 1993, Mani et al., 2006), and contingency adaptability (Lou, 2002; Poppo and Zenger, 2002).

Goal expectations are the extent that the objectives of GI activities have reached consensus and explicitly included in a contract (e.g., environmental objectives such as the rate of CO_2, NO_x, and SO_x emissions to be reduced and fuel to be saved by the installation of green ship technology, so as to comply with the regulations in MARPOL). Activity expectations are the level of details and precisely defined standards of conduct of the exchange parties in developing GI (e.g., the implementation of a particular shipping method or technology, such as weather routing or voyage optimization systems in performing green shipping services). Contingency adaptability is the ability to adapt to uncertainties and contingencies that occur in the course of the development of GI activities. For example, the enforcement of new environmental regulations and requirements, or difficulties in acquiring or developing green shipping technologies, and the uncertainty over the possible exchange hazards (e.g., opportunism where shipping firms and partners are investing in co-specialized assets, such as green R&D projects).

The development of GI is complex, and opportunism and economic and technological uncertainties are embedded in the cooperation between shipping firms and partners. Contractual governance is, therefore, an important tool that governs the cooperation relationship by defining the objectives (i.e., goal expectations) and boundaries of appropriate behaviour (i.e., activity expectations), and setting the rules for resolving future disputes and the contingencies of cooperation (i.e., contingency adaptability). With contractual governance, shipping firms and partners can rely on the agreed goal, principles, procedures, and standards of action to implement, evaluate, and improve the GI activities, hence, facilitating an effective and successful adoption of GI and promoting collaborative relationships in the shipping community. Similarly, contractual governance is also suggested for improving cooperative innovation performance (Wu, 2016) and facilitating inter-organizational knowledge transfer (Lee and Cavusgil, 2006; Jiang et al., 2013).

Examples of contractual governance include establishing formal agreements on compliance with respect to the environmental regulations, requirements, or standards and specifications of GI. Shipping firms can use contractual governance to specify environmental regulations for the compliance of their partner firm in the development of GI. For example, the anti-fouling paint applied to the hull of a vessel complies with the International Convention for the Control of Harmful Anti-Fouling Systems on Ships of the IMO, and the use of technical measures such as the Energy Efficiency Design Index (EEDI) or Ship Energy Efficiency Management Plan (SEEMP) to comply with the regulations on the energy efficiency of ships in MARPOL Annex VI. Moreover, contractual governance can also foster the implementation of GI in the shipping industry through specification of environmental requirements such as the use of slow-steaming or retrofitted vessels to reduce bunker consumption and GHG emissions; the use of environmental management concepts (e.g., cradle-to-cradle principle) to increase the recycling rate of shipping equipment; and the use of fuel switching while the vessel is calling at the port. Furthermore, contractual governance enables shipping firms and their partners to specify transaction-specific commitments (e.g. the agreed capital investment and expertise involved in the GI project) which are particularly important for the R&D of green ships and green technologies. Overall, such agreements among contractual parties not only facilitate the effective and successful development of GI in the shipping industry but can also lead to continuous improvements in shipping operations (Lun et al., 2015). Hence, based on the previous arguments, it is posited that

H2a: Contractual governance is positively related to the adoption of GI by a firm

3.2.2.2. Relational governance

In a cooperation relationship for GI development, shipping firms can use a contract to govern the contingencies and potential opportunism problems by codifying the duties, requirements, and responsibilities of each party. However, the complexity and comprehensiveness of contracts are problematic, particularly in the development of innovations. Drafting a complete contract that specifies all possible future contingencies is not feasible, or the contract will not only be rigid and costly to monitor its enforcement and compliance, but also hamper information exchange, knowledge transfer and collaborative innovation among shipping firms and their business partners (Luo, 2002; Wang et al., 2011; Kim, 2013). Under such circumstances, relational governance can be a useful mechanism to address the limitations of formal contracts (e.g., opportunism problems, inherently incomplete and intentionally ambiguous contracts) by formulating an information-symmetrical, reciprocal, and flexible relationship among business partners, which in turn promotes the effective development of GI.

Relational governance can be achieved through the development of relational norms and trust between shipping firms and their business partners. Relational norms consist of flexibility, information exchange, and solidarity. First, improving *flexibility* enables shipping firms and their partners to agilely adjust their shipping operations in response to circumstantial changes throughout the implementation of GI (e.g., partners can use a variety of green equipment, technologies, and shipping methods to satisfy the environmental requirements of shipping operations which is flexible for them). Both parties can thus quickly achieve joint solutions and smoothly adapt to unforeseen contingencies (Poppo and Zenger, 2002; Liu et al., 2009). Second, proactive *information exchange* between partners ensures symmetrical distribution of information between the partners. This helps to mitigate any opportunistic behaviors, allows the anticipation of each other’s needs, and facilitates cooperation and coordination (Lusch and Brown, 1996;

Jap and Ganesan, 2000). For example, involving business partners in R&D collaborations with research institutions fosters a lively exchange and direct feedback with both the academic and business worlds, which in turn ensures that scientific findings can rapidly be transformed into practical applications for both shipping firms and their partners. Lastly, increasing the sense of *solidarity* shifts the behaviour and interests of the partners from self-centred towards the interests and objectives of the partnership (Rokkan et al., 2003). This encourages the attaining of mutually beneficial endeavours, participating in joint problem solving, and coordinating actions toward shared objectives (Lumineau and Henderson, 2012). For example, to demonstrate reciprocal commitment to the partnership, many shippers and their service providers present “innovation awards” and “environmental awards” to their business partners in recognition of their commitment to innovation and the environment in the partnership (for e.g., the CMA CGM received the Blue Circle Award from the Vancouver Fraser Port Authority which recognized their efforts to reduce air emission). These awards help shipping firms and their partners to develop solidarity norms that enhance cooperation efficiency as they are expected to perform in ways that aim for mutual benefits and toward shared environmental objectives.

Furthermore, a high level of *trust* between partners can reduce transaction costs (e.g., negotiation costs that result from cooperation) and prevent opportunism (Das and Teng, 1998). Shipping firms and their partners can concentrate their resources on enhancing their capacity to assimilate and utilize knowledge, which in turn promote collaborative innovation activities (Zaheer et al., 1998; Lane et al., 2001) and meet joint goals (Atuahene-Gima and Li, 2002).

In the shipping industry, shipping firms can achieve relational governance through the supplier engagement activities that allow for engagement (e.g., environmental/ innovation seminars and workshops, involvement of suppliers in R&D processes, etc.). In the course of the supplier engagement activities, relational norms and trust between shipping firms and their business partners can be established via proactive information exchange, knowledge generation, and expectations sharing among business partners for the effective development and implementation of GI. For example, to share best practices and create an ideal environment to engage in innovation-related activities, DHL has offered “Innovation and Business Workshops” and “Idea Generation Workshops” to their partners (DHL, 2017). Such workshops allow DHL to establish a trusting and constructive relationship with their partners by listening to their needs, sharing best practices and solutions information, collaborating with solution experts, and jointly engaging in the generation of ideas for new products, services, or processes. Therefore, DHL and their business partners can maintain a better understanding about each other's requirements and capabilities, and consequently, cultivate a trusting relationship and shared expectations on attitudes and behaviours for the development of GI (e.g., "green optimization"). Overall, relational governance is expected to be a useful means for governing the cooperation relationship and mitigating opportunism by developing a socially constructed environment that promotes and nourishes cooperation. Relational governance facilitates the optimal utilization of resources and changes to shipping operations that can be made in a flexible manner throughout the development of GI. Hence, based on the previous arguments, it is posited that

H2b: Relational governance is positively related to the adoption of GI by a firm

3.2.2.3. Organizational governance

Organizational governance is an important mechanism of environmental governance which drives the environmental performance of shipping activities (Lun et al., 2015). Shipping firms exercise organizational governance by implementing process control measures such as corporate environmental policies, standard operating procedures, environmental rules, and environmental reporting activities to ensure that green shipping operations are properly carried out. Implementing such measures allows shipping managers to examine and compare actual and anticipated environmental performance outcomes of shipping operations, identify non-conformance issues and improvements, and take the necessary actions to ensure that the environmental objectives are achieved (Lun et al., 2015).

Earlier studies on innovation suggest that organizational governance can positively impact the effectiveness of innovation development, because the governance mechanism facilitates the precise application of knowledge (Turner and Makhija, 2006; Rijsdijk and van den Ende, 2011). For example, effective implementation of green process innovation in shipping (e.g. fleet optimization for fuel efficiency) relies on proper configuration of individual shipping processes, green technologies, fleet planning strategies, etc. Establishing appropriate environmental policies and standard operating procedures help to precisely specify the method for performing individual shipping processes, the use of green technology, the features of a particular fleet planning strategy, etc. Shipping managers will therefore gain precise knowledge of particular processes, technologies, or planning strategies to make consistent and effective decisions (e.g., properly maintain and manage routes and speed, and achieve fleet optimization and/or use green technologies) throughout the development process. Therefore, using standardized methods and procedures can reduce ambiguity, develop coordination, and enhance operational efficiencies in the innovation process (Poskela and Martinsuo, 2009).

Moreover, by introducing environmental reporting protocols (e.g. Global Reporting Initiative (GRI)), shipping firms not only can regularly and systematically use reporting measures to quantify the environmental impacts of their shipping operations (e.g., analyse eco-efficiency indicators such as fuel consumption intensity, CO_2 emission intensity, etc.), but also use the performance outcomes to identify continuous improvement opportunities for green shipping operations. Tracking key performance metrics over time can facilitate the improvement of operating performance and lead to innovations (Roy and Sivakumar, 2012). Hence, it is suggested that organizational governance is a means of achieving the desired organizational objectives (Turner and Makhija, 2006; Chen et al., 2009) and critical for the development of innovations (Poskela and Martinsuo, 2009; Rijsdijk and van den Ende, 2011). Therefore, based on the previous arguments, it is posited that

H2c: Organizational governance is positively related to the adoption of GI by a firm

3.2.2.4. Joint impact of contractual and relational governances on GI adoption

Per the above discussion, both contractual and relational governance can help to improve the cooperation relationship between shipping firms and their business partners, and facilitate the effective development of GI. However, each governance mechanism has its own benefits and limitations under an uncertain environment (e.g., changes in regulatory/environmental requirements, availability of resources such as expertise and green technologies). The extant literature suggests that contractual and relational governances can address each other's limitations and complement each other to improve performance (Poppo and Zenger 2002; Lee and Cavusgil 2006; Liu et al., 2009; Li et al., 2010; Wang et al., 2011).

Relational governance can support contractual governance in two ways. First, as it is infeasible to draft a complete contract that specifies all unforeseeable changes (Wuyts and Geyskens, 2005) or because excessively specific terms and guidelines can cause rigidity (Luo, 2002), contractual governance alone cannot maintain the continuity of a cooperation relationship when unforeseeable changes emerge (Poppo and Zenger, 2002). Relational governance is therefore recommended as a more flexible and adaptive mechanism that helps to overcome the adaptive limits of contractual governance and complement it by fostering continuance and bilateralism when unforeseeable changes arise (MacNeil, 1978; Poppo and Zenger, 2002). Second, since the drafting and enforcement costs of a comprehensive contract that incorporates details on the cooperation process in its entirety are high, relational governance which emphasizes norms and trust can work as a complementing self-enforcing safeguard to minimize such costs by reducing opportunities for contract breaches and renegotiation (Lee and Cavusgil, 2006; Yang et al., 2012).

On the other hand, contractual governance can also support relational governance. Since relational norms and trust are not formalized in a contract, different expectations and misunderstandings of behaviors in a cooperation relationship can lead to uncertainties, conflicts, and opportunism. Therefore, contractual governance can complement the limitations of relational governance by clearly specifying expectations, contingencies, adaptive processes, and disciplinary actions against opportunism (Weitz and Jap, 1995; Lee and Cavusgil 2006). Overall, contractual governance provides the formalized terms, conditions, and contingencies that promote cooperation, whereas relational governance facilitates trust, norms of flexibility, continuance, and bilateralism between shipping firms and their partners. It is expected that contractual and relational governance mechanisms complement each other, and foster the successful development of GI. Accordingly, it is posited that

H2d: Contractual and relational governances are complementary in facilitating the GI adoption of a firm

3.2.2.5. Joint impact of contractual and organizational governances on GI adoption

Contractual and organizational governance are useful control mechanisms to guide the development of GI. However, the use of the former alone may not be sufficient due to limitations, such as rigidity and the lack of a comprehensive contract (Lun et al., 2015). Contracts are the formal agreement between shipping firms and their business partners that incorporate the roles, responsibilities, and obligations of each party in the development of GI. It is not possible to contractually prescribe all performing methods or procedures of shipping processes. Therefore, organizational governance can complement contractual governance by introducing formalized standard operating procedures, rules and routines, and rigorous reporting protocols to ensure that green shipping operations are properly performed. This not only provides important references for shipping firms and business partners to reinforce how the agreed objectives are to be achieved but also helps to maintain the flexibility of contracts and eliminate opportunism. Moreover, publishing environmental reports in accordance with GRI guidelines allows shipping firms to systematically share environmental experiences and information with their business partners, which in turn facilitates information symmetry. Business partners can thus achieve a better understanding of each other's greening capabilities, and as a result, create mutual environmental objectives and reduce the negotiation process and costs of a contract. Overall, organizational governance complements the limitations of contractual governance in terms of rigidity and lack of comprehensiveness. It is expected that jointly using both contractual and organizational governance mechanisms lead shipping firms and their business partners to achieve their environmental objectives, as well as effectively develop and implement GI. Accordingly, it is posited that

H2e: Contractual and organizational governances are complementary in facilitating the GI adoption of a firm

3.2.3. Effects of GI adoption on organizational performance

The positive correlation between GI adoption and OP has been discussed in the recent literature (e.g., Cheng et al., 2014a; Dong et al., 2014; Li, 2014). In comparison with non-innovative firms, firms can obtain competitive advantages by developing innovative products, processes, and technologies. However, mixed results have been found in the relationship between GI and OP. Li (2014) rejected a positive relationship between GI adoption and firm financial performance due to the high initial capital for GI adoption and a long payback period. Similarly, Dong et al. (2014) argued that environmental performance improvements due to GI (e.g., end-of-pipe innovation) may come at the cost of financial losses, which is resultant of the large amount of capital investment in pollution prevention and control technologies.

Nevertheless, the majority of studies support a positive relationship between GI adoption and OP (e.g., Pujari, 2006; López-Gamero et al., 2010). Chen et al. (2006) suggested that firms that focus on GI can enjoy a first-mover advantage and enhance their OP. With respect to the relationship between GI adoption and economic performance, adopting green product innovation not only positively affects competitiveness and market recognition (Dong et al., 2014), but also assists firms to obtain benefits such as better financial performance (e.g., high ROI), cost reductions, improved corporate image and reputation, and increased sales and market share through product differentiation (Tien et al., 2005; Fraj-Andrés et al., 2009; Rennings and Zwick, 2012). Green process and technological innovation focus on significantly refined processes, technology and equipment that can improve eco- and operating efficiencies, and shipping competencies, and thus generate cost savings (Kemp and Horbach, 2007). For example, Maersk Line utilized slow streaming with retrofitted vessels and vessel performance optimization tool, Eco-Voyage to reduce their emissions and bunker consumption, which in turn reduced the total cost per forty-foot equivalent (FFE) unit by 10.6% and total bunker costs by 21% from 2012 to 2013. Moreover, by implementing an intelligent management system for port operations, Shanghai International Port achieved significant improvement in operating efficiencies and profitability. After more than two years' production practices, the throughput capability of the port increased by 47.3%, the average berthing time at the port decreased by 17.4%, the utilization rate of equipment improved by 11%, and the profit growth of the port was RMB 173.4 million (Shanghai International Port Group, 2017).

In addition to the positive impact of GI adoption on economic performance, its impact on environmental performance has also been empirically verified in previous studies. Arundel and Kemp (2009) suggested that GI could benefit both economic and environmental performances. Carrión-Flores and Innes (2010) argued that GI is a key driver for reducing pollutants and toxic emissions. Firms can simultaneously achieve cost savings, improve productivity and product quality, meet government and customer pollution targets, as well as enhance their environmental performance. In the shipping industry, for example, CMA CGM improved its carbon performance by 50% from 120 CO_2 g/TEU-km in 2005 to approximately 60 CO_2 g/TEU-km in 2015 by implementing different types of green innovation, which included retrofitted vessels that improve the hydrodynamics and reduce the fuel consumption and CO_2 emissions, fast oil recovery system and ballast water treatment system on the fleet, established the Fleet Navigation and Support Center to optimize routes, speeds, and fuel consumption, and developed new green containers that save 1 to 2 tons of fuel and reduce emissions of 3 to 6 tons of CO_2 per day. Moreover, by fitting new vessels with an important technical innovation, hybrid liquefied natural gas/fuel engine, CMA CGM can drastically reduce their emissions by 20% in CO_2, 92% in SO_x, and 10% to 20% in NOx depending on the operating speed of the vessel.

Furthermore, in the course of developing GI, the learning competencies, organizational memory, and knowledge-based expertise of firms are enhanced and thus, prompt their innovativeness and OP improvements (Hanvanich et al., 2006). Besides, environmental commitment and green human capital can positively influence innovation performance and green adaptive ability (Chang, 2016). Firms can realize both resource efficiency and innovation capability improvements through the development of green process innovations (Fraj-Andrés et al., 2009). In the shipping industry, firms are keen on participating in R&D activities with universities to initiate GI. For example, DB Schenker established a cooperative laboratory at Darmstadt Technical University (TU Darmstadt) to facilitate teaching, staff recruitment, and R&D activities on logistics planning systems and multimodality and logistics technologies. The lab also provides teaching and further education for TU Darmstadt students and their employees, and most importantly, enables them to efficiently and effectively transform the scientific findings into practical applications.

Accordingly, it is suggested that, in the shipping industry, firms can improve their environmental performance, profitability, and operation effectiveness by implementing various forms of GI such as environmental management systems, eco-design, green information systems, etc. (e.g., Green et al., 2012). Hence, based on the previous arguments, it is posited that

H3a: Green management innovation is positively related to the OP of a firm
H3b: Green service innovation is positively related to the OP of a firm
H3c: Green process innovation is positively related to the OP of a firm
H3d: Green technological innovation is positively related to the OP of a firm

Moreover, the extant literature contends that using a holistic approach (i.e., adopting a spectrum of dimensions of GI, rather than a single dimension) to adopt GI would enable firms to achieve a greater degree of performance improvement (Naranjo-Gil, 2009; Cheng et al., 2014a). Cheng et al. (2014a) argued that the development of GI without a holistic view could be counter-productive. Firms need to understand the complementary nature of different types of GI, so as to effectively implement comprehensive innovation programmes. Particularly, the functions of green management (e.g., innovation department) and technological (e.g., green ship technologies) innovations are to direct and guide the adoption of green process and service innovations of shipping firms. Adopting green management and technological innovations alone may lead to financial burden (e.g., capital investment in technologies, human resources costs of expertise, etc.) to shipping firms, as their benefits on OP can only be realized with the implementation of green processes (e.g., introduce vessels that fitted with green ship technologies to perform slow-steaming, so as to reduce emissions and fuel consumptions) and services (e.g., employ expertise from diverse field in the innovation department to initiate green consulting services to customer, so as to create sales and businesses) innovations. Therefore, the use of a holistic approach to implementing GI provides strategic (e.g., valuable, inimitable, and non-substitutable) resources that enable a firm to achieve better OP. While the previous literature has discussed the components of GI separately, their interrelationships have not been examined holistically (Lozano, 2015). Therefore, it is posited that

H4: As opposed to adopting a single component of GI, firms that use a holistic approach to adopt GI will strengthen the positive relationship between GI and organizational performance.

3.2.4. Mediating effects of environmental and innovation performances: implications for economic performance

The extant literature has shown that environmental (e.g., Jacobs et al., 2010; Li, 2014), innovation (e.g., Oke et al., 2012) and economic performances are positively linked. Collins and Smith (2006) examined the relationship between innovation strategies and firm performance; they contended that innovation performance could be a mediator or an intervening variable that impacts the relationship between innovation strategies and economic performance. Over the course of the development of GI activities (e.g., R&D collaborations), innovation performance contributes to a favourable organizational environment, where creativity and knowledge are valued and flourish, staff members are open to new ideas to (re)-design and introduce novel shipping services/processes that lead to improved innovation performance, and as a consequence, enable shipping firms to achieve a superior economic performance (e.g., reduce the time from inception of ideas to actualize the green processes or launch of green services to the market). Moreover, previous studies (e.g., Klassen and McLaughlin, 1996; Jacobs et al., 2010; Li, 2014) have indicated that improved environmental performance can facilitate superior economic performance in two ways; through revenue, and through cost. In terms of the former, improved environmental performance allows shipping firms to improve their market share, increase their profit margin, and achieve a higher ROA due to improved corporate image and quality of green shipping services. In terms of the latter, firms are able to reduce costs in energy consumption and waste treatment, disposal of waste, and avoid fines for environmental accidents by improving the eco- and operating efficiencies of their shipping activities. Therefore, based on the previous arguments, it is posited that

H5a: The relationship between GI and economic performance is mediated by environmental performance

H5b: The relationship between GI and economic performance is mediated by innovation performance

3.2.5. Moderating role of environmental uncertainty

Environmental uncertainty is defined as the effects of inaccurate predictions on environmental change on operational efficiency. It is related to the complexity of the external environment (Duncan, 1972). Environmental uncertainty consists of demand/customer and supply uncertainties, competitive intensity, and technological uncertainty (Paulraj and Chen, 2007). The unpredictability and variability of market demand and technological development are the main factors that underpin environmental uncertainty (Fynes et al., 2004). From a green management perspective, environmental uncertainty is associated with inaccurate predictions of market demand for green services and insufficient knowledge of green technology (López-Gamero et al., 2010). Accordingly, this study follows the conceptualization provided in Davis (1993), which considers that there are three different types of uncertainty embedded in green shipping operations: supply, demand, and technological uncertainties.

Supply uncertainty refers to the inconsistency of service/product quality, timeliness and the inspection requirements of the suppliers (Chen and Paulraj, 2004). Changes in the supply process in which operations and underlying technologies are rapidly changing could lead to a high degree of supply uncertainty (Lee, 2002). Demand uncertainty refers to the difficulties in assessing customer needs, anticipating market demand and predicting the changes in customer preferences (Land et al., 2012). Lee (2002) indicated that the demand for innovative products/services is highly unpredictable and hence, innovative products/services incur a great deal of demand uncertainty. Technological uncertainty refers to the unpredictability of technological development including rapid changes in product and process technologies, technological complexity, and difficulty, as well as the continual evolution of novel technologies (Fynes et al., 2004).

In the context of green shipping operations, supply uncertainty arises from the inconsistency in environmental performance between shipping partners or suppliers, and irregularity in quality of green shipping services and fulfillment of environmental requirements. In high supply uncertainty, shipping firms may fail to meet the environmental requirements (e.g., emissions targets or limits) of customers or regulators when performing shipping operations with suppliers with inconsistent environmental performance and irregular quality of service. The non-conformance or non-compliance of environmental requirements of customers or regulators may lead shipping firms to the breach of contracts or subject to penalties, fines, or financial consequences. Demand uncertainty arises from difficulties in assessing customer needs for green shipping services and predicting market trends and needs for green innovative shipping solutions. For example, shipping firms initiate green optimization services for their customers. These services involve expertise from a variety of areas (e.g., environmental experts, operation consultants, dedicated IT support, etc.). The rapid changes in customer needs for these services imply that shipping firms need to accommodate by using different experts and seeking different resources, which in turn affect their OP. Technological uncertainty arises from the difficulty of implementing green shipping technologies due to the level of complexity and rapid changes. In high technological complexity, shipping firms may not able to develop the green shipping technologies (e.g., fleet optimization system) alone, which therefore encourages more R&D collaborations between firms to exchange and share knowledge and resources with the intent of developing the green technologies. As a result, the innovation performance of firms may improve through the knowledge sharing and R&D activities.

According to the contingency theory, there is no best way to organize a firm (Lawrence and Lorsch, 1967). The best way to organize a firm depends on how the firm relates to the external environment (Scott, 1995). Therefore, OP is affected by the “match” or “fit” between the structure and processes of a firm with the environmental conditions (Donaldson, 2001). As such, it can be argued that in different contextual situations, a firm will employ appropriate initiatives that positively impact its OP. In other words, it is posited that the effectiveness of the GI activities of shipping firms on their resultant OP is contingent on environmental uncertainty. Moreover, the extant literature has applied the contingency theory to explain the presence of potential contingency variables as moderators, and confirmed their relationships between constructs in innovation studies (e.g., Li and Atuahene-Gima, 2001; Jansen et al., 2006) and operations management studies (e.g., Germain et al., 2008; Flynn et al., 2010; Wong et al., 2011).

On the contrary, Horbach et al. (2012) argued that energy and resource savings in operating processes have led to increased turnovers. However, due to the high initial start-up costs, energy saving activities may increase costs in the short-run and lead to reduced turnovers. Under an uncertain environment, shipping firms tend to develop green technological innovation to respond to the changing environment, which incurs significant costs and initial capital investment (e.g., R&D expenditure for green engines and green ships, costs related to the risk of shipping process improvements that are subject to consumer acceptance and service quality). Moreover, the lengthy payback period of some of the investments in green services and processes (e.g., retrofitting, mega vessels for slow steaming or cold ironing technologies) will not contribute to a positive impact on economic performance in the short-run. Therefore, engaging in GI activities involves significant R&D, managerial, and operational costs, and risks that may not offset the economic benefits under high environmental uncertainty. The positive relationship between GI and economic performance will not be strengthened under high environmental uncertainty. Based on the previous arguments, it is therefore posited that

H6a-d: Under high environmental uncertainty, the positive relationship between GI and (i) environmental and (ii) innovation performances will be strengthened, but the positive relationship between GI and (iii) economic performance will not be strengthened.

3.3. Research framework and summary of hypotheses

The research framework and summary of the hypotheses are provided in Figure 3.

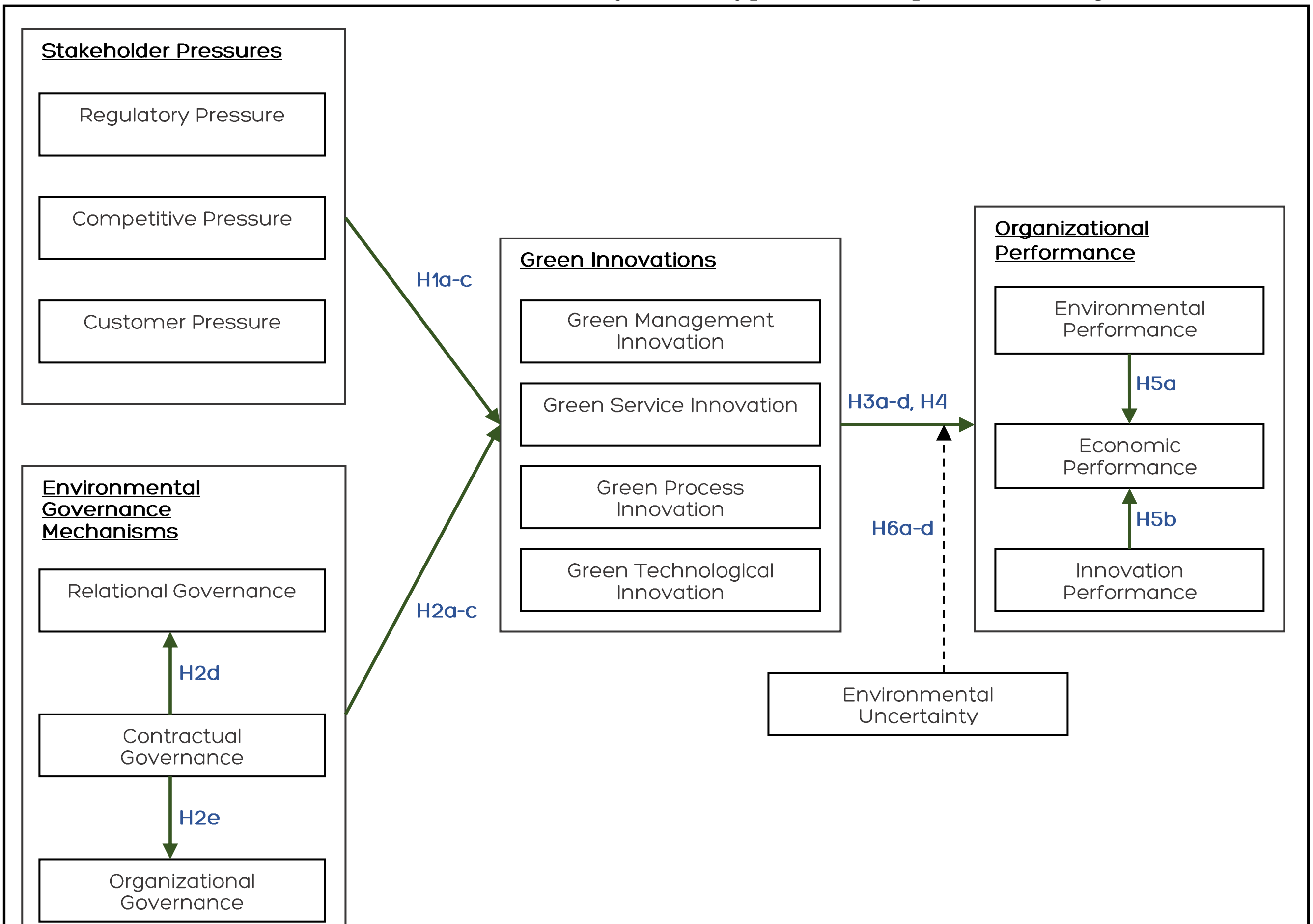


Figure 3. Research framework

<u>Notes:</u>

H1a: Regulatory pressure is positively related to the adoption of GI by a firm
H1b: Competitive pressure is positively related to the adoption of GI by a firm
H1c: Customer pressure is positively related to the adoption of GI by a firm
H2a Contractual governance is positively related to the adoption of GI by a firm
H2b: Relational governance is positively related to the adoption of GI by a firm
H2c: Organizational governance is positively related to the adoption of GI by a firm
H2d: Contractual and relational governances are complementary in facilitating the GI adoption of a firm
H2e: Contractual and organizational governances are complementary in facilitating the GI adoption of a firm
H3a: Green management innovation is positively related to the OP of a firm
H3b: Green service innovation is positively related to the OP of a firm
H3c: Green process innovation is positively related to the OP of a firm
H3d: Green technological innovation is positively related to the OP of a firm
H4: As opposed to adopting a single component of GI, firms that use a holistic approach to adopt GI will strengthen the positive relationship between GI and organizational performance.
H5a: The relationship between GI and economic performance is mediated by environmental performance
H5b: The relationship between GI and economic performance is mediated by innovation performance
H6a-d: Under high environmental uncertainty, the positive relationship between GI and (i) environmental and (ii) innovation performances will be strengthened, but the positive relationship between GI and (iii) economic performance will not be strengthened.

4. Research methodology

4.1. Review of research methods

Empirical research method

The empirical research method refers to field-based research that uses data that is collected from naturally occurring situations or experiments, rather than by laboratory, simulation models, or mathematical modelling, where the researchers have more control over the events being studied. (Flynn et al., 1990; Scudder and Hill, 1998). The empirical research can be used for theory building, theory verifying, application, and providing evidence (Gupta et al., 2006). The extant literature has suggested various research designs for data collection, which include case study, survey, panel study, archival analysis, focus group, field experiment, etc. (Flynn et al., 1990). Although the survey research is most widely used by empirical researchers, the mixed methods (e.g., case study and survey) have also been consistently used in empirical research (Scudder and Hill, 1998). By utilizing various research methodologies, the empirical research is more likely to yield highly productive outputs with lowered risk of biased findings, improve triangulation, and provide an accurate picture of the business processes (Gupta et al., 2006; Boyer and Swink, 2008). Accordingly, mixed-methods of case study, survey, and secondary data analysis is used in this study.

Case study research

A case study is a history of a past or current phenomenon, obtained from multiple sources of evidence. It includes data from different sources such as direct observation, systematic interviews, and public and private archives (Voss et al., 2002). Case study research is one of the most powerful research methods in operations management (Boer et al., 2015). It can be used for various research purposes such as exploring the topic concerned, and developing, testing and extending theories (Karlsson, 2016). A case study research is particularly useful for investigating how and why questions (Yin, 2013). The results of case studies can lead to new insights, and have high validity for practitioners.

Voss et al. (2002) and Barratt et al. (2011) highlighted the dilemma of selecting the ideal number of cases for study, suggesting that although multiple cases can improve external validity and help prevent observer bias, fewer cases provide the opportunity for more in-depth observation. Single case studies enable researchers to capture more details from the context in which the phenomena are being studied (Dyer and Wilkins, 1991;

Eisenhardt, 1991). A single in-depth case study can be used in longitudinal research (Narasimhan and Jayaram, 1998; Voss et al., 2002), and if it is an extreme exemplar where the case has sharply contrasting characteristics (Miles and Huberman, 1984; Yin, 2013). Leading companies in the sector are useful for benchmarking purposes in case studies (Choi and Hong, 2002; Fisher, 2007). Moreover, the validity of a single case study can be improved through triangulation with multiple means of data collection (e.g., quantitative survey or secondary data).

Survey research

Survey research is one of the most widely used methods to perform empirical research in the field of operations management (Karlsson, 2016). A survey generally involves the collection of information from individuals through mailed questionnaires, telephone calls, interviews, etc., to identify the units to which they belong (Rossi et al., 2013). According to Pinsonneault and Kraemer (1993), there are three distinct characteristics of survey research including, first, that the purpose of a survey is to generate quantitative descriptions of some aspects of the studied population. Second, the main method of information collection is to ask respondents structured and predefined questions, and their answers, which refer to some other unit of analysis, constitute the data for analysis. Third, information is collected from a sampling fraction of the population, and thus can be used to generalize the findings to the population.

Survey research contributes to the advancement of scientific knowledge in different ways (Babbie, 1990). Confirmatory (also known as theory testing or explanatory) survey research is often singled out by researchers (e.g., Malhotra and Grover, 1998). Confirmatory surveys can be used when knowledge of a phenomenon has been articulated in a theoretical form by using well-defined concepts, models and propositions (Karlsson, 2016). The data collection is conducted specifically with the aim to test the adequacy of the concepts developed relevant to the phenomenon, the hypothesized correlations among the concepts, and the validity of the models. Moreover, collecting data through mailed or self-administered questionnaires has numerous advantages such as cost savings, no time constraints, ensures anonymity, reduces interviewer bias, etc. (Forza, 2002).

Secondary data analysis

The extant literature suggests that there are a number of advantages to conducting secondary data analysis (e.g., Brewer, 2006; Corti, 2008; Goodwin, 2012). Secondary data analysis is an effective method to analyze data when there is difficulty in accessing hard-to-reach samples, and examining particularly sensitive issues, small populations and rare phenomena (Heaton, 2004). It helps to enhance quality control by validating the research, and thus improving the transparency, trustworthiness and credibility of the findings (Andrews et al., 2012). Moreover, secondary data analysis enables researchers to eliminate the time used to recruit participants and minimize financial expenses incurred for data collection (Corti, 2008).

4.2. Research study design

This study uses a mixed methods research design that consists of both qualitative (i.e. exploratory case study) and quantitative (i.e., participatory survey and post-hoc analysis) studies. As noted by Creswell and Clark (2007), conducting mixed methods research is challenging as it requires more work and time to complete. The increased time demand generally arises from the time required to implement both aspects of the study (Niglas, 2004, Molina-Azorín, 2011). However, mixed methods research enables researchers to develop a conceptual framework, validate quantitative results by combining the information extracted from the qualitative study, and construct indices from qualitative data that can be utilized to analyze quantitative data (Madey, 1982; Onwuegbuzie and Leech, 2004). Moreover, researchers are able to combine empirical precision with descriptive precision (Onwuegbuzie, 2003), and the macro and micro levels of a study (Onwuegbuzie and Leech, 2005). Finally, the results can be triangulated to offset bias found in mono-method studies, which in turn, enhances the validity and generalizability of the findings (Greene et al., 1989).

First, the exploratory case study was conducted by employing a mix of methods. A qualitative approach (i.e., "critical" case study) was used to illustrate the key components and the pursuit of GI by a shipping firm, and a quantitative approach (i.e., data envelopment analysis (DEA)) was used to examine the influence of GI adoption on the environmental and economic performances of this firm. Critical case sampling was used because it has been recommended as a useful method for identifying a case with a rich source of information relative to the research in question (Eisenhardt, 1989; Stuart et al., 2002). Maersk Line was selected as the "critical case" to conduct the in-depth analysis.

Second, a participatory survey study was conducted which focused on a sample of 1,837 PRD-based shipping firms to empirically validate the measurement models of GI adoption that were developed based on the results of the exploratory case study and literature review. To provide a comprehensive picture of GI adoption, the survey study also aims to reveal the relationships among the antecedents and adoption of GI and performance implications of GI adoption.

Third, to supplement the research findings of the participatory survey study and for triangulation purposes, a post-hoc analysis was conducted with secondary data. This post-hoc analysis aims to explore whether GI adoption by shipping firms can lead to better economic performance. The results provide additional evidence that supports positive performance implications with GI adoption. To collect the objective data, a list of 129 publicly listed shipping firms was compiled from the major stock exchanges and their financial data were obtained from Thomson Reuters Eikon.

5. Exploratory case study

5.1. Research design and method

The purpose of this study is to investigate the extent to which GI has been adopted in liner shipping operations and its impact on firm performance. A “critical” case study approach is used to longitudinally examine the key components of GI and its implications for the environmental and economic performances of a firm. The case study research method is “an empirical inquiry that investigates a contemporary phenomenon within its real-life context” (Yin, 2013). The method works by performing an in-depth examination of a single instance or event (i.e., a case), which involves looking at the case, collecting data, analyzing information, and reporting results in a systematic way. Critical case sampling is a useful method for identifying a case or a firm with a potentially rich source of information relative to the research in question (Flyvbjerg, 2006). A single case study is acceptable as an appropriate method for theory development (Eisenhardt, 1989; Stuart et al., 2002) as long as parameters are established. These parameters can be transformed into different dependent and independent variables (Meredith, 1998) for testing purposes. Here, Maersk Line is selected as the case in this study because it is one of the earliest companies to participate in environmental reporting in the liner shipping industry, and follow the sustainability reporting guidelines of the GRI to ensure that the reported content and quality are complete, comparable, accurate, timely, and reliable. Their environmental reports are sufficiently transparent about their environmental shipping activities so that they provide diverse examples of exemplary GI activities. In addition, Maersk Line had achieved the best performance in total capacity, throughput, and profit level among the major liner carriers over the study period of 2007 to 2015. Such significant achievements support the use of Maersk Line because the company fulfills the criteria for a “critical case” (Flyvbjerg, 2006).

Moreover, a timeframe of 2007 to 2015 is chosen for the case study because, first, the innovation department of Maersk Line (i.e., Maersk Maritime Technology) was established in 2007, and since then, a number of GI projects have been launched and significant amounts of human and financial capital invested. It is therefore worthwhile to examine the variations in the environmental and economic performances of Maersk Line that are caused by adopting GI. Second, while most of the earlier GI projects initiated by Maersk Line were completed within a three-year period, an additional four to five years is necessary to longitudinally assess the performance implications of GI. Therefore, a nine-year timeframe is considered appropriate and sufficiently long enough for the assessment.

Furthermore, a mixed methods approach is used for this case study, which includes a qualitative analysis to collect data on GI capabilities and a quantitative analysis to collect performance data. In the former, the unit of analysis is the GI activities of Maersk Line. Secondary information sources include internal company reports (i.e., annual and sustainability reports), company news and profiles, reports, and service catalogues published in the nine years that constitute the study period (i.e., 2007-2015). Following the methodology suggested by Ellinger et al. (2005), GI is analyzed in terms of different dimensions, such as, for e.g., organizational management, shipping products/services, shipping processes, and information technology, and the complexity and diversity of their GI activities are examined.

To determine the implications of adopting GI for performance, a two-level analysis is carried out. First, a firm-level analysis is used to examine the relationship between GI and environmental performance. Eco-efficiency indicators (i.e., fuel consumption intensity, and CO_2, NO_x, and SO_x emission intensities) are also used to measure the environmental performance of Maersk Line. Second, an industry-level analysis is carried out to compare and measure the economic performance of Maersk Line against that of other liner carriers. There are two input variables - i.e., operating costs and shipboard capacity, and two output variables - i.e., profit and throughput, which act as the performance indicators for assessing economic performance. Then, the DEA is used as a means to test and compare the efficiency levels of these firms.

5.2. Case study: Maersk Line

5.2.1. Green management innovation

Green management innovation in Maersk Line is exemplified through three innovative management initiatives (Maersk Maritime Technology, the Maersk Ship Performance System and ENERPLAN) as follows.

- **Maersk Maritime Technology (MMT)** is a dedicated innovation department at Maersk Line that was established in 2007. The department consists of over 140 experts who span a spectrum of fields, such as those who specialize in naval architecture, engines, propulsion, fuel, paint and chemicals, machinery and automation systems, as well as hydrodynamics and performance analytics. The focus of MMT is on the optimization of vessels to achieve high standards of environmental performance and substantial savings in energy consumption. MMT works closely with suppliers in the marine industry to develop future technologies for both newly built and existing fleets. MMT contributes to the competitiveness of Maersk Line by providing sustainable and cost-effective solutions in the areas of performance management, new building and conversion of vessels, vessel optimization, ship management support, regulatory affairs, as well as technological innovation.

- The **Maersk Ship Performance System (MSPS**) was developed to facilitate performance improvements in Maersk Line vessels by Maersk Line Vessel Management and the MMT Hydrodynamics & Performance Analytics department in 2009. The MSPS can extract information on CO_2 emissions from a particular vessel or a group of vessels. Such information greatly facilitates decision-making amongst Maersk Line stakeholders and the MMT in providing recommendations for performance improvements. According to the MMT, a substantial amount of savings in the first three years resultant of the implementation of the MSPS has already been realized. For instance, as a result of higher propulsion efficiency, 160,000 tons of fuel and US$90 million had been saved from 2009 to 2012. An overall scorecard was introduced in 2012. The scorecard consists of four vessel key performance indicators (KPIs), namely energy, safety, daily operating costs, and best practice sharing.
- The **ENERPLAN (**Energy Efficient Transport Planning) research project was a research collaboration project between Maersk Line and two Danish universities, namely the Management Engineering department at the Technical University of Denmark (DTU) and IT University of Copenhagen between 2010 and 2014. The aim was to develop green, logistics decision support tools to aid energy consumption reduction at Maersk Line and mitigate the adverse environmental impacts of container shipping activities. Through ENERPLAN, Maersk Line provided in-depth knowledge of the problems under scrutiny and converted the research results into actual energy saving initiatives that have a significant impact on reducing CO_2 emissions. The two collaborating universities provided expertise in mathematical optimization. By designing more efficient shipping routes and advancing logistics handling, the project reduced energy consumption by three to five per cent. The research collaboration developed intelligent IT-based planning tools for the shipping industry that helped to reduce energy consumption and its negative environmental impacts.

5.2.2. Green service/product innovation

Two prominent examples of green service/product innovation found at Maersk Line are the Cradle-to-Cradle Passport database and retrofitting.

- The **Cradle-to-Cradle Passport** was developed with DSME Shipyards to improve the quality of recycled steel and use better-recycled materials in ship building. The shipping industry mainly depends on two finite resources: steel and oil. While the shipping industry has been searching for new energy sources and addressing the challenges of high oil prices through efficiency improvement, steel recycling continues to be a challenge for shipping firms. The recycling concept originated from the cradle-to-cradle principle of the Environmental Protection Encouragement Agency (EPEA), which refers to the optimal lifecycle of the materials used in a product. The Cradle-to-Cradle Passport has been implemented on all Triple-E class vessels. Information on approximately 95% (by weight) of the materials used to build a ship is documented in detail, stored on an online database, and updated throughout the life of the ship. Maersk Line can then locate and recycle the materials and components to a greater extent and achieve a better-quality level.
- **Retrofitting** enables Maersk Line to increase fuel efficiency and vessel capacity, as well as reduce CO_2 emissions. Maersk Line has often retrofitted and modified the designs of its existing vessels. In 2013, Maersk Line adopted a new and radical approach to simultaneously perform multiple retrofits on an entire vessel class. A total of 137 vessels (121 owned vessels and 16 chartered-in vessels) were retrofitted. For instance, to retrofit a Maersk Stepnica Class (8,379 TEU) vessel, first, the navigation bridge is cut off and then raised. The container capacity of the vessel can thus be increased by ten per cent. Second, the engine is modified to enhance its efficiency at low speeds, and the bulbous bow is removed and replaced with a smaller one. The fuel consumption of the vessel is thus reduced by five per cent accordingly. This "retrofitting" of the Stepnica Class vessels reduces fuel consumption by 15% per container, which is as efficient as some newly built vessels.

5.2.3. Green process innovation

The green process innovations of Maersk Line include ECO-Voyage and the Responsible Procurement Programme.

- **ECO-Voyage** is a novel vessel performance optimization tool developed through the collaboration of MMT with several Maersk Line captains. ECO-Voyage employs real-time weather data to improve vessel schedule reliability and fuel efficiency across the fleet. This novel innovation continuously analyzes information on the estimated times of arrival, expected ocean currents, draughts, wind, and waves along a planned route in order to determine the efficiency of the propulsion plant and the economical speed of the vessel throughout a voyage. The information is shared with the fleet via a central server, and the vessels that are sailing on the same route can thus study the data and the performance of other vessels. The tool enables the captains of Maersk Line to identify alternative voyage plans and compare their differences in fuel consumption. Moreover, it enables large vessels to prepare a dual speed voyage to optimize the use of the waste heat recovery system, which is a technological innovation. The potential annual saving on fuel with the use of ECO-Voyage is approximately 0.5 - 1.0%.
- The **Responsible Procurement Programme** came about when the value of the goods and services purchased by Maersk Line reached US$13 billion in 2013. Responsible procurement and supplier performance thus became an important issue. By working with responsible suppliers, Maersk Line could mitigate the risks of accidents, delays, and government penalties. Therefore, Maersk Line implemented the Responsible Procurement Programme, in which suppliers are assessed against the company's Third-Party Code of Conduct. The purpose of the programme is not to penalize suppliers. Instead, it focuses on the simultaneous achievement of continuous improvement, capacity building, and risk management through active dialogue with suppliers. At the end of 2013, 746 suppliers had enlisted in the programme, which accounted for 37% of the procurement expenditures of Maersk Line. The purchasing policy of new containers is an example of their responsible procurement. Maersk Line only purchases new containers that are fitted with sustainable container floorboards (e.g., bamboo or FSC-certified wood). In 2013, 78,000 new containers were purchased. The total number of containers fitted with sustainable floorboards reached 1 million TEUs, equal to 34% of all of the containers at Maersk Line.

5.2.4. Green technological innovation

The practices of Maersk Line that demonstrate green technological innovation consists of their waste heat recovery system and the ballast water treatment system.

- The **waste heat recovery system** is integral for the energy efficiency of the Triple-E vessels which transforms waste heat into a source of power. The system captures the hot exhaust gas that is emitted from the engines to produce extra energy for propulsion. The exhaust gas that leaves the engine has a very high heat potential. When this heat is utilized in an exhaust gas boiler, it becomes possible to generate steam. The waste heat system then supplies the steam to a turbine that is connected to a generator, which then recovers the electrical energy. Through the system, the waste heat of the engine is converted into a valuable source of electricity, and in the process, reduces the CO_2 emissions of the ship. Such a system has been installed on 78 Maersk Line vessels, including 8 E-class vessels and 20 Triple-E class vessels. With the installation of such an advanced waste heat recovery system, the CO_2 emissions of the Maersk Line vessels were reduced by approximately nine per cent while MMT utilized the gained knowledge to further advance the design of the system and raised the overall fuel saving to more than 22%.
- The **ballast water treatment system** was invented by Maersk Line with DESMI Ocean Guard to mitigate the adverse environmental impacts of ballast water discharge and comply with international regulations. Vessels carry ballast water to provide stability and aid with steering during the voyage. Discharging ballast water that originates from one marine environment into another can introduce invasive species into the marine ecosystem, thus potentially impacting the ecological balance. In 2004, the IMO adopted the Ballast Water Management Convention, which requires the installation of a ballast water treatment system on board of all ships in international trade. This novel energy efficient system combines ozone gas with UV radiation in a three-step process to purify the ballast water. The first treatment used is pressurized filtration, which removes most of the organisms above 50 microns, as well as the bulk of the sediment in the water. The second step is to use UV radiation with low-pressure lamps. The low-pressure lamps reduce the energy consumption of the system by 30-50% in comparison with competing systems that use medium-pressure UV lamps. The third step is to use low-pressure lamps to generate ozone, which is injected into the ballast water stream after the UV treatment. Ozone is one of the most dominant oxidants that aid the system with treatment even in extremely challenging water conditions at a full flow-rate.

5.3. **Data analysis - Firm performance**

In this study, firm performance is examined from both environmental and economic perspectives. Two levels of analysis are carried out to assess firm performance. In the above, details on the firm-level analysis in which the adoption of GI in the Maersk Line is investigated have been provided. In the following, eco-efficiency indicators are used to determine the correlation between the adoption of GI and the environmental performance of Maersk Line. Moreover, the details for an industry-level analysis that compares the economic performance of Maersk Line with other leading liner carriers in the industry will be outlined. Evidence to validate a research model might be qualitative or quantitative or both (Eisenhardt, 1989). Therefore, in this study, a qualitative approach (i.e., case study) is used to illustrate the pursuit of GI by Maersk Line and a quantitative approach (i.e., eco-efficiency indicators and DEA analysis) to examine the association between the adoption of GI and the environmental and economic performances of a firm.

5.3.1. **Economic performance**

To assess the operational efficiency of liner carriers, it is useful to identify the efficient liner carriers by performing a DEA. In a DEA, efficiency is defined as the ratio of the output to the input of a production or operation system, and a firm under study is called a decision-making unit (DMU). The DEA is applied, which is a quantitative analytical tool, to measure and evaluate the efficiency of the organizations under study (Boussofiane et al., 1991), and identify the efficient DMUs. DEA has become a useful analytical tool for measuring and evaluating firm performance. DEA is a benchmarking technique based on linear programming to convert input and output measures into a single comprehensive measure of performance in terms of an “efficiency score” for each group of DMUs. The DEA, as proposed by Charnes, Cooper, and Rhodes (CCR) (1978), involves the derivation of efficiency scores for a set of comparable DMUs, relative to one another. The CCR model assumes a constant return to scale (CRS) for all the inputs and outputs. The input-oriented model focuses on how many inputs can be reduced while maintaining the same level of output. The CCR model has been used as a valid tool to measure operational efficiency in previous shipping research (see for e.g., Tongzon, 2001; Lun and Cariou, 2009; Lun, 2011; Lun and Marlow, 2011). In this study, the CCR model is used to examine and compare the economic performance of the sample firms. There are advantages of using the DEA because (1) it does not require the relative importance or weights of the input and output measures, and (2) each input and output variable can be measured independently in any useful unit, without being transformed into a single metric (Shimshak et al., 2009).

Measuring performance is a complex endeavour that requires more than a single criterion for characterization; a multi-factor performance measurement model can thus provide better characterization (Chakravarthy, 1986). The proper selection of the input and output variables used in a performance model can be guided by the pertinent literature (e.g., Seiford and Zhu, 1999; Zhu, 2000; Düzakin and Düzakin, 2007). The economic performance model that measures the efficiency and cost-effectiveness of a firm consists of two inputs, namely operating costs and shipboard capacity, and two outputs, namely profit and throughput. It was found that Maersk Line has developed diverse GI to improve the eco- and operational efficiencies of their shipping activities, optimize route planning and scheduling, and better utilize resources (e.g., vessels, equipment and technologies, containers, etc.), which, in turn, enable Maersk Line to reduce its operating costs and increase gross profit with reductions in energy consumption, bunker costs, and unit cost of container transportation. Table 5 shows examples of GI at Maersk Line and implications for its economic performance.

A sample of 12 leading liner carriers is used in this study, namely Maersk Line, Hapag-Lloyd, APL, CSCL, OOCL, HMM, Yang Ming, K-Line, Hanjin, COSCO, CSAV, and ZIM. Each of these firms is treated as a DMU. The total shipboard capacity of the 12 sample firms is 43.48% of the entire shipboard capacity in the world. This means that 43.48% of the population is used to evaluate the performance implications of GI. The secondary and objective data (i.e., the input and output data) are extracted from the annual and financial reports of the sample firms, and the UNCTAD *Review of Maritime Transport*, which is generally regarded as a valid and reliable source. Moreover, as the sample of DMUs consists of 12 liner carriers, the rule-of-thumb requirements for an acceptable sample size in DEA analysis are met. Gould and Roll (1989), and Dyson et al. (2001) stated that the number of DMUs should be at least twice the number of input and output variables. Bowlin (1998) emphasized on the need to have at least three times the number of DMUs as there are input and output variables. In this study, the model consists of two input variables, two output variables, and 12 DMUs, so all three of the aforementioned rule-of-thumb requirements are addressed, and the developed DEA model should hold high construct validity. Furthermore, in a basic DEA model, the values of the numbers need to be strictly positive since analysis cannot be completed with zero or negative values. This study follows the data scaling method in Lovell (1995) and transforms all positive and negative gross profit values, which represent losses in the data set, into a 0 to 1 scale prior to analysis. Sarkis (2007) argued that this method would maintain translation invariance and not cause any apparent uneven improvements in the output values. DEA-Solver software was used to analyze the data. Table 6 shows the complete data set. The output and input variables used in this analysis are defined as follows.

- **Input variables**:

1) Operating cost - comprises cargo, vessel, voyage, equipment repositioning, and terminal operating costs.
2) Capacity - total capacity of all the container-carrying vessels known to be operated by liner carriers (United Nations Conference on Trade and Development, 2015).

- **Output variables**:

1) Gross profit - difference between operating revenue and operating cost.
2) Throughput - total cargo volume transported in all trades and modes.

Table 5: Examples of GI at Maersk Line and implications for its economic performance

Green innovation initiatives at Maersk Line	Economic performance implications	Description*
▪ ENERPLAN (Energy Efficient Transport Planning) research project ▪ ECO-Voyage	▪ Operational cost savings through operational efficiency improvements that are driven by green innovation adoption.	▪ "The EBIT margin gap to peers was estimated at around 9% which was significantly above the 5% ambition level. The achievement came from ***5.4% lower unit costs*** mainly due to ***improved network efficiencies*** and lower bunker price. ***Efficiencies were achieved*** through increased volumes in line with market as well as ***continued vessel network optimization*** and ***active capacity management***…… Bunker consumption in kg/FFE was reduced by 7.9%." (A.P. Moller - Maersk A/S, 2015, p.12) ▪ "Profit was USD 461m compared to a loss of USD 553m in 2011. The improvement was driven by increase in freight rates and ***operational cost savings mainly from vessel network efficiencies***. The result ***improved the return on invested capital (ROIC), from negative 3.1% in 2011 to positive 2.4% in 2012***." (A.P. Moller - Maersk A/S, 2013a, p.36-37)
▪ Retrofitting ▪ ECO-Voyage ▪ Waste heat recovery system	▪ Fuel/energy cost saving through eco-efficiency improvement that is driven by green innovation adoption.	▪ "Total cost per FFE decreased by 10.6% to 2,731 USD/FFE mainly driven by ***decreasing bunker consumption*** and ***operational cost savings***. Maersk Line continued to ***utilize slow and equal steaming to reduce emissions*** and ***despite 4.1% volume growth Maersk Line reduced bunker consumption by 12.1%...... total bunker costs decreased by 21.0% to USD 5.3bn compared to 2012***." (A.P. Moller - Maersk A/S, 2014, p.27) ▪ "Maersk Line continued to ***utilize super slow steaming to reduce emissions and save bunker cost***…… total bunker costs decreased by 1% to USD 6.7bn compared to 2011." (A.P. Moller - Maersk A/S, 2013a, p.37) ▪ "Bunker consumption per TEU/day decreased by 2%...... With the ***aim of reducing emissions and costs***, Maersk Line is continuously seeking new ways of ***optimizing bunker consumption***. One initiative introduced during 2011 was ***super slow steaming*** which is primarily being used on the backhaul trades." (A.P. Moller - Maersk A/S, 2012, p.23) ▪ "***Slow steaming***, which was implemented by Maersk Line in 2009 for the Group's container vessels to ***reduce bunker consumption and environmental impacts***, became standard in 2010 for major container shipping companies." (A.P. Moller - Maersk A/S, 2011a, p.17) ▪ "In an effort to ***reduce costs and greenhouse gas emissions, service speed was reduced further in 2009***……, Combined with a number of other measures, this ***cut fuel consumption by 12%. Total fuel costs were reduced by 42% relative to 2008***, reflecting falling fuel prices during the year and ***lower consumption***." (A.P. Moller - Maersk A/S, 2010a, p.18) ▪ "Total fuel costs rose by 43%, affected negatively by an increase in the average bunker price of 51%, ***but positively affected by approximately 5% lower fuel consumption due to a large number of fuel reduction measures, including service speed reductions***." (A.P. Moller - Maersk A/S, 2008, p.17)

* Sources: A.P. Moller - Maersk A/S, *Annual Report*, various years.

Table 6: Data used to evaluate economic performance of liner carriers (2007 – 2015)

Operator	2015				2014				2013			
	Input		Output		Input		Output		Input		Output	
	Operating Cost**	Capacity*	Gross Profit**	Throughput*	Operating Cost	Capacity	Gross Profit	Throughput	Operating Cost	Capacity	Gross Profit	Throughput
Maersk Line	20,405.00	2,526.49	3,324.00	19,044.00	23,139.00	2,505.94	4,212.00	18,884.00	22,883.00	2,149.52	3,313.00	17,600.00
Hapag-Lloyd	9,469.97	732.66	344.43	7,401.00	8,052.66	762.61	993.94	5,907.00	7,678.09	639.15	1,056.02	5,496.00
APL	5,021.95	545.85	388.05	4,938.00	7,945.77	629.48	671.01	5,822.00	8,247.25	570.50	583.94	6,030.00
CSCL	5,157.80	751.51	123.22	7,809.42	5,674.16	750.64	201.64	8,093.00	5,807.13	564.15	-336.59	8,191.20
OOCL	5,262.43	520.33	691.02	5,576.00	5,875.80	510.12	645.79	5,586.00	5,772.05	453.04	459.54	5,294.00
HMM	4,946.40	399.79	44.12	3,031.34	6,293.38	392.87	144.29	3,302.00	6,481.56	364.37	-171.72	3,120.00
Yang Ming	3,909.56	487.77	-24.11	4,018.36	4,243.28	561.17	181.13	3,960.00	4,106.99	363.06	-137.91	3,560.56
K Line	10,294.55	397.62	744.97	2,059.00	10,215.48	368.75	1,038.76	3,145.00	10,913.69	341.85	980.27	3,016.00
Hanjin	NA#	NA	NA	NA	7,798.98	671.21	420.55	4,552.89	9,233.48	555.28	203.19	4,747.70
COSCO	8,870.80	854.17	347.03	9,827.68	10,240.62	879.70	655.38	9,437.54	10,811.32	715.22	-143.92	8,701.58
CSAV	NA##	NA	NA	NA	2752.24	320.27	-10.78	1774.15	3,210.42	259.39	-4.47	1,879.26
ZIM	2,775.00	296.55	216.10	2,308.00	3,165.46	305.19	131.28	2,360.00	3,555.00	282.41	127.00	2,519.00

Operator	2012				2011				2010			
	Input		Output		Input		Output		Input		Output	
	Operating Cost	Capacity	Gross Profit	Throughput	Operating Cost	Capacity	Gross Profit	Throughput	Operating Cost	Capacity	Gross Profit	Throughput
Maersk Line	24,938.00	2,104.83	2,179.00	17,000.00	24,099.00	1,820.82	1,009.00	16,200.00	19,515.00	1,746.64	4,507.00	14,600.00
Hapag-Lloyd	7,951.67	648.98	850.69	5,255.00	7,350.90	560.20	1,144.14	5,198.00	6,383.50	470.17	1,848.37	4,947.00
APL	8,988.20	600.17	523.43	6,176.00	8,819.46	591.74	391.24	5,958.00	8,152.91	524.71	1,269.18	5,662.00
CSCL	5,302.82	557.17	-73.35	8,030.43	4,701.34	460.91	-328.82	7,438.00	4,400.72	457.13	740.89	7,208.06
OOCL	5,806.72	397.43	652.34	5,217.00	5,484.26	374.71	527.58	5,033.14	4,671.09	290.35	1,362.32	4,767.67
HMM	7,158.65	314.77	-310.86	3,003.00	6,643.74	285.18	-158.20	2,964.00	6,330.06	259.94	659.79	2,903.00
Yang Ming	3,890.47	343.48	-119.10	3,696.04	3,549.93	322.72	-313.58	3,472.59	3,317.45	317.30	523.28	3,205.75
K Line	11,049.64	342.57	1,015.98	3,244.00	11,520.42	347.99	309.62	3,165.00	10,366.77	325.28	1,480.31	3,094.00
Hanjin	9,074.78	497.64	325.72	4,477.04	8,432.99	447.33	-159.37	4,167.21	7,237.64	400.03	863.18	3,705.95
COSCO	11,432.09	624.06	-613.15	8,016.24	13,867.88	565.73	-765.84	6,910.04	12,425.74	495.94	1,826.50	6,215.37
CSAV	3,388.41	348.04	43.37	1,933.41	5,630.54	382.79	-834.62	3,127.65	4,742.02	195.88	472.61	2,894.16
ZIM	3,766.00	304.07	194.00	2,407.00	3,768.00	281.53	16.00	2,423.00	3,315.00	215.73	402.00	2,219.00

Operator	2009				2008				2007			
	Input		Output		Input		Output		Input		Output	
	Operating Cost	Capacity	Gross Profit	Throughput	Operating Cost	Capacity	Gross Profit	Throughput	Operating Cost	Capacity	Gross Profit	Throughput
Maersk Line	20,232.00	1,740.94	-303.00	13,800.00	26,404.00	1,638.90	2,262.00	12,400.00	23,819.00	1,573.55	2,002.00	12,400.00
Hapag-Lloyd	4,329.70	496.72	404.39	4,637.00	8,762.67	491.95	380.44	5,546.00	8,149.03	454.53	350.99	5,454.00
APL	6,535.95	470.90	-20.37	4,578.00	8,328.98	394.80	956.15	4,930.00	6,865.60	342.46	1,294.37	4,716.00
CSCL	3,731.42	431.58	-841.18	6,741.79	4,872.03	418.82	147.91	6,942.15	4,491.95	387.17	642.41	7,298.83
OOCL	4,273.78	364.38	76.41	4,158.49	5,658.20	351.54	872.66	4,834.69	4,645.84	275.06	1,005.19	4,601.63
HMM	5,137.96	258.65	-348.76	2,511.00	6,611.03	194.35	650.92	2,657.00	5,023.23	157.21	456.28	2,367.00
Yang Ming	2,820.76	317.47	-494.71	2,784.08	3,555.16	276.02	9.47	3,075.08	3,391.10	240.43	129.87	3,146.17
K Line	8,856.65	309.50	150.58	3,081.00	11,252.63	293.32	1,414.76	3,103.00	11,248.80	267.99	2,036.44	3,200.00
Hanjin	524.94	365.61	-1.77	3,219.79	7,886.64	321.92	602.81	3,426.25	6,915.30	337.38	548.73	3,624.07
COSCO	10,599.98	491.58	-576.18	5,234.29	15,791.27	426.81	3,178.36	5,792.59	11,470.08	390.35	3,277.99	5,708.55
CSAV	3,486.75	141.96	-453.04	1,790.38	4,688.55	108.93	198.29	2,191.43	3,786.48	117.87	364.51	2,129.04
ZIM	2,848.00	215.72	-399.00	1,800.00	4,262.00	243.07	63.00	2,520.00	3,531.00	203.23	278.00	2,379.00

* Thousands of TEUs

** US$ Million

\# Data not available due to the bankruptcy of Hanjin

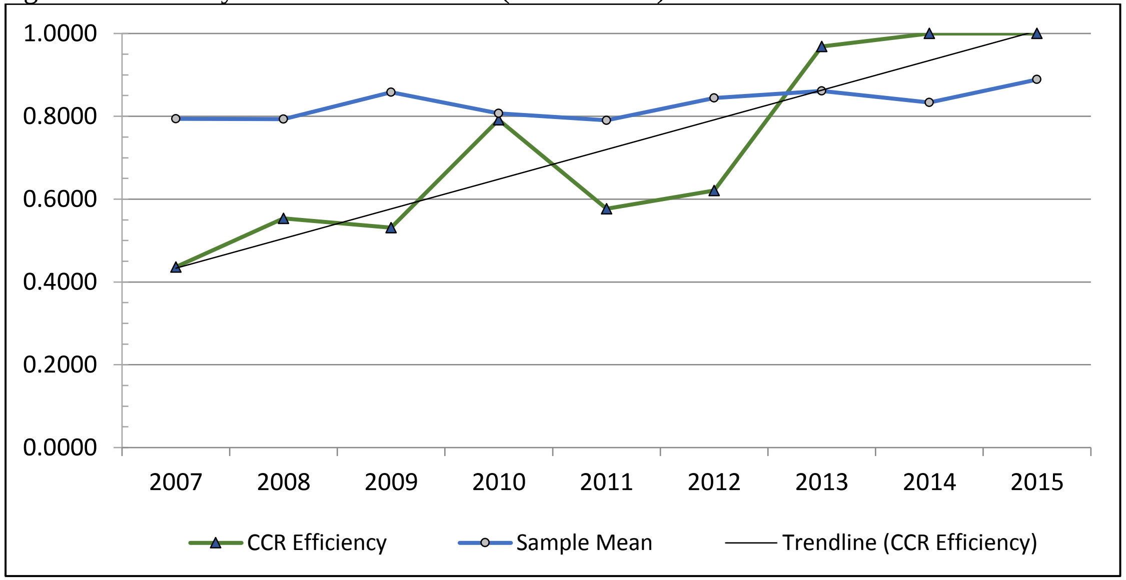
\## Data not available due to the merger with Hapag-Lloyd

A longitudinal analysis of the performance of Maersk Line was conducted over the period of 2007 to 2015, during which Maersk Line actively pursued GI. A longitudinal analysis involves repeated observations of the same items and compares the results over a period of time. The year 2007 was used as the starting year of analysis because the innovation department of Maersk Line was established in 2007 and most of the GI projects were launched and completed between 2007 and 2015. Thus, the study tracked the variations in the performance of Maersk Line over this period of time. Among the 12 sample liner carriers, Maersk Line ranked the highest in terms of total capacity, throughput, profit level, and operating cost. The DEA results in Table 7 show that, over the period of 2007 to 2015, Maersk Line obtained an efficiency score of 1 in 2014 and 2015. From 2007 to 2013, its scores were 0.4362, 0.5534, 0.5309, 0.7919, 0.5764, 0.6207, and 0.9690, respectively. With the use of the DEA, each DMU is evaluated by comparing its performance with that of the other DMUs. The DEA assigns an efficiency score of 1 (i.e., 100%) to the efficient DMUs. Inefficient DMUs receive lower efficiency scores depending on how efficiently they use their inputs to generate outputs compared with the efficient DMUs. One of the greatest values in using a DEA is the identification of a set of efficient DMUs that constitutes a benchmark for the inefficient DMUs. This set of efficient DMUs provides targets for the inefficient DMUs so that they improve their performance. The results indicate that Maersk Line was an inefficient DMU from 2007 to 2013 as its scores were lower than 1 (which ranged from 0.4362 to 0.9690), and became an efficient DMU in 2014 and 2015 (with efficiency scores of 1) when two inputs (i.e., operating cost and capacity) and two outputs (i.e., gross profit and throughput) were used to evaluate its firm performance against other DMUs. To examine the performance change over the period of time since the adoption of GI, the efficiency scores significantly improved in comparison with the average score of the sample DMUs (see Figure 4), even though Maersk Line was an inefficient DMU in the first seven years that the company adopted GI (i.e., 2007 to 2013), particularly from 2009 to 2010, and from 2012 to 2013. In addition, in terms of ranking of the DMUs, the results also indicate that Maersk Line substantially improved over the assessment period. Its rankings over the periods of 2007-2009 were 12, 2010-2012 were 6 to 12, and 2013-2015 were 1 to 5. The results of DEA suggest that, first, although Maersk Line is an inefficient DMU from 2007 to 2013, its efficiency and performance improved as a result of improving its eco-efficiency through the use of GI. Maersk Line has consequently evolved into an efficient carrier in recent years. Second, although different DMUs may have their own success factors or competitive advantages which eventually affect their operating efficiency and cost-

Table 7: DEA results

DMU No.	DMU Name	CCR Efficiency Score																	
		2015	Rank	2014	Rank	2013	Rank	2012	Rank	2011	Rank	2010	Rank	2009	Rank	2008	Rank	2007	Rank
1	Maersk Line	1.0000	1	1.0000	1	0.9690	5	0.6207	12	0.5764	11	0.7919	6	0.5309	12	0.5534	12	0.4362	12
2	Hapag-Lloyd	0.8866	6	0.8583	6	1.0000	1	0.8446	7	1.0000	1	0.9928	3	0.9935	6	0.6723	8	0.6365	9
3	APL	0.8429	7	0.8446	7	0.9039	6	0.7606	9	0.7093	9	0.6594	10	0.7928	7	0.8079	6	0.8113	7
4	CSCL	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1
5	OOCL	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	1.0000	1	0.9799	4
6	HMM	0.6590	10	0.7675	8	0.6359	12	0.6744	10	0.7466	8	0.6801	9	0.7746	9	0.8295	5	0.8440	6
7	Yang Ming	0.7659	8	0.7095	9	0.7374	9	0.7906	8	0.7996	6	0.7078	8	0.7005	11	0.6665	9	0.6941	8
8	K Line	1.0000	1	1.0000	1	1.0000	1	1.0000	1	0.9045	4	0.9699	4	1.0000	1	0.7281	7	0.9049	5
9	Hanjin	-	-	0.6194	11	0.6903	10	0.6739	11	0.6312	10	0.5642	12	1.0000	1	0.6589	10	0.5901	11
10	COSCO	1.0000	1	0.9797	5	0.8654	7	0.8912	5	0.7569	7	0.7849	7	0.7196	10	1.0000	1	1.0000	1
11	CSAV	-	-	0.5117	12	0.6844	11	0.8896	6	0.5063	12	0.8998	5	1.0000	1	1.0000	1	1.0000	1
12	ZIM	0.7334	9	0.7093	10	0.8502	8	0.9838	4	0.8534	5	0.6292	11	0.7847	8	0.6013	11	0.6307	10
	Sample Avg.	0.8888		0.8333		0.8614		0.8441		0.7904		0.8067		0.8580		0.7932		0.7940	

Figure 4: Efficiency score of Maersk Line (2007 – 2015)



effectiveness, the adoption of GI may lead to important competitive advantages of a DMU.

5.3.2. **Environmental performance**

In examining the environmental performance of Maersk Line, it was observed that they pursue different components of GI (i.e., green management, service/product, process, and technological innovations) to reduce CO_2 emissions in their container transport operations, enhance energy efficiency tracking on vessels, and optimize capacity and shipping network efficiency. These, in turn, support the eco-efficiency improvement of Maersk Line and reductions in CO_2 emissions and energy intensity of their shipping activities. Table 8 shows examples of the GI practices of Maersk Line and the implications for its environmental performance.

To track the variations in the environmental performance of Maersk Line over the period of 2007 to 2015, eco-efficiency indicators suggested by van Berkel (2007) and Verfaillie et al. (2000) were used. The concept of eco-efficiency refers to the creation of more products or services while consuming fewer resources and creating less waste and pollution. A firm is encouraged to seek environmental improvements that yield parallel economic benefits (Côté et al., 2006). An eco-efficiency indicator is a ratio that measures the environmental influences of production outputs (e.g., tons of CO_2 emissions or energy consumption per TEU). Many eco-efficiency indicators have been proposed that encompass both GHG emissions and energy consumption. For the purpose of this study, eco-efficiency indicators that measure fuel consumption, and CO_2, NO_x, and SO_x emission intensities are adopted. A firm-level longitudinal analysis was conducted to track changes in the environmental performance of Maersk Line during 2007-2015, and determine the implications of improvements in environmental performance for operational efficiency and cost-effectiveness (i.e., DEA scores). The data from the sustainability reports and annual reports of A.P. Moller - Maersk A/S were extracted for analysis, and the complete data set is presented in Table 9. It is evident from the results in Table 9 that, over the period of 2007 to 2015, all of the eco-efficiency indicators have steadily decreased. In 2007, the transporting of one TEU consumed 0.942 ton of fuel oil but emitted 2.9532 tons of CO_2, 0.0731 ton of NO_x, and 0.044 ton of SO_x. With the establishment of the innovation department and the launching of various GI initiatives, the eco-efficiency performance of Maersk Line significantly improved (see Figure 5). In 2015, the transporting of one TEU required only 0.4656 ton of fuel oil and emitted 1.4689 tons of CO_2, 0.0369 ton of NO_x, and 0.024 ton of SO_x. In comparing the eco-efficiency of the indicators between 2007 and

2015, it is obvious that Maersk Line achieved a 51% saving in fuel consumption, 50% reductions in the emission of CO_2 and NO_x, and 45% reduction in the emission of SO_x. In view of the considerable improvements in eco-efficiency, operational efficiency, and cost-effectiveness at Maersk Line upon its active pursuit of GI, it is concluded that there is a significant positive association between the adoption of GI, and the environmental and economic performances of a firm.

Table 8: Examples of GI at Maersk Line and implications for its environmental performance

Green innovation initiatives at Maersk Line	Environmental performance implications	Description*
▪ Green alliance with customers to initiate new green shipping services	▪ CO_2 emissions and energy intensity reduction through the development of innovative customer relationship management.	▪ "In 2014, Maersk Line entered into the…… ***multi-annual agreements with a customer*** committing ***Maersk Line to a tailored CO_2 target in alliance with the customer***. For example, ***Maersk Line*** and ***Philips*** signed a five-year Carbon Pact in 2015, with ***Maersk Line undertaking to cut CO_2 emissions by 20% for every Philips container moved*** between 2016 and 2020, as well as ***integrating CO_2*** and ***other sustainability indicators*** into the ***commercial supplier relationship***." (A.P. Moller - Maersk A/S, 2016, p.11)
▪ Maersk Maritime Technology ▪ Maersk Ship Performance System	▪ CO_2 emissions and energy intensity reduction through the installation of a novel ship performance system.	▪ "By the end of 2012, Maersk Line's ***ship performance system was installed on approximately 90% of the chartered fleet***. The ***new improved energy efficiency tracking*** on the charter fleet ***has saved approximately 142,000 tonnes of fuel*** and ***442,000 tonnes of CO_2*** in 2012." (A.P. Moller - Maersk A/S, 2013b, p.57)
▪ Maersk Ship Performance System ▪ Retrofitting ▪ ECO-Voyage	▪ CO_2 emissions and energy intensity reduction, and operational efficiency improvement through the implementation of shipping network optimization and innovative green ships.	▪ "The main contributors to ***Maersk Line's continuous reductions in CO_2 emissions*** are ***operational optimisation through network and data efficiencies***, ***new more efficient vessels*** coming into service and ***retrofitting of existing vessels***. Our Triple-E vessels made up an estimated ***5 percent of the reductions achieved*** in 2015. A ***retrofitting*** initiative raises the bridge on 18 Maersk Line vessels ***allowing for an extra layer of containers, which reduces emissions***." (A.P. Moller - Maersk A/S, 2016, p.11)
▪ Retrofitting ▪ ECO-Voyage	▪ Eco-efficiency improvement and emissions intensity reduction through the implementation of innovative shipping processes and green technologies.	▪ "From 2007 to 2010 we ***reduced our CO_2 emissions per container moved by 14.5%*** by improving our operational efficiency, most importantly ***through the application of slow steaming***, which alone has ***cut CO_2 emissions by approximately 7%*** in just 18 months." (A.P. Moller - Maersk A/S, 2011b, p.53) ▪ "The increased use of ***slow steaming*** is the main contributor to the positive result. The average speed has been reduced by 2 knots over the course of the year. ***Capacity was also optimised*** as vessels were taken out on the Europe-Asia trade lane…… As a result, ***absolute CO_2 and SO_x emissions decreased by 2.4 million tonnes and 42,000 tonnes respectively***…… ***Technical upgrades*** and the delivery of ***new and more efficient vessels*** are expected to ***lead to further reductions in fuel and CO_2*** in the near future." (A.P. Moller - Maersk A/S, 2013b, p.56)
▪ Retrofitting ▪ Waste heat recovery system	▪ CO_2 emissions intensity reduction through the implementation of green products (i.e. retrofitted vessels) and technological innovations (i.e., waste heat recovery system).	▪ "***Technological innovation further increases our ability to reach our CO_2 reduction targets***. Maersk Line is aggressively pursuing technical solutions including ***waste heat recovery systems***, which are standard on all our new ships (***reducing CO_2 emissions by 10%***). Two other examples are ***optimised hull designs*** (***resulting in an almost 8% reduction in CO_2 emissions***), and auto-tuning of our main engines." (A.P. Moller - Maersk A/S, 2010b, p.76)

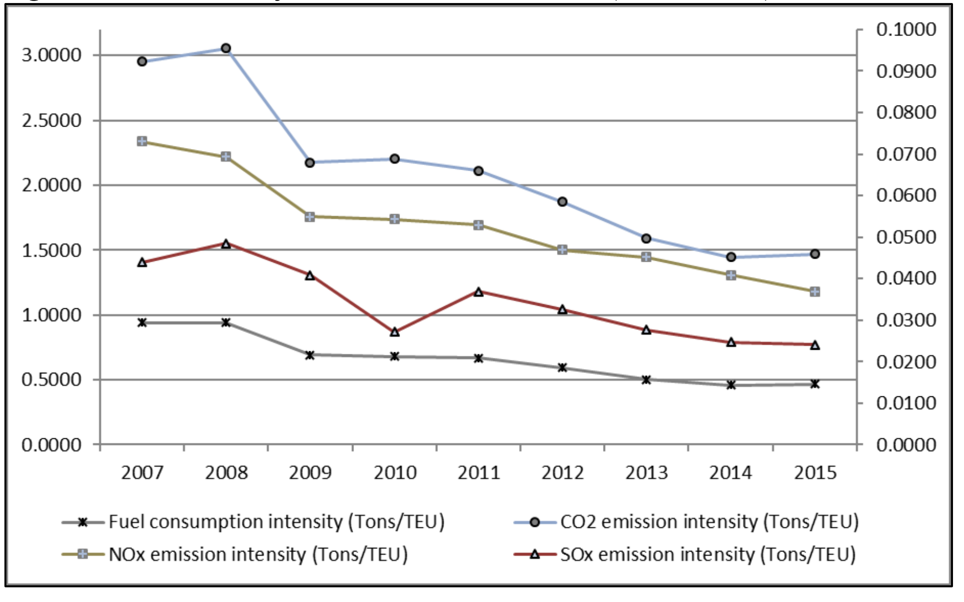
* Sources: A.P. Moller - Maersk A/S, *The A.P. Moller - Maersk Group's Sustainability Report*, various years.

Table 9: Data used to evaluate environmental performance of Maersk Line (2007 – 2015)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Throughput*	12,400.00	12,400.00	13,800.00	14,600.00	16,200.00	17,000.00	17,600.00	18,884.00	19,044.00
Fuel consumption (Fuel oil + Diesel) **	11,681.00	11,687.37	9,550.59	9,914.00	10,820.00	10,059.00	8,853.00	8,707.00	8,866.00
CO_2 emission**	36,619.66	37,889.04	30,002.33	32,149.00	34,187.00	31,792.00	28,014.00	27,332.00	27,973.00
NO_x emission**	905.96	859.27	758.08	793.00	858.00	797.00	795.00	771.00	702.00
SO_x emission**	545.39	602.00	563.12	397.00	597.00	555.00	488.00	466.00	458.00
Eco-efficiency indicator#									
(1) Fuel consumption intensity^	0.9420	0.9425	0.6921	0.6790	0.6679	0.5917	0.5030	0.4611	0.4656
(2) CO_2 emission intensity^	2.9532	3.0556	2.1741	2.2020	2.1103	1.8701	1.5917	1.4474	1.4689
(3) NO_x emission intensity^	0.0731	0.0693	0.0549	0.0543	0.0530	0.0469	0.0452	0.0408	0.0369
(4) SO_x emission intensity^	0.0440	0.0485	0.0408	0.0272	0.0369	0.0326	0.0277	0.0247	0.0240

* Thousands of TEUs
** Thousands of Tons
\# (1) Fuel consumption intensity = Fuel consumption/Throughput; (2) CO_2 emission intensity = CO_2 emission/Throughput; (3) NO_x emission intensity = NO_x emission/Throughput; and (4) SO_x emission intensity = SO_x emission/Throughput.
^ Tons per TEU

Figure 5: Eco-efficiency indicators of Maersk Line (2007 – 2015)



6. Quantitative survey study

6.1. Development of survey questionnaire

6.1.1. Operationalization of GI constructs

GI is one of the major research areas in environmental and operations management. Unfortunately, studies on the measurement of specific innovations remain fragmented. An extensive search for existing measures produced limited results, particularly in the context of the shipping industry. Such a deficiency has led to the development of GI measures for this study based on conceptual definitions of the constructs from an exploratory case study, and the extant literature. To develop measurement scales that operationalize the GI constructs, a traditional approach suggested by Churchill (1979) is adopted in this study. This approach was further developed by Gerbing and Anderson (1988) and commonly used in operations management studies. All constructs were measured with multiple item scales. The reason for using multiple items for each latent construct (variable) is because this provides a greater degree of reliability than using singular items (Koufteros et al., 2007).

Because the term innovation is inherently ambiguous, evaluating GI adoption relies on qualitative judgements and knowledge which may be context-specific (Nelson & Winter, 1977; Quinn, 1985). Firms generally evaluate their innovations with general standards that are detached from the rich and complex reality of innovation (Dougherty and Corse, 1995). Moreover, shipping firms may implement diverse sector-specific GI (e.g., innovative ship engines, port automation systems) that may not apply to other sectors. Therefore, the measurement items were intentionally developed as generic in nature rather than specific to any particular sector of the shipping industry. Instead, the definitions and examples of GI were enclosed with the cover letter to the potential respondents for better understanding.

Specifically, a list of 19 measurement items for the four constructs of GI adoption, i.e., green management innovation (GMI), green service innovation (GSI), green process innovation (GPI), and green technological innovation (GTI) was developed based on a combination of a case study, in-depth interviews with shipping professionals, and an extensive review of the relevant literature (e.g., Organisation for Economic Co-operation and Development (1997, 2005); Chen et al. (2006); Chen (2008); Cheng and Shiu (2012)). The respondents were asked to assess the extent to which GI is adopted in their company on a five-point Likert scale, where 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high.

GMI1	Implements environmental management systems to manage shipping operations
GMI2	Collects updated information on green innovation relevant to the shipping industry
GMI3	Participates in research and development activities relevant to green innovation
GMI4	Communicates green innovation information with employees/customers
GMI5	Shares green shipping experiences among various departments involved in the implementation of green innovation
GSI1	Initiates shipping services to prevent pollution
GSI2	Initiates shipping services to save energy/resources
GSI3	Introduces novel shipping services to prevent pollution
GSI4	Introduces novel shipping services to save energy/resources
GSI5	Redesigns green shipping services to enhance environmental operations
GSI6	Introduces recovery/recycling "end-of-life" shipping equipment
GPI1	Reviews and modifies shipping processes to prevent pollution
GPI2	Reviews and modifies shipping processes to save energy/resources
GPI3	Uses novel shipping processes to prevent pollution
GPI4	Uses novel shipping processes to save energy/resources
GPI5	Incorporates recovery/recycling systems into shipping processes
GTI1	Reviews and adopts technologies to support green management, service, and process innovation
GTI2	Uses novel technologies or equipment to support green management, service, and process innovation
GTI3	Uses novel technologies to manage shipping documentation and information, and provide relevant environmental information

6.1.2. Operationalization of GI antecedents

6.1.2.1. External drivers – Stakeholder pressures

The three types of stakeholder pressures, i.e., regulatory, competitive, and customer pressures, were measured with items that capture the essential aspects of the institutional antecedents of the decisions of shipping firms on GI adoption as previously conceptualized and validated. Regulatory pressure (RPI) was assessed with 4 items that were developed based on Horbach et al. (2012) and Lin and Ho (2011). Competitive pressure (COP) was assessed with 4 items that were developed based on Liu et al. (2010) and Zhu et al. (2013). Customer pressure (CUP) was assessed with 4 items that were developed based on Lin and Ho (2011) and Agan et al. (2013). The respondents were asked to assess the extent that they perceived regulatory, competitive, and customer pressures on a five-point Likert scale, where 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree.

RPI1	Adopts green shipping innovation to comply with the regulations/restrictions imposed by government on the industry sector
RPI2	Adopts green shipping innovation to cope with future government environmental legislations
RPI3	Experiences frequent inspections or audits from relevant governing bodies in relation to compliance with environmental rules and regulations
RPI4	Incentives offered by government are significant motivators for the adoption of green shipping innovation
COP1	Adopt green shipping innovation to improve company image
COP2	Adopt green shipping innovation to achieve business objectives
COP3	Adopt green shipping innovation to enhance organizational performance
COP4	Generally believe that the benefits of green shipping innovation adoption outweigh the costs incurred
CUP1	Expect your company to adopt green shipping innovation
CUP2	Will switch to competitors who adopt green shipping innovation
CUP3	Will withhold contracts if company does not meet their environmental requirements
CUP4	Have a clear environmental policy statement

6.1.2.2. Internal drivers – Environmental governance mechanisms

The three types of environmental governance mechanisms, i.e., contractual, relational, and organizational governance, were measured with items that capture the essential aspects of the inter- and intra-organizational control mechanisms that guide and facilitate the GI adoption of shipping firms as previously conceptualized and validated. Contractual governance (CTM) was assessed with 5 items that were developed based on Lusch and Brown (1996) and Cannon et al. (2000). Relational governance (RLM) was assessed with 4 items that involve information exchange, solidarity and flexibility norms, which were developed based on Jap and Ganesan (2000) and Liu et al. (2009). Organizational governance (ORM) was assessed with 6 items that were developed based on Cardinal (2001), Sroufe (2003) and Chen et al. (2009). The respondents were asked to assess the extent that they employed contractual, relational, and organizational governance on a five-point Likert scale, where 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree.

RLM1	Frequently and informally share and exchange information that support the implementation of green shipping operations
RLM2	Notify each other about events or changes that might impact green shipping operations
RLM3	Are flexible enough to cooperatively respond to requests for changes, and make necessary adjustments in green shipping services to cope with changing circumstances
RLM4	Commit to environmental improvements that enable bilateral benefits rather than individual benefits
CTM1	Environmental requirements of business partners for shipping operations
CTM2	Rights and obligations of both parties in the implementation of green shipping operations
CTM3	Methods of monitoring or assessing environmental performance of business partners
CTM4	Methods of handling complaints and disputes in green shipping operations
CTM5	Methods of handling contingencies in green shipping operations
ORM1	Incorporates organizational environmental policies and procedures into business operations
ORM2	Initiates a dedicated department to manage environmental affairs
ORM3	Implements cross-functional cooperation to facilitate the development of green shipping operations
ORM4	Introduces and documents operating procedures to regularly track and monitor the latest information and trends relevant to green shipping
ORM5	Introduces and documents operating procedures to periodically track and evaluate internal environmental performance
ORM6	Introduces and documents operating procedures to identify and resolve environmental problems and non-conformance

6.1.3. Operationalization of organizational performance

The three types of OPs, i.e., environmental, innovation, and economic performances, were measured with items that capture the essential aspects of performance outcomes. Environmental performance (ENP) was assessed with 5 items that were developed based on Sroufe (2003) and Rao and Holt (2005). Innovation performance (INP) was assessed with 4 items that were developed based on Cordero (1990) and Oke et al., (2012). Economic performance (ECP) was assessed with 12 items that were developed based on Dess and Robinson (1984) and Klassen and Laughlin (1996). The respondents were asked to assess the extent that they achieved environmental, innovation, and economic performances on a five-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.

ENP1	Generated less air pollutants/carbon emissions
ENP2	Discharged less waste water
ENP3	Produced less solid wastes
ENP4	Consumed less hazardous materials
ENP5	Increased materials or equipment recycling/recovery
INP1	Performed better in introducing novel shipping services and processes to meet customer needs
INP2	Is perceived by customers to be more innovative
INP3	Increased number of green innovations in shipping service portfolio
INP4	Used less time between conception of a green innovation and its introduction into the market place
ECP1	Has a positive impact on the financial performance of company
ECP2	Reduced costs for energy consumption
ECP3	Reduced costs for waste treatment
ECP4	Reduced fees incurred for waste discharge
ECP5	Reduced fines incurred for environmental accidents
ECP6	Improved corporate image
ECP7	Improved productivity
ECP8	Improved quality of shipping services
ECP9	Increased sales volume (by attracting more customers)
ECP10	Improved market share
ECP11	Improved profit margin
ECP12	Achieved higher return on assets

6.1.4. Operationalization of environmental uncertainty

To assess the perceived environmental uncertainty (EU) in shipping firms, 4 items were adapted based on Chen and Paulraj (2004) and Germain et al. (2008), to measure the supply, demand, and technological uncertainties perceived by shipping firms. The respondents were asked to assess their perceived environmental uncertainty on a five-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.

EU1	Business partners consistently meet the environmental requirements
EU2	Business partners provide green shipping services with consistent quality
EU3	Customer needs for green shipping services are difficult to assess
EU4	Green shipping technologies are difficult to implement due to high degree of technological complexity and rapid technological changes

After generating the measurement items for each construct, a panel of three shipping and logistics academics and four industry professionals was invited to review the relevance and clarity to ensure the face validity of the measurements. The panel was also asked to comment on the measurement scales for clarity, comprehensiveness, and if any, ambiguity. Moreover, a pilot test was also conducted with 15 graduates from a Master's programme in international shipping and transport logistics. The graduates were asked to comment on the wording and seminal meaning of the measurement items for content validity. Based the feedback received, the measurement items were refined by improving the wording. All of the measurement items were then organized into a survey questionnaire administered to shipping firms in the PRD region.

6.2. Data collection and sampling

This study focuses on the shipping industry in the PRD region of China, including Hong Kong, Macau, and the major cities in Guangdong Province (e.g., Guangzhou, Shenzhen, etc.). The shipping industry is a pillar industry that supports regional economic development and international trade. According to UNCTAD in their *Review of Maritime Transport 2015*, the ports of Hong Kong, Shenzhen, and Guangzhou are in the top ten world container ports (ranked 4^{th}, 3^{rd}, and 7^{th} respectively) in terms of container throughput from 2012 to 2014, and their total container throughput accounted for approximately 30% of the top ten world container ports. These hub ports serve the global manufacturing base in China and the world market. While the shipping industry encounters increasing regulatory and customer pressures on green shipping operations, many shipping firms (e.g., Maersk, CMA CGM, and Hapag-Lloyd) have begun to respond to environmental concerns by embracing GI to green their operations. As such, it is timely to develop valid and reliable scales and items for the evaluation of GI adoption, and conduct a participatory survey to investigate the linkage between GI adoption and the OP of shipping firms. This sample frame provides an appropriate research setting to capture data on the GI adoption of shipping firms and improve the generalizability of the study findings. The sample of PRD-based shipping firms was identified from the logistics yellow page section of the *Shipping Gazette*, a bi-weekly magazine published by the shipping industry in Hong Kong. The sample totalled 2,721 potential respondents from different sectors of the shipping industry, which included 'shipping companies and freight agents', 'warehouse and logistics centre', 'mid-stream and barge operations', and 'feeder agents'. The issue of bad contacts was acknowledged as the *Shipping Gazette* database could be outdated, and thus the respondent name and company address were confirmed by accessing their company website and online business directories. A total of 884 bad contacts were eliminated, mainly due to the termination of business or duplication. The final sample was reduced to 1,837 respondents.

A key informant approach was used to collect the data to test the hypotheses (Phillips and Bagozzi, 1986). A survey package that contained the questionnaire, a cover letter that outlined the research objectives and assured the respondents of their anonymity, and a pre-paid return envelope, was mailed to the target informants. The target informants included operations, environmental management or quality assurance managers, or a member of the senior management (e.g., CEO/president, vice president/director, general manager) team of the target firms, as supposedly, they have the relevant knowledge on the level of GI adoption and OP in their firms. The data collection process took place between October 2014 and January 2015. In total, 239 completed questionnaires were received after three waves of mailings were carried out (49 responses in the first wave, 72 responses in the second wave, and 118 responses in the third wave). However, 13 questionnaires, were deemed unusable due to incomplete responses, which resulted in 226 usable responses. The response rate was 12.3 percent, which is comparable to that of similar surveys on green management and innovation studies (e.g., Kim et al., 2006; Golgeci and Ponomarov, 2013; Cuerva et al., 2014; Maas et al., 2014), and common for extensive organizational-level surveys.

6.3. Respondent characteristics

Table 10 summarizes the demographic characteristics of the respondents. It can be seen that 61.9% of the respondent firms are 3PL/freight forwarders. The majority of the respondent firms also employ 11 to 50 employees, which accounts for 27% of the total number of respondent firms.

Table 10. Demographic characteristics of respondents

Characteristic	Frequency	%	Characteristic	Frequency	%
Type of company ownership			Number of employees		
State-owned	7	3.1	1-10	27	11.9
Privately-owned	162	71.7	11-50	61	27.0
Collectively-owned (subsidized by government)	0	-	51-100	54	23.9
Publicly-listed	37	16.4	101-500	41	18.1
Foreign joint venture	20	8.8	>500	43	19.0
Industry sector			Turnover of company (HKD$)		
Transport carrier	64	28.3	Under 10 million	38	16.8
Terminal operator	14	6.2	10-19 million	23	10.2
3PL/Freight forwarder	140	61.9	20-29 million	47	20.8
Midstream operator	2	0.9	30-39 million	44	19.5
Other	6	2.7	40 million or more	74	32.7
Number of years company established			Business scope		
1-5	15	6.6	Hong Kong only	15	6.6
6-10	33	14.6	China only	8	3.5
11-15	31	13.7	Hong Kong and China	60	26.5
16-20	46	20.4	International	143	63.3
21-25	24	10.6	Other	0	-
26-30	22	9.7			
31-35	18	8.0			
36 or longer	37	16.4			

Note: n = 226

6.4. Issues of survey data collection

6.4.1. Non-response bias

In terms of the issues of the survey data collection, first, the extrapolation method suggested in Armstrong and Overton (1977) was used to test for non-response bias. A t-test was conducted to determine whether there is any significant difference in the four dimensions of GI between the respondents who were contacted early (i.e., the first wave of mailing) or later (i.e., the third wave of mailing). The respondents who were contacted at a later date can be considered representative of the non-respondents (Armstrong and Overton, 1977). The *t*-test results confirmed that there are no significant differences ($p < 0.05$) in the mean value of the four dimensions of GI between the respondents who were contacted earlier and later, which suggests that non-response bias is not an issue in this study.

6.4.2. Common method variance

Common method variance (CMV) might pose an issue on the validity of the study results due to the cross-sectional and key-informant research design. Following the suggestions in Podsakoff et al. (2003), four steps were used to address the CMV issues, two procedural steps to control for potential CMV and two statistical tests to evaluate CMV problems. For the procedural steps, first, a cover letter was enclosed with the survey questionnaire to explain the purpose of the study, and the respondents were assured of their anonymity and confidentiality of the shared information to reduce evaluation apprehension. Second, the survey questions were divided into different sections based on the position of their respective variables in the model, e.g., dependent or independent variables (Podsakoff et al., 2003). Third, statistically, a Harmon's one-factor test was conducted to assess whether a single latent factor would account for all the theoretical constructs. A chi-square (χ^2) difference test was conducted between the single latent factor model (χ^2 = 8553.013, df = 2369; comparative fit index (CFI) = 0.718; incremental fit index (IFI) = 0.719; root mean square error of approximation (RMSEA) = 0.108; standardized root mean square residual (SRMR) = 0.078) and the hypothesized model (χ^2 = 4430.574, df = 2278; CFI = 0.902; IFI = 0.903; RMSEA = 0.065; SRMR = 0.0412). A significant difference was found between the chi-square values of the two models ($\Delta\chi^2$ = 4122.439, Δdf = 91, $p < 0.001$), thus providing preliminary evidence that CMV is not an issue in this study. Lastly, following Lindell and Whitney (2001), the industry sector of firm was used as the marker variable to test for potential CMV. This marker variable is theoretically unrelated to the constructs of this study. Malhotra et al. (2006) suggested that when a survey questionnaire is used to collect data, the correlation between two theoretically unrelated variables will typically not exceed 0.10. As shown in Table 11, the results show that the industry sector of the firms as a marker variable is insignificantly related (with correlations < 0.10 and $p > 0.05$) to any of the dependent and independent variables, thus providing further evidence that CMV is not an issue in this study.

Table 11. Mean, standard deviations, and correlations of the constructs

Variable		*Mean*	*S.D.*	*CR*	*AVE*	ECP	ENP	INP	GTI	GPI	GSI	GMI	EU	COP	CUP	RPI	CTM	RLM	ORM
1.	ECP	3.528	0.712	0.970	0.729	**0.854**													
2.	ENP	3.861	0.820	0.951	0.797	0.837**	**0.893**												
3.	INP	3.639	0.803	0.917	0.735	0.825**	0.765**	**0.858**											
4.	GTI	3.353	1.091	0.953	0.872	0.593**	0.576**	0.633**	**0.934**										
5.	GPI	3.212	1.157	0.971	0.872	0.672**	0.636**	0.711**	0.869**	**0.934**									
6.	GSI	3.145	1.185	0.965	0.822	0.648**	0.610**	0.679**	0.901**	0.905**	**0.907**								
7.	GMI	2.935	1.053	0.938	0.752	0.625**	0.610**	0.677**	0.780**	0.798**	0.784**	**0.867**							
8.	EU	3.251	0.623	0.857	0.600	0.560**	0.478**	0.665**	0.711**	0.766**	0.735**	0.698**	**0.774**						
9.	COP	3.372	0.863	0.923	0.751	0.682**	0.660**	0.759**	0.843**	0.845**	0.827**	0.811**	0.733**	**0.867**					
10.	CUP	3.138	0.683	0.889	0.668	0.583**	0.579**	0.700**	0.752**	0.769**	0.734**	0.808**	0.709**	0.782**	**0.817**				
11.	RPI	3.371	0.812	0.908	0.713	0.709**	0.621**	0.724**	0.778**	0.816**	0.822**	0.758**	0.653**	0.813**	0.707**	**0.845**			
12.	CTM	3.080	0.831	0.956	0.815	0.699**	0.629**	0.687**	0.773**	0.738**	0.744**	0.738**	0.649**	0.814**	0.712**	0.764**	**0.903**		
13.	RLM	3.294	0.741	0.926	0.758	0.637**	0.598**	0.656**	0.766**	0.784**	0.750**	0.735**	0.667**	0.792**	0.714**	0.740**	0.768**	**0.870**	
14.	ORM	3.342	0.859	0.961	0.805	0.694**	0.672**	0.730**	0.837**	0.841**	0.822**	0.796**	0.663**	0.824**	0.794**	0.818**	0.752**	0.751**	**0.897**
Marker variable		-	-	-	-	-0.18	-0.198	-0.107	-0.214	-0.161	-0.233	-0.169	-0.12	-0.23	-0.119	-0.133	-0.185	-0.204	-0.066

Notes: Square root of AVE is on the diagonal; RPI: regulatory pressure and incentive; COP: competitive pressure; CUP: customer pressure; RLG: relational governance; CTM: contractual governance; ORM: organizational governance; GMI: green management innovation; GSI: green service innovation; GPI: green process innovation; GTI: green technological innovation; ENP: environmental performance; INP: innovation performance; ECP: economic performance; and EU: environmental uncertainty

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

7. Data analysis and findings of quantitative survey study

The data analysis in this study is conducted in three steps. First, a confirmatory factor analysis (CFA) with the use of AMOS 20.0 was performed to evaluate the validity and reliability of the constructs. Reliability was evaluated by using Cronbach's alpha, composite reliability (CR) and average variance extracted (AVE) values. Second, the first- and second-order of the GI structures were tested by using CFA to determine whether a parsimonious measure of the construct should be formed. Lastly, structural equation modelling (SEM) was used to test the hypotheses. In the CFA, the goodness-of-fit was examined with multiple criteria, including the CFI, IFI, RMSEA, and SRMR. The rule of thumb cut-off criteria of the CFI and IFI > 0.90 was used as suggested by Hu and Bentler (1999), and RMSEA < 0.10 and SRMR < 0.08 as suggested by Steiger (1990).

7.1. Measurement validation and reliability

In this study, the measurement items were first developed based on theory and research in Chapter 3 and Chapter 5. CFA was used to assess how well the observed variables, i.e., measurement items, reflect unobserved or latent variables (i.e., the sub-dimensions) in the hypothesized structure. According to Lai et al. (2002) and Zhu et al. (2008), a strong a priori basis warrants the use of CFA instead of exploratory factor analysis (EFA).

To validate the measurements and their reliability, a corrected-item-total-correlation (CITC) analysis was conducted to identify if any item was not consistent with the rest of the scale. Following Churchill (1979), items with a coefficient less than 0.50 were removed. The coefficient scores of regulatory pressure ranged from 0.559 to 0.845; competitive pressure from 0.773 to 0.828; customer pressure from 0.626 to 0.725; relational governance from 0.725 to 0.759; contractual governance from 0.766 to 0.804; organizational governance from 0.799 to 0.846; green management innovation from 0.661 to 0.791; green service innovation from 0.734 to 0.867; green process innovation from 0.814 to 0.882; green technological innovation from 0.797 to 0.841; environmental performance from 0.649 to 0.742; innovation performance from 0.607 to 0.801; economic performance from 0.641 to 0.833; and environmental uncertainty from 0.527 to 0.631. Since the coefficient scores of all 71 items were above 0.50, ranging from 0.527 (EU2) to 0.882 (GPI4), no items were removed and the 71 items were kept for the analysis.

The reliability of the constructs and scales was assessed by using Cronbach's alpha and CR. As shown in Table 12, the Cronbach's alpha and CR of all the constructs are greater than 0.80, the cut-off point as suggested by Hair et al. (2006), and ranged from 0.856 to 0.971, which indicate that the measurement scales are adequately reliable (Fornell and Larcker, 1981; O'Leary-Kelly and Vokurka, 1998).

Table 12. Construct reliability and validity analysis

Factor	*Measurement items*			*Factor loading*	*t-value*	*Reliability and validity (Goodness-of-fit indices)*
Regulatory Pressure (RPI)[a]	1	RPI1	Adopts green shipping innovation to comply with the regulations/restrictions imposed by government on the industry sector	0.917	-	$\chi^2 = 103.441$, $df = 46$, $p < 0.001$, CFI = 0.974, IFI = 0.974, RMSEA = 0.074, SRMR = 0.0508, Cronbach's alpha = 0.869, CR = 0.908, AVE = 0.713.
	2	RPI2	Adopts green shipping innovation to cope with future government environmental legislations	0.898	22.089	
	3	RPI3	Experiences frequent inspections or audits from relevant governing bodies in relation to compliance with environmental rules and regulations	0.670	10.210	
	4	RPI4	Incentives offered by government are significant motivators for the adoption of green shipping innovation	0.708	11.842	
Competitive Pressure (COP)[a]	5	COP1	Adopt green shipping innovation to improve company image	0.917	-	Cronbach's alpha = 0.919, CR = 0.923, AVE = 0.751.
	6	COP2	Adopt green shipping innovation to achieve business objectives	0.917	22.311	
	7	COP3	Adopt green shipping innovation to enhance organizational performance	0.857	19.005	
	8	COP4	Generally believe that the benefits of green shipping innovation adoption outweigh the costs incurred	0.732	13.892	
Customer Pressure (CUP)[a]	9	CUP1	Expect your company to adopt green shipping innovation	0.892	-	Cronbach's alpha = 0.890, CR = 0.889, AVE = 0.668.
	10	CUP2	Will switch to competitors who adopt green shipping innovation	0.776	14.066	
	11	CUP3	Will withhold contracts if company does not meet their environmental requirements	0.688	11.437	
	12	CUP4	Have a clear environmental policy statement	0.841	15.861	
Relational Governance (RLM)[a]	13	RLM1	Frequently and informally share and exchange information that support the implementation of green shipping operations	0.846	-	$\chi^2 = 132.613$, $df = 79$, $p < 0.001$, CFI = 0.987, IFI = 0.987, RMSEA = 0.055, SRMR = 0.0329, Cronbach's alpha = 0.912, CR = 0.926, AVE = 0.758.
	14	RLM2	Notify each other about events or changes that might impact green shipping operations	0.850	15.894	
	15	RLM3	Are flexible enough to cooperatively respond to requests for changes, and make necessary adjustments in green shipping services to cope with changing circumstances	0.919	14.367	
	16	RLM4	Commit to environmental improvements that enable bilateral benefits rather than individual benefits	0.856	15.132	
Contractual Governance (CTM)[a]	17	CTM1	Environmental requirements of business partners for shipping operations	0.886	-	Cronbach's alpha = 0.960, CR = 0.956, AVE = 0.815.
	18	CTM2	Rights and obligations of both parties in the implementation of green shipping operations	0.900	20.299	
	19	CTM3	Methods of monitoring or assessing environmental performance of business partners	0.929	21.859	
	20	CTM4	Methods of handling complaints and disputes in green shipping operations	0.916	21.113	
	21	CTM5	Methods of handling contingencies in green shipping operations	0.888	19.636	
Organizational Governance (ORM)[a]	22	ORM1	Incorporates organizational environmental policies and procedures into business operations	0.880	-	Cronbach's alpha = 0.961, CR = 0.961, AVE = 0.805.
	23	ORM2	Initiates a dedicated department to manage environmental affairs	0.852	17.651	
	24	ORM3	Implements cross-functional cooperation to facilitate the development of green shipping operations	0.868	18.334	
	25	ORM4	Introduces and documents operating procedures to regularly track and monitor the latest information and trends relevant to green shipping	0.894	19.484	
	26	ORM5	Introduces and documents operating procedures to periodically track and evaluate internal environmental performance	0.910	20.217	
	27	ORM6	Introduces and documents operating procedures to identify and resolve environmental problems and non-conformance	0.962	18.916	
Green Management Innovation (GMI)[b]	28	GMI1	Implements environmental management systems to manage shipping operations	0.854	-	$\chi^2 = 259.078$, $df = 133$, $p < 0.001$, CFI = 0.980, IFI = 0.980, RMSEA = 0.065, SRMR = 0.0224, Cronbach's alpha = 0.938, CR = 0.938, AVE = 0.752.
	29	GMI2	Collects updated information on green innovation relevant to the shipping industry	0.847	19.352	
	30	GMI3	Participates in research and development activities relevant to green innovation	0.785	14.532	
	31	GMI4	Communicates green innovation information with employees/customers	0.911	18.874	
	32	GMI5	Shares green shipping experiences among various departments involved in the implementation of green innovation	0.912	18.898	
Green Technological Innovation (GTI)[b]	33	GTI1	Reviews and adopts technologies to support green management, service, and process innovation	0.944	-	Cronbach's alpha = 0.954, CR = 0.953, AVE = 0.872.
	34	GTI2	Uses novel technologies or equipment to support green management, service, and process innovation	0.946	29.079	
	35	GTI3	Uses novel technologies to manage shipping documentation and information, and provide relevant environmental information	0.913	25.523	

Cont. Table 12. Construct reliability and validity analysis

Factor	*Measurement items*			*Factor loading*	*t-value*	*Reliability and validity (Goodness-of-fit indices)*
Green Service Innovation (GSI)[b]	36	GSI1	Initiates shipping services to prevent pollution	0.868	-	Cronbach's alpha = 0.965, CR = 0.965, AVE = 0.822.
	37	GSI2	Initiates shipping services to save energy/resources	0.945	24.848	
	38	GSI3	Introduces novel shipping services to prevent pollution	0.976	24.356	
	39	GSI4	Introduces novel shipping services to save energy/resources	0.960	23.375	
	40	GSI5	Redesigns green shipping services to enhance environmental operations	0.905	20.179	
	41	GSI6	Introduces recovery/recycling "end-of-life" shipping equipment	0.768	17.080	
Green Process Innovation (GPI)[b]	42	GPI1	Reviews and modifies shipping processes to prevent pollution	0.921	-	Cronbach's alpha = 0.971, CR = 0.971, AVE = 0.872.
	43	GPI2	Reviews and modifies shipping processes to save energy/resources	0.946	27.326	
	44	GPI3	Uses novel shipping processes to prevent pollution	0.952	28.007	
	45	GPI4	Uses novel shipping processes to save energy/resources	0.953	28.185	
	46	GPI5	Incorporates recovery/recycling systems into shipping processes	0.893	22.703	
Environmental Performance (ENP)[a]	47	ENP1	Generated less air pollutants/carbon emissions	0.939	-	χ^2 = 616.191, df = 251, $p < 0.001$, CFI = 0.945, IFI = 0.946, RMSEA = 0.080, SRMR = 0.0445, Cronbach's alpha = 0.957, CR = 0.951, AVE = 0.797.
	48	ENP2	Discharged less waste water	0.955	29.614	
	49	ENP3	Produced less solid wastes	0.866	21.515	
	50	ENP4	Consumed less hazardous materials	0.873	21.810	
	51	ENP5	Increased materials or equipment recycling/recovery	0.828	19.001	
Innovation Performance (INP)[a]	52	INP1	Performed better in introducing novel shipping services and processes to meet customer needs	0.862	-	Cronbach's alpha = 0.915, CR = 0.917, AVE = 0.735.
	53	INP2	Is perceived by customers to be more innovative	0.912	19.263	
	54	INP3	Increased number of green innovations in shipping service portfolio	0.913	19.267	
	55	INP4	Used less time between conception of a green innovation and its introduction into the market place	0.733	13.181	
Economic Performance (ECP)[a]	56	ECP1	Has a positive impact on the financial performance of company	0.883	-	Cronbach's alpha = 0.970, CR = 0.970, AVE = 0.729.
	57	ECP2	Reduced costs for energy consumption	0.863	18.558	
	58	ECP3	Reduced costs for waste treatment	0.831	17.176	
	59	ECP4	Reduced fees incurred for waste discharge	0.848	17.844	
	60	ECP5	Reduced fines incurred for environmental accidents	0.838	17.431	
	61	ECP6	Improved corporate image	0.854	18.122	
	62	ECP7	Improved productivity	0.887	19.739	
	63	ECP8	Improved quality of shipping services	0.893	20.019	
	64	ECP9	Increased sales volume (by attracting more customers)	0.820	16.732	
	65	ECP10	Improved market share	0.849	17.869	
	66	ECP11	Improved profit margin	0.806	16.147	
	67	ECP12	Achieved higher return on assets	0.818	16.647	
Environmental Uncertainty (EU)[a]	68	EU1[R]	Business partners consistently meet the environmental requirements	0.841	-	Cronbach's alpha = 0.856, CR = 0.857, AVE = 0.600.
	69	EU2[R]	Business partners provide green shipping services with consistent quality	0.760	12.304	
	70	EU3	Customer needs for green shipping services are difficult to assess	0.743	11.967	
	71	EU4	Green shipping technologies are difficult to implement due to high degree of technological complexity and rapid technological changes	0.750	12.095	

Notes: [a] = A five-point Likert measurement scale: 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree.
[b] = A five-point Likert measurement scale: 1 = 0-20% very low; 2 = 21-40% low; 3 = 41-60% moderate; 4 = 61-80% high; and 5 = 81-100% very high. [R] = Reverse-coded item.

Following the suggestion in O'Leary-Kelly and Vokurka (1998), the convergent validity of each measurement scale was evaluated by conducting another CFA with the maximum likelihood approach. As summarized in Table 12, all indicators in their respective constructs have statistically significant ($p < 0.05$) factor loadings from 0.670 to 0.976, which suggest the convergent validity of the theoretical constructs. Furthermore, the AVE of each construct exceeds the recommended minimum value of 0.5 (Fornell and Larcker, 1981), which indicates that the amount of variance is largely captured by each construct instead of each measurement error, thus providing evidence of the convergent validity of the measurement scales. Table 11 presents the means, standard deviations, and correlations of all the theoretical constructs. The bivariate correlations among the stakeholder pressures, environmental governance mechanisms, GI, OP, and environmental uncertainty range from 0.478 to 0.905 with significance $p < 0.01$, which indicate good criterion validity (Nunnally, 1978).

The discriminant validity of the constructs was tested by measuring the degree to which each construct and its indicators are different from another construct and its indicators. A series of χ^2 difference tests were conducted between nested CFA models for all pairs of constructs. For each pair of constructs, the χ^2 was compared between the unconstrained (the correlations between two constructs are freely estimated) and the constrained (the correlations between two constructs are constrained to 0, thus implying perfect discriminant validity) models (Segars, 1997). As summarized in Table 13, the significant χ^2 differences between all pairs of constructs demonstrate discriminant validity (Bagozzi et al., 1991; Segars, 1997). In addition, as shown in Table 11, the square root of AVE of all the constructs is greater than the correlation between any pair of them. This suggests that the relationship between the measurement items of their respective construct is greater than the relationship of the measurement items across constructs. This result provides further evidence of discriminant validity (Anderson and Gerbing, 1988).

Table 13. Discriminant validity analysis

Construct pairs		Unconstrained χ^2	Unconstrained *df*	Constrained χ^2	Constrained *df*	$\Delta\chi^2$
Regulatory pressure						
↔	Competitive pressure	39.730	17	248.496	18	208.766***
↔	Customer pressure	42.893	18	172.481	19	129.588***
↔	Relational governance	37.368	17	190.115	18	152.747**
↔	Contractual governance	58.357	25	227.054	26	168.697***
↔	Organizational governance	81.981	31	311.653	32	229.672***
↔	Green management innovation	63.788	25	238.400	26	174.612***
↔	Green service innovation	47.786	29	290.599	30	242.813*
↔	Green process innovation	50.454	24	289.706	25	239.252***
↔	Green technological innovation	36.144	13	224.363	14	188.219***
↔	Environmental performance	66.333	23	168.031	24	101.698***
↔	Innovation performance	62.566	17	206.060	18	143.494***
↔	Economic performance	217.519	88	351.228	89	133.709***
↔	Environmental uncertainty	27.836	16	125.524	17	97.688*
Competitive pressure						
↔	Customer pressure	38.399	17	186.362	18	147.963**
↔	Relational governance	55.819	17	224.108	18	168.289***
↔	Contractual governance	38.276	24	246.663	25	208.387*
↔	Organizational governance	66.651	30	290.107	31	223.456***
↔	Green management innovation	63.453	23	226.878	24	163.425***
↔	Green service innovation	74.536	27	271.020	28	196.484***
↔	Green process innovation	56.705	25	293.514	26	236.809***
↔	Green technological innovation	20.564	11	236.506	12	215.942*
↔	Environmental performance	96.602	24	198.722	25	102.120***
↔	Innovation performance	74.009	18	217.500	19	143.491***
↔	Economic performance	281.688	88	401.566	89	119.878***
↔	Environmental uncertainty	32.242	17	154.390	18	122.148*
Customer pressure						
↔	Relational governance	51.313	18	174.952	19	123.639***
↔	Contractual governance	61.531	25	187.895	26	126.364***
↔	Organizational governance	87.582	31	262.710	32	175.128***
↔	Green management innovation	60.251	25	243.042	26	182.791***
↔	Green service innovation	70.490	29	206.617	30	136.127***
↔	Green process innovation	50.276	24	206.684	25	156.408***
↔	Green technological innovation	30.569	11	168.496	12	137.927***
↔	Environmental performance	76.453	23	150.806	24	74.353***
↔	Innovation performance	31.718	17	147.120	18	115.402*
↔	Economic performance	244.641	89	323.815	90	79.174***
↔	Environmental uncertainty	45.597	18	163.149	19	117.552***
Relational governance						
↔	Contractual governance	68.256	25	236.769	26	168.513***
↔	Organizational governance	75.568	29	237.937	30	162.369***
↔	Green management innovation	54.575	23	198.182	24	143.607***
↔	Green service innovation	94.241	28	255.173	29	160.932***
↔	Green process innovation	55.713	24	245.654	25	189.941***
↔	Green technological innovation	24.365	12	191.296	13	166.931*
↔	Environmental performance	91.663	23	175.271	24	83.608***
↔	Innovation performance	58.646	17	159.832	18	101.186***
↔	Economic performance	261.149	88	359.749	89	98.600***
↔	Environmental uncertainty	45.161	18	145.103	19	99.942***
Contractual governance						
↔	Organizational governance	77.484	39	244.689	40	167.205***
↔	Green management innovation	82.970	32	229.989	33	147.019***
↔	Green service innovation	85.591	39	247.199	40	161.608***
↔	Green process innovation	81.871	33	240.516	34	158.645***
↔	Green technological innovation	33.059	18	206.393	19	173.334*
↔	Environmental performance	88.407	32	190.102	33	101.695***
↔	Innovation performance	66.659	25	185.442	26	118.783***
↔	Economic performance	280.792	104	403.505	105	122.713***
↔	Environmental uncertainty	55.941	24	149.663	25	93.722***

Notes: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

Cont. Table 13. Discriminant validity analysis

Construct pairs		Unconstrained χ^2	Unconstrained *df*	Constrained χ^2	Constrained *df*	$\Delta\chi^2$
Organizational governance						
↔	Green management innovation	75.857	39	267.350	40	191.493***
↔	Green service innovation	132.246	45	354.103	46	221.857***
↔	Green process innovation	70.411	40	314.400	41	243.989**
↔	Green technological innovation	46.910	22	287.183	23	240.273**
↔	Environmental performance	129.746	39	248.819	40	119.073***
↔	Innovation performance	72.474	31	219.182	32	146.708***
↔	Economic performance	344.303	118	474.289	119	129.986***
↔	Environmental uncertainty	46.674	30	152.111	31	105.437*
Green management innovation						
↔	Green service innovation	90.810	38	274.934	39	184.124***
↔	Green product innovation	102.849	34	304.435	35	201.586***
↔	Green technological innovation	47.594	19	225.509	20	177.915***
↔	Environmental performance	79.845	32	171.495	33	91.650***
↔	Innovation performance	75.357	25	194.488	26	119.131***
↔	Economic performance	294.152	104	385.084	105	90.932***
↔	Environmental uncertainty	52.417	25	166.939	26	114.522***
Green service innovation						
↔	Green product innovation	104.349	37	446.955	38	342.606***
↔	Green technological innovation	63.315	23	376.494	24	313.179***
↔	Environmental performance	130.645	38	226.039	39	95.394***
↔	Innovation performance	67.655	31	188.627	32	120.972***
↔	Economic performance	409.456	117	514.010	118	104.554***
↔	Environmental uncertainty	51.993	30	187.715	31	135.722**
Green product innovation						
↔	Green technological innovation	45.913	19	320.733	20	274.820***
↔	Environmental performance	84.329	33	190.857	34	106.528***
↔	Innovation performance	64.728	26	201.335	27	136.607***
↔	Economic performance	293.777	105	409.646	106	115.869***
↔	Environmental uncertainty	60.156	26	210.188	27	150.032***
Green technological innovation						
↔	Environmental performance	54.303	16	135.441	17	81.138***
↔	Innovation performance	32.462	13	128.597	14	96.135**
↔	Economic performance	232.636	76	313.027	77	80.391***
↔	Environmental uncertainty	40.304	13	159.106	14	118.802***
Environmental performance						
↔	Innovation performance	81.776	25	246.582	26	164.806***
↔	Economic performance	401.535	100	647.635	101	246.100***
↔	Environmental uncertainty	66.366	24	118.707	25	52.341***
Innovation performance						
↔	Economic performance	263.915	91	480.395	92	216.480***
↔	Environmental uncertainty	34.582	18	134.323	19	99.741*
Economic performance						
↔	Environmental uncertainty	226.010	89	290.971	90	64.961***

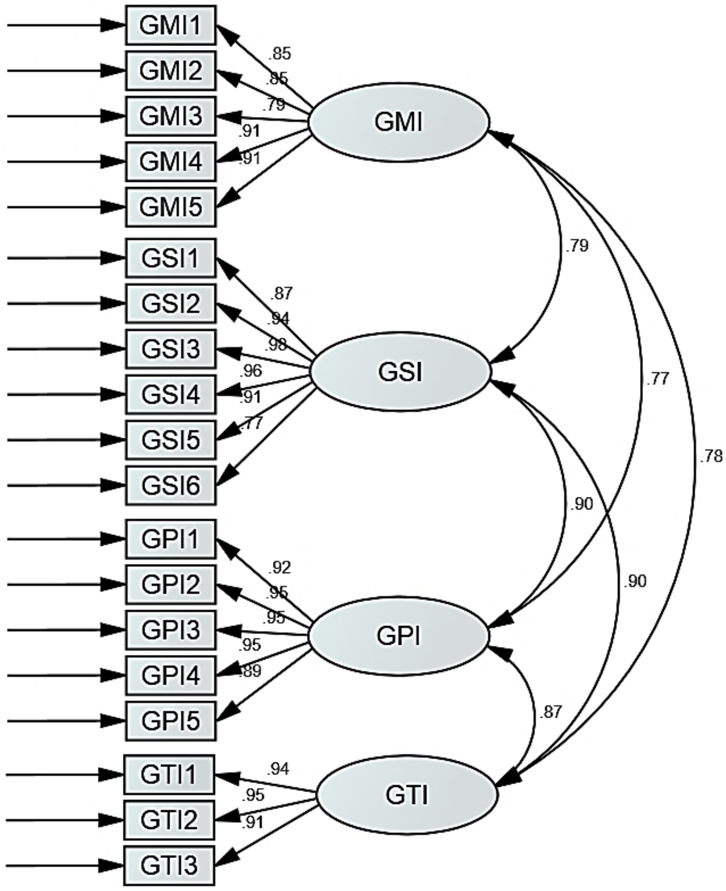
Notes: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

7.2. Validation of measurement model for GI adoption

7.2.1. Testing first- and second-order models of GI adoption

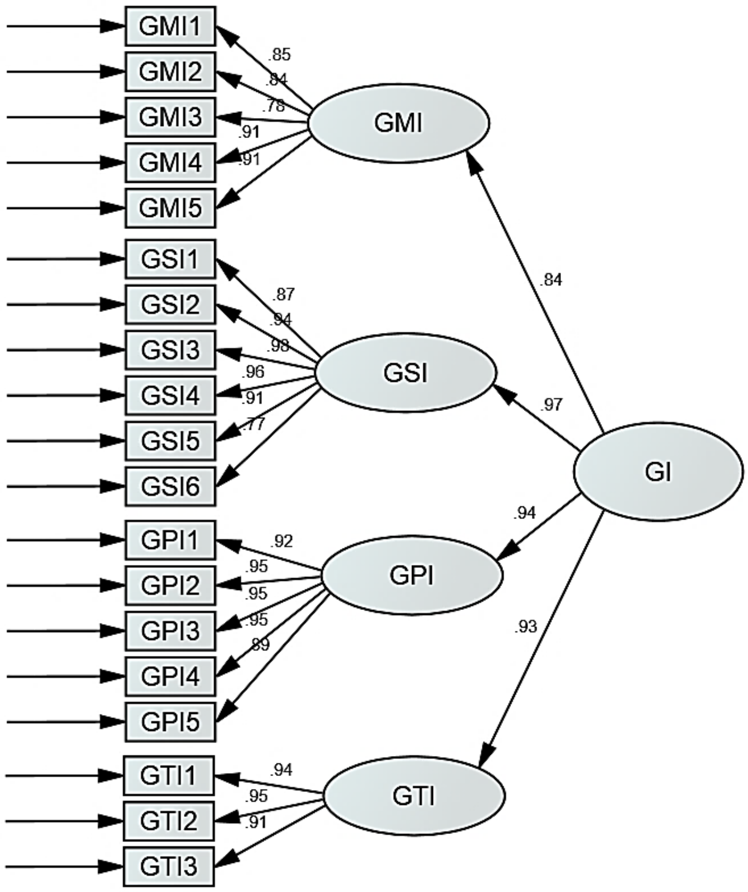
Having achieved satisfactory reliability and validity results, whether the construct is a more parsimonious measure at the second-order level, which consists of four sub-dimensions including GMI, GSI, GPI, and GTI, was tested on the basis that the GI adoption construct has multiple dimensions. Podsakoff et al. (2006) suggested that a second-order level construct should be employed when a construct is complex, as such a model considers each dimension as a critical component of the construct. Previous green shipping and green supply chain management studies (e.g., Zhu et al., 2008; Lai et al., 2013) were followed to test the measurement model of the GI constructs with two steps by using the CFA. The goodness-of-fit and the factor loadings of the models were compared. As discussed earlier, GMI, GSI, GPI, and GTI are specified as the a priori factors of GI adoption. In the first-order model, GMI, GSI, GPI, and GTI are correlated measurement factors for GI adoption. Alternatively, GI adoption may be operationalized as a second-order model, where the four factors are governed by a higher-order factor, i.e., GI. The results of the model estimation are shown in Figures 6 and 7.

Figure 6. First-order factor measurement model for GI adoption



Chi-square (133) = 259.078 ($p < 0.001$), χ^2/df=1.948, CFI=0.980, IFI=0.980, RMSEA=0.065, SRMR=0.0224.

Figure 7. Second-order factor measurement model for GI adoption



Chi-square (134) = 263.059 (p < 0.001), χ^2/df=1.963, CFI=0.979, IFI=0.979, RMSEA=0.065, SRMR=0.0229.

The *first-order* model for testing the GI construct (as shown in Figure 6) implies that GMI, GSI, GPI, and GTI are correlated but not governed by a common latent factor. The measurement items load positively and significantly to their respective theoretical construct with standardized loadings that range from 0.77 to 0.98 at p < 0.001, and an acceptable goodness-of-fit index (χ^2 = 259.078; *df* = 133; CFI = 0.980; IFI = 0.980; RMSEA = 0.065; and SRMR = 0.0224). In sum, the test results support the first-order model for the GI adoption construct. The test for the *second-order* model (as shown in Figure 7) implies that a higher-order latent factor, i.e., the overall traits of GI adoption, governs the correlations among GMI, GSI, GPI, and GTI. The second-order model indicates that the four sub-dimensional constructs load positively and significantly to the GI construct with standardized loadings that range from 0.84 to 0.97 at p < 0.001. The second-order model also shows an acceptable model fit (χ^2 = 263.059; *df* = 134; CFI = 0.979; IFI = 0.979; RMSEA = 0.065; and SRMR = 0.0229), which is almost identical to the first-order model. Moreover, the second-order model is slightly more restrictive and provides more information about the relationship between the higher-order GI adoption construct and the lower-order factors in the form of path coefficients rather than correlations. This result suggests that the second-order model is a better predictor of GI adoption.

Based on these results, the structure of the GI constructs and complementarity of the GI dimensions were examined. Two models were compared by computing the target coefficient value (T) (Marsh and Hocevar, 1985) to examine the extent to which a higher order construct accounts for the variance of a lower order construct. A T value close to the theoretical upper limit of 1.0 indicates that the lower order constructs are totally captured by the higher order constructs (Marsh and Hocevar, 1985). A T value of 0.98 (i.e., 259.078/263.059) is found between the first- and second-order models, thus indicating that the second-order construct accounts for 98.4 percent of the covariance among the first-order factors. Collectively, these results confirm that GI is a reflective second-order construct.

7.3. Hypothesis testing

7.3.1. Drivers of GI adoption

7.3.1.1. Stakeholder pressures and GI adoption

First, a structural equation model was established to test the relationships between stakeholder pressures and the adoption of GI of firms (H1a-1c). According to the results summarized in Table 14, the overall fit of the structural model is good, with CFI = 0.961 and IFI = 0.961, which are well above the recommended 0.90 thresholds (Hu and Bentler, 1999), and RMSEA = 0.080 and SRMR = 0.0334, which are well below the 0.10 and 0.08 thresholds (Steiger, 1990). With respect to the relationships among the three different types of stakeholder pressures (i.e., regulatory, competitive, and customer pressures) and GI adoption, regulatory pressure is positively and significantly associated with GI adoption with path estimates of 0.369 (t = 4.793, $p < 0.001$), which lends support for H1a. Competitive pressure is positively and significantly associated with GI adoption with path estimates of 0.465 (t = 4.878, $p < 0.001$), which lends support for H1b. Customer pressure is also positively and significantly associated with GI adoption with path estimates of 0.169 (t = 2.740, $p < 0.01$), which lends support for H1c. The result support H1a to H1c in that stakeholder pressures (i.e., regulatory, competitive, and customer pressures) is positively related to GI adoption.

Table 14. Structural model testing – Stakeholder pressures and GI adoption

Structural path				*Standardized estimate β*	*Hypothesis - Result*
Institutional pressures and green innovation					
H1	RPI	→	GI	0.369 (4.793) ***	H1a - Supported
	COP	→	GI	0.465 (4.878) ***	H1b - Supported
	CUP	→	GI	0.169 (2.740) **	H1c - Supported
Model fit: χ^2 = 235.696, *df* = 97; p < 0.001; CFI = 0.961; IFI = 0.961; RMSEA = 0.080; SRMR = 0.0334.					

Notes: Number in parentheses is *t*-value.
*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

7.3.1.2. Environmental governance mechanisms and GI adoption

Second, the relationships between environmental governance mechanisms and the adoption of GI by firms were tested (H2a-2c). As shown in Table 15, the overall fit of the structural model is good, with CFI = 0.969 and IFI = 0.969 which are well above the recommended 0.90 thresholds (Hu and Bentler, 1999), and RMSEA = 0.072 and SRMR = 0.0358 which are well below the 0.10 and 0.08 thresholds (Steiger, 1990). With respect to the relationships among the three types of environmental governance mechanisms (i.e., relational, contractual, and organizational governance) and GI adoption, relational governance is positively and significantly associated with GI adoption with path estimates of 0.270 (t = 4.584, p < 0.001), which lends support for H2a. Contractual governance is positively associated with GI adoption with path estimates of 0.177 (t = 3.108, p < 0.01), which lends support for H2b. Organizational governance is also positively and significantly associated with GI adoption with path estimates of 0.558 (t = 8.849, p < 0.001), which lends support for H2c. The results support H2a to H2c in that environmental governance mechanisms (i.e., relational, contractual, and organizational governance) are positively related to GI adoption.

Table 15. Structural model testing – Environmental governance mechanisms and GI adoption

Structural path				*Standardized estimate β*	*Hypothesis - Result*
Environmental governance and green innovation					
H2	RLM	→	GI	0.270 (4.584) ***	H2a - Supported
	CTM	→	GI	0.177 (3.108) **	H2b - Supported
	OGM	→	GI	0.558 (8.849) ***	H2c - Supported
Model fit: χ^2 = 309.605, *df* = 143; *p* < 0.001; CFI = 0.969; IFI = 0.969; RMSEA = 0.072; SRMR = 0.0358.					

Notes: Number in parentheses is *t*-value.
*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

7.3.1.3. Mediating effects of relational and organizational governances

To further examine the mediating effects of relational and organizational governances in the relationships between contractual governance and GI adoption (H2d and H2e), the bootstrapping method in AMOS was used to test for an indirect relationship as recommended by Preacher and Hayes (2008). Bootstrapping is a nonparametric statistical method based on resampling strategies for estimation and hypothesis testing (Preacher et al., 2007). The establishment of a mediation relationship with a higher statistical power is recommended to replace the three tests in Sobel (1982) and test in Baron and Kenny (1986) that are commonly used to establish a mediating relationship (MacKinnon et al., 2002; Zhao et al., 2010). Mediating effects (with n = 1000 bootstrap re-samples) are demonstrated while the indirect effects are significant and the bias-corrected confidence interval (CI) (95%) does not include zero (Preacher and Hayes, 2008). If the CI includes zero, the mediation hypothesis is not supported.

As illustrated in Table 16, Model A shows the bootstrapping analysis result that examines the mediating effects of relational governance on the relationship between contractual governance and GI adoption. The standardized indirect effect of contractual governance on GI through relational governance is 0.207. The 95% bias-corrected CI is between 0.112 (lower bound) and 0.323 (upper bound), and thus does not contain zero. Since both the direct ($\beta = 0.177$, $p < 0.05$) and indirect ($\beta = 0.207$, $p < 0.001$) effects of contractual governance on GI are positive and statistically significant, the mediation is partial (Zhao et al. 2010). Given that the relationship between contractual governance and GI is partially mediated by relational governance, the mediator (relational governance) accounts for 53.9% of the variance (i.e., indirect effect/total effect: 0.207/0.384). This indicates that the percentage of the total effect of contractual governance on GI that is mediated through relational governance is approximately 54%, and thus H2d is supported.

Model B repeats the above analysis by examining the mediating effects of organizational governance in the relationship between contractual governance and GI adoption. The standardized indirect effect of contractual governance on GI through organizational governance is 0.417. The 95% bias-corrected CI is between 0.319 (lower bound) and 0.533 (upper bound), and thus does not contain zero. Since both the direct ($\beta = 0.177$, $p < 0.05$) and indirect ($\beta = 0.417$, $p < 0.01$) effects of contractual governance on GI are positive and statistically significant, it is a partial mediation. While organizational governance partially mediates the relationship between contractual governance and GI, the mediator (organizational governance) accounts for 70.2% of the variance (i.e., indirect effect/total effect: 0.417/0.594). This indicates that the percentage of the total effect of contractual governance on GI that is mediated through organizational governance is approximately 70%, and thus H2e is supported.

Table 16. Results of mediating effects – Environmental governance mechanisms and GI adoption

Relationship			*Standardized estimate* *Total Effect*[#]	*Direct Effect*	*Indirect Effect*	*95% CI for mean indirect effect*	*t-value*	*p*	χ^2	*df*	χ^2/df	*CFI*	*IFI*	*RMSEA*	*SRMR*	*Hypotheses - Results*
Model A: Mediating effect of relational governance on relationship between contractual governance and GI (**H2d**)																
RLM	→	GI	0.270***	0.270***			4.584	***	309.605	143	2.165	0.969	0.969	0.072	0.0358	H2d - Supported
CTM	→	GI	0.384**	0.177*	0.207***	0.112, 0.323	3.108	**								
CTM	→	RLM	0.768**	0.768**			12.076	***								
Model B: Mediating effect of organizational governance on relationship between contractual governance and GI (**H2e**)																
ORM	→	GI	0.558**	0.558**			8.849	***	309.605	143	2.165	0.969	0.969	0.072	0.0358	H2e - Supported
CTM	→	GI	0.594**	0.177*	0.417**	0.319, 0.533	3.108	**								
CTM	→	ORM	0.748**	0.748**			11.880	***								

Notes: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Significance levels based on 1000 bootstrapping samples with 95 percent bias-corrected percentile method.

7.3.2. Impacts of GI adoption on organizational performance

Then, the relationships between GI adoption and OP outcomes (H3a-3d, H4) were tested. As shown in Table 17, all five structural models have a good overall fit with the CFI (which ranges from 0.946 to 0.952) and IFI (which ranges from 0.946 to 0.952) that are well above the recommended 0.90 threshold (Hu and Bentler, 1999), and the RMSEA (which ranges from 0.081 to 0.083) and SRMR (which ranges from 0.0371 to 0.0408) which are below the 0.10 and 0.08 thresholds (Steiger, 1990).

With respect to the relationships between the four sub-dimensions of GI and OP (i.e., environmental (ENP), innovation (INP), and economic (ECP) performance), green management innovation (GMI) is positively and significantly associated with ENP, INP, and ECP with standardized estimates of 0.609 ($t = 9.635$, $p < 0.001$), 0.694 ($t = 10.034$, $p < 0.001$), and 0.623 ($t = 8.780$, $p < 0.001$) respectively, which lends support for H3a.

Green service innovation (GSI) is positively and significantly associated with ENP, INP, and ECP with path estimates of 0.601 ($t = 9.910$, $p < 0.001$), 0.687 ($t = 10.326$, $p < 0.001$), and 0.634 ($t = 8.862$, $p < 0.001$) respectively, which lends support for H3b.

Green process innovation (GPI) is positively and significantly associated with ENP, INP, and ECP with path estimates of 0.635 ($t = 10.918$, $p < 0.001$), 0.720 ($t = 11.351$, $p < 0.001$), and 0.684 ($t = 11.594$, $p < 0.001$) respectively, which lends support for H3c.

Green technological innovation (GTI) also is positively and significantly associated with the ENP, INP, and ECP with path estimates of 0.574 ($t = 9.617$, $p < 0.001$), 0.654 ($t = 10.086$, $p < 0.001$), and 0.609 ($t = 9.970$, $p < 0.001$) respectively, which lends support for H3d.

Moreover, the results also indicate that GI (as a second-order construct) is positively and significantly associated with the three dimensions of OP (i.e., ENP, INP, ECP) with standardized estimates of 0.646 ($t = 11.041$, $p < 0.001$), 0.741 ($t = 11.413$, $p < 0.001$), and 0.692 ($t = 11.440$, $p < 0.001$) respectively.

In addition to compare the impacts of GI with the four sub-dimensions (GMI, GSI, GPI, and GTI) on OP (ENP, INP, and ECP), the path estimates among GI, GMI, GSI, GPI, GTI and ENP are 0.646, 0.609, 0.601, 0.635, and 0.574 respectively. The path estimates among GI, GMI, GSI, GPI, GTI and INP are 0.741, 0.694, 0.687, 0.720, and 0.654

respectively. The path estimates among GI, GMI, GSI, GPI, GTI and ECP are 0.692, 0.623, 0.634, 0.684, and 0.609 respectively. A higher coefficient value means greater impact of the independent variable on the dependent variable (Mazarrón and Cañas, 2009). The results show that GI is more influential on the positive outcomes of OP in comparison with the four sub-dimensions (GMI, GSI, GPI, and GTI), which lend support for H4.

Table 17. Structural model testing – GI adoption and organizational performance

Structural path				*Standardized estimate β*	*Hypothesis - Result*
Green management innovation and organizational performance					
H3a	GMI	→	ENP	0.609 (9.635) ***	H3a - Supported
	GMI	→	INP	0.694 (10.034) ***	
	GMI	→	ECP	0.623 (8.780) ***	
Model fit: χ^2 = 671.518, *df* = 273; *p* < 0.001; CFI = 0.946; IFI = 0.946; RMSEA = 0.081; SRMR = 0.0408.					
Green service innovation and organizational performance					
H3b	GSI	→	ENP	0.601 (9.910) ***	H3b - Supported
	GSI	→	INP	0.687 (10.326) ***	
	GSI	→	ECP	0.634 (8.862) ***	
Model fit: χ^2 = 743.252, *df* = 290; *p* < 0.001; CFI = 0.946; IFI = 0.946; RMSEA = 0.083; SRMR = 0.0371.					
Green process innovation and organizational performance					
H3c	GPI	→	ENP	0.635 (10.918) ***	H3c - Supported
	GPI	→	INP	0.720 (11.351) ***	
	GPI	→	ECP	0.684 (11.594) ***	
Model fit: χ^2 = 676.003, *df* = 275; *p* < 0.001; CFI = 0.949; IFI = 0.950; RMSEA = 0.081; SRMR = 0.0377.					
Green technological innovation and organizational performance					
H3d	GTI	→	ENP	0.574 (9.617) ***	H3d - Supported
	GTI	→	INP	0.654 (10.086) ***	
	GTI	→	ECP	0.609 (9.970) ***	
Model fit: χ^2 = 562.499, *df* = 226; *p* < 0.001; CFI = 0.952; IFI = 0.952; RMSEA = 0.081; SRMR = 0.0396.					
Green innovation and organizational performance					
H4	GI	→	ENP	0.646 (11.041) ***	H4 - Supported
	GI	→	INP	0.741 (11.413) ***	
	GI	→	ECP	0.692 (11.440) ***	
Model fit: χ^2 = 637.034, *df* = 249; *p* < 0.001; CFI = 0.947; IFI = 0.947; RMSEA = 0.083; SRMR = 0.0405.					

Notes: Number in parentheses is *t*-value.
*** *p* < 0.001

7.3.2.1. Mediating effects of environmental and innovation performance

To examine the mediating effects of ENP and INP in the relationship between GI and ECP, the bootstrapping method was also used (i.e., the same method used to test H2d and H2e) to test for indirect relationships. Mediating effects (with n = 1000 bootstrap re-samples) are demonstrated while the indirect effects are significant and the bias-corrected confidence interval (CI) (95%) does not include zero (Preacher and Hayes, 2008). If the CI includes zero, the mediation hypothesis is not supported. As shown in Table 18, Model A shows the result of the bootstrapping analysis that examined the mediating effects of ENP on the relationships between GI and ECP. The standardized indirect effect of GI on ECP through ENP is 0.448. The 95% bias-corrected CI is between 0.320 (lower bound) and 0.566 (upper bound), and thus does not contain zero. Since both the direct (β = 0.244, p < 0.001) and indirect (β = 0.448, p < 0.01) effects of GI on ECP are positive and statistically significant, the mediation is partial (Zhao et al. 2010). Given that the relationship between GI and ECP is partially mediated by ENP, the mediator (ENP) accounts for 64.7% of the variance (i.e., indirect effect/total effect: 0.448/0.692). This indicates that the percentage of the total effect of GI on ECP that is mediated through ENP is approximately 65%, and thus H5a is supported.

Model B repeats the above analysis by examining the mediating effects of INP in the relationships between GI and ECP. The standardized indirect effect of GI on ECP through INP is 0.549. The 95% bias-corrected CI is between 0.439 (lower bound) and 0.675 (upper bound), and thus does not contain zero. Since both the direct ($\beta = 0.143$, $p < 0.05$) and indirect ($\beta = 0.549$, $p < 0.01$) effects of GI on ECP are positive and statistically significant, it is a partial mediation. While INP partially mediates the relationship between GI and ECP, the mediator (INP) accounts for 79.3% of the variance (i.e., indirect effect/total effect: 0.549/0.692). This indicates that the percentage of the total effect of GI on ECP that is mediated through INP is approximately 79%, and thus H5b is supported.

Table 18. Results of mediating effects – GI adoption and organizational performance

Relationship			*Standardized estimate* *Total Effect*[#]	*Direct Effect*	*Indirect Effect*	*95% CI for mean indirect effect*	*t-value*	*p*	χ^2	*df*	χ^2/df	*CFI*	*IFI*	*RMSEA*	*SRMR*	*Hypothesis - Result*
Model A: Mediating effect of environmental performance on the relationship between GI and economic performance (**H5a**)																
GI	→	ENP	0.646**	0.646**			11.041	***	637.034	249	2.558	0.947	0.947	0.083	0.0405	H5a - Supported
GI	→	ECP	0.692**	0.244***	0.448**	0.320, 0.566	4.746	***								
ENP	→	ECP	0.694**	0.694**			12.234	***								
Model B: Mediating effect of innovation performance on the relationship between GI and economic performance (**H5b**)																
GI	→	INP	0.741**	0.741**			11.413	***	637.034	249	2.558	0.947	0.947	0.083	0.0405	H5b - Supported
GI	→	ECP	0.692**	0.143*	0.549**	0.439, 0.675	2.164	*								
INP	→	ECP	0.742**	0.742**			9.415	***								

Notes: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.
Significance levels based on 1000 bootstrapping samples with 95 percent bias-corrected percentile method.

7.3.3. Moderating effects of environmental uncertainty on the relationships between GI adoption and organizational performance

To examine the moderating effects of EU on the relationships between GI and OP (H6a-6d), a two-group model was developed by dividing the sample into low (n=114, mean=2.81) and high (n=112, mean=3.70) EU groups based on the median of its composite score (Germain et al., 2008; Wong et al., 2011). Next, multi-group and structural path analyses were conducted by using AMOS. A multi-group analysis for each dimension of the GI was conducted to investigate the performance impacts under low and high EU. Table 19 summarizes the results of the multi-group and structural path analyses.

As illustrated in Table 19, Model A summarizes the path estimates and χ^2 statistics for the path from the second-order construct, GI, to the outcomes of OP (i.e., ENP, INP, and ECP) under low and high EU (H6). Significant differences can be found in the χ^2 statistics ($\Delta\chi^2 = 33.977$, $\Delta df = 3$, $p < 0.001$) between the baseline model (i.e., the structural model parameters vary freely across the two groups), and the constrained model (i.e., the structural parameters are constrained to be equal across the two groups), thus suggesting variance of the model under low and high EU. Then the difference of the paths between the low and high EU groups is examined; the significant χ^2 difference ($\Delta\chi^2$ with $p < 0.05$) indicates the moderating effect of EU. The results show that the relationship between GI and ENP is significant with the low ($\beta = 0.627$, $p < 0.001$) and high ($\beta = 0.668$, $p < 0.001$) EU groups. The significant difference in the χ^2 statistics ($\Delta\chi^2 = 13.239$, $p < 0.001$), and the difference in β suggest that the relationship between GI and ENP is strengthened under high EU, thus H6(i) is supported. Moreover, the results show that the relationship between GI and INP is significant with low ($\beta = 0.620$, $p < 0.001$) and high ($\beta = 0.663$, $p < 0.001$) EU. The significant difference in the χ^2 statistics ($\Delta\chi^2 = 12.334$, $p < 0.001$) and the difference in β, suggest that the relationship between GI and INP is strengthened under a high EU, and thus H6(ii) is supported. Finally, the relationship between GI and ECP is also significant under low ($\beta = 0.592$, $p < 0.001$) and high ($\beta = 0.572$, $p < 0.001$) EU, but the χ^2 difference test shows invariance of the relationship across low and high EU ($\Delta\chi^2 = 0.217$, $p > 0.05$), and thus H6(iii) is supported.

Table 19. Results of multi-group analysis (Environmental uncertainty)

Model	χ^2	*df*	χ^2/df	*CFI*	*IFI*	*RMSEA*	*SRMR*	$\Delta\chi^2$	Δdf	χ^2 *difference test (p)*	*Low environmental uncertainty (n=114)*	*High environmental uncertainty (n=112)*	*Hypothesis- Result*
Model A: Multi-group analysis for **H6**													
1. Baseline model	1166.466	519	2.248	0.902	0.903	0.075	0.0463						
2. Constrained model	1200.444	522	2.300	0.897	0.898	0.076	0.0640	33.977	3	***			
3. Constrained path:													
i. GI → ENP	1179.705	520	2.269	0.900	0.901	0.075	0.0739	13.239	1	***	0.627^{+} (5.392) ***	0.668 (8.689) ***	H6(i) - Supported
ii. GI → INP	1178.800	520	2.267	0.900	0.901	0.075	0.0639	12.334	1	***	0.620 (5.852) ***	0.663 (7.756) ***	H6(ii) - Supported
iii. GI → ECP	1166.683	520	2.244	0.902	0.903	0.075	0.0471	0.217	1	n.s.	0.592 (6.278) ***	0.572 (6.204) ***	H6(iii) - Supported
Model B: Multi-group analysis for **H6a**													
1. Baseline model	1191.793	562	2.121	0.906	0.907	0.071	0.0448						
2. Constrained model	1202.178	565	2.128	0.905	0.906	0.071	0.0516	10.385	3	*			
3. Constrained path:													
i. GMI → ENP	1191.975	563	2.117	0.906	0.907	0.071	0.0462	0.182	1	n.s.	0.527 (5.769) ***	0.530 (5.898) ***	H6a(i) - Not supported
ii. GMI → INP	1191.866	563	2.117	0.906	0.907	0.071	0.0454	0.073	1	n.s.	0.619 (6.548) ***	0.577 (6.042) ***	H6a(ii) - Not supported
iii. GMI → ECP	1194.572	563	2.122	0.906	0.907	0.071	0.0516	2.779	1	n.s.	0.495 (6.519) ***	0.507 (4.419) ***	H6a(iii) - Supported
Model C: Multi-group analysis for **H6b**													
1. Baseline model	1433.677	605	2.370	0.891	0.892	0.078	0.0435						
2. Constrained model	1451.314	608	2.387	0.889	0.891	0.079	0.0569	17.637	3	***			
3. Constrained path:													
i. GSI → ENP	1441.766	606	2.379	0.890	0.892	0.078	0.0714	8.089	1	**	0.546 (4.702) ***	0.560 (7.848) ***	H6b(i) - Supported
ii. GSI → INP	1437.848	606	2.373	0.891	0.892	0.078	0.0556	4.171	1	*	0.531 (5.690) ***	0.599 (6.635) ***	H6b(ii) - Supported
iii. GSI → ECP	1433.734	606	2.366	0.891	0.893	0.078	0.0444	0.058	1	n.s.	0.546 (6.070) ***	0.547 (6.225) ***	H6b(iii) - Supported
Model D: Multi-group analysis for **H6c**													
1. Baseline model	1159.084	566	2.087	0.916	0.917	0.068	0.0428						
2. Constrained model	1187.543	569	2.087	0.912	0.913	0.070	0.0568	28.459	3	***			
3. Constrained path:													
i. GPI → ENP	1164.946	567	2.055	0.915	0.916	0.069	0.0641	5.862	1	*	0.572 (5.264) ***	0.610 (8.364) ***	H6c(i) - Supported
ii. GPI → INP	1168.505	567	2.061	0.915	0.916	0.069	0.0669	9.421	1	**	0.628 (5.567) ***	0.646 (8.519) ***	H6c(ii) - Supported
iii. GPI → ECP	1159.284	567	2.045	0.916	0.917	0.068	0.0428	0.200	1	n.s.	0.541 (6.379) ***	0.556 (6.099) ***	H6c(iii) - Supported
Model E: Multi-group analysis for **H6d**													
1. Baseline model	1008.640	468	2.155	0.915	0.916	0.072	0.0435						
2. Constrained model	1024.448	471	2.175	0.913	0.914	0.072	0.0494	15.808	3	***			
3. Constrained path:													
i. GTI → ENP	1012.460	469	2.159	0.915	0.916	0.072	0.0540	3.820	1	*	0.491 (4.786) ***	0.515 (6.761) ***	H6d(i) - Supported
ii. GTI → INP	1012.400	469	2.159	0.915	0.916	0.072	0.0517	3.759	1	*	0.489 (5.276) ***	0.566 (6.253) ***	H6d(ii) - Supported
iii. GTI → ECP	1008.754	469	2.151	0.916	0.917	0.072	0.0440	0.114	1	n.s.	0.450 (5.078) ***	0.420 (4.202) ***	H6d(iii) - Supported

Notes: Number in parentheses is *t*-value.
+ Path coefficients (β).
*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; *n.s.* = Not significant.

The above analysis was repeated with Model B to examine the moderating effects of EU on the relationships between GMI and OP. Significant differences were found in the χ^2 statistics ($\Delta\chi^2$ = 10.385, p < 0.05) between the baseline and constrained models, thus suggesting variance of the model under low and high EU. However, the results showed no significant χ^2 differences between the low and high EU groups for the relationship between GMI and ENP ($\Delta\chi^2$ = 0.182, p > 0.05), and thus H6a(i) is not supported. Moreover, the results showed no significant χ^2 differences in the relationship between GMI and INP ($\Delta\chi^2$ = 0.073, p > 0.05), and thus, H6a(ii) is not supported. Finally, the results showed no significant χ^2 differences between the low and high EU groups for the relationship between GMI and ECP ($\Delta\chi^2$ = 2.779, p > 0.05), and thus H6a(iii) is supported.

The above analysis was repeated with Model C to examine the moderating effects of EU on the relationships between GSI and OP. Significant differences were found in the χ^2 statistics ($\Delta\chi^2$ = 17.637, p < 0.001) between the baseline and constrained models, thus suggesting variance of the model under low and high EU. The results showed that the relationship between GSI and ENP is significant with the low (β = 0.546, p < 0.001) and high (β = 0.560, p < 0.001) EU groups. The significant difference in the χ^2 statistics ($\Delta\chi^2$ = 8.089, p < 0.01) and the difference in β suggest that the relationship between GSI and ENP is strengthened under a high EU, and thus H6b(i) is supported. Moreover, the results indicate that the relationship between GSI and INP is significant with low (β = 0.531, p < 0.001) and high (β = 0.599, p < 0.001) EU. The significant difference in the χ^2 statistics ($\Delta\chi^2$ = 4.171, p < 0.05) and the difference in β suggest that the relationship between GSI and INP is strengthened under a high EU, and thus H6b(ii) is supported. Finally, the relationship between GSI and ECP is significant with low and high EU, however, no significant χ^2 difference was found between the low and high EU groups for the relationship between GSI and ECP ($\Delta\chi^2$ = 0.058, p > 0.05), and thus H6b(iii) is supported.

The above analysis was repeated with Model D to examine the moderating effects of EU on the relationships between GPI and OP. Significant differences were found in the χ^2 statistics ($\Delta\chi^2$ = 28.459, p < 0.001) between the baseline and constrained models, thus suggesting variance of the model under low and high EU. The results showed that the relationship between GPI and ENP is significant with low (β = 0.572, p < 0.001) and high (β = 0.610, p < 0.001) EU groups. The significant difference in the χ^2 statistics ($\Delta\chi^2$ =

5.862, $p < 0.05$), and the difference in β suggest that the relationship between GPI and ENP is strengthened under high EU, and thus H6c(i) is supported. Moreover, the results indicated that the relationship between GPI and INP is significant under low ($\beta = 0.628$, $p < 0.001$) and high ($\beta = 0.646$, $p < 0.001$) EU. The significant difference in the χ^2 statistics ($\Delta\chi^2 = 9.421$, $p < 0.01$) and the difference in β suggest that the relationship between GPI and INP is strengthened under a high EU, and thus H6c(ii) is supported. Finally, the relationship between GPI and ECP is significant under low and high EU, however, no significant χ^2 difference was found between the low and high EU groups for the relationship between GPI and ECP ($\Delta\chi^2 = 0.200$, $p > 0.05$), and thus H6c(iii) is supported.

Lastly, the above analysis was repeated with Model E to examine the moderating effects of EU on the relationships between GTI and OP. Significant differences were found in the χ^2 statistics ($\Delta\chi^2 = 15.808$, $p < 0.001$) between the baseline and constrained models, thus suggesting variance of the model under low and high EU. The results showed that the relationship between GTI and ENP is significant with low ($\beta = 0.491$, $p < 0.001$) and high ($\beta = 0.515$, $p < 0.001$) EU groups. The significant difference in the χ^2 statistics ($\Delta\chi^2 = 3.820$, $p < 0.05$), and the difference in β suggest that the relationship between GTI and ENP is strengthened under high EU, and thus H6d(i) is supported. Moreover, the results indicate that the relationship between GTI and INP is significant under low ($\beta = 0.489$, $p < 0.001$) and high ($\beta = 0.566$, $p < 0.001$) EU. The significant difference in the χ^2 statistics ($\Delta\chi^2 = 3.759$, $p < 0.05$) and the difference in β suggest that the relationship between GTI and INP is strengthened under a high EU, and thus H6d(ii) is supported. Finally, the relationship between GTI and ECP is significant under low and high EU, however, no significant χ^2 difference was found between the low and high EU groups for the relationship between GTI and ECP ($\Delta\chi^2 = 0.114$, $p > 0.05$), and thus H6d(iii) is supported.

8. Secondary data analysis study

8.1. Research method

To supplement the research findings of the participatory survey study, a post-hoc analysis with secondary data was conducted to investigate whether firms that adopt GI achieve better economic performance in comparison to those that do not adopt GI. While the survey study focused on the shipping firms in the PRD region of China, including Hong Kong, Macau, and the major cities in Guangdong Province (e.g., Guangzhou, Shenzhen, etc.), the supplementary analysis focused on international shipping firms which would significantly benefit the generalizability of the findings of this research work. For this reason, 129 publicly listed shipping firms from the major stock exchanges, including the New York Stock Exchange (NYSE), NASDAQ, London Stock Exchange (LSE), Euronext, Börse Frankfurt, Tokyo Stock Exchange (TSE), Hong Kong Stock Exchange (HKEX), and Shanghai Stock Exchange (SSE) under the sub-sectors of "Marine Transportation" and "Logistics" were compiled into a list. The financial data of the shipping firms (i.e. ROA, return on equity (ROE), and asset turnover) from 2011 to 2013 were obtained from Thomson Reuters Eikon which provides access to trusted financial data and the analytics of the 129 publicly listed shipping firms. According to Lang and Lundholm (1993), corporate reports are important as they are considered to be an important source of company information by external users. They provide opportunities for comparative analyses of management attitude and policies across the reporting periods (Guthrie et al., 2004). For the purpose of this study, corporate reports (e.g., annual and environmental reports) are collected from the website of the respective shipping firms. The six-step procedures in Krippendorf (2012) were adopted for the content analysis to systematically sample, code, and validate the data.

8.2. Independent variables – Green management and technological innovation

Two dimensions of GI, green management innovation and green technological innovation, are used as the independent variables in this study. Green management and technological innovations are essential components of GI, which direct and support the development of green process and service innovations and facilitate the improvement of operating efficiency of firms. Examining the relationship between green management and technological innovations and their economic performance outcomes can provide further evidence to support the results of the survey study, and verify that shipping firms can achieve better economic performance through the adoption of GI. The content analysis procedures and criteria in Krippendorff (2012) were applied to search for key words in the company reports (i.e., annual and environmental reports) of the shipping firms. Since the sample firms are publicly listed companies, the information disclosed in financial reports and environmental reports is strictly regulated by law and endorsed by external auditors (e.g., Deloitte and PricewaterhouseCoopers). The accuracy, reliability, and comprehensiveness of information are therefore robust.

To determine whether shipping firms have adopted green management innovation or green technological innovation, a dichotomous variable was used to code the shipping firms if they fulfilled any one of the criteria shown in Tables 20 and 21. Those who adopted green management/technological innovation (GI firms) were coded as "1", and those that failed to fulfill any one of the criteria (non-GI firms) were coded as "0".

Moreover, to eliminate self-reporting bias, firms that have adopted GI must report precise information that shows (1) the particular type of green technology adopted (e.g., waste-heat recovery systems with detailed specifications), (2) the economic/ environmental benefits achieved by the adoption of GI (e.g., percent of CO_2 emission reduced), or (3) the implemented innovation project can be verified with their cooperation partners (e.g., details of R&D project can be found on the company website of business partner). The classification criteria of firms that adopt green management and technological innovations and selected examples of firms are shown in Tables 20 and 21.

Table 20. Classification criteria of firms that adopt green management innovation and selected examples

Green management innovation - implements novel organizational management methods, and through external relations (e.g. inter-organizational collaborations or R&D partnerships with universities in green innovation projects) to facilitate operating efficiency improvement, energy saving efforts, pollution prevention, and waste and material recycling or reuse.

Classification criterion		**Selected examples**
Criterion 1	Implements environmental/innovation training and workshops for employees/customers	"To proactively meet customer needs and promote further technological innovation, we established the new *IT Strategy Committee* and the *Technology, Innovation, and Environment Committee* in February 2016. The committee builds an internal organization that allows us to move forward in cross-divisional way. We look for new values that we can offer our customers, while fully leveraging our collective capabilities. This gives us a competitive advantage as a group that provides a broad range of services." (Mitsui O.S.K. Lines, 2017) "In April 2015, we began *Kirari Dojo (Creative Solutions Workshops)*, a programme that seeks to develop employees into leaders who will drive innovation. Targeting mid-career employees that we hope will establish and advance projects focused on differentiation...... As a result of participating in such programmes and seeing their Creative Solutions become a reality and operational improvements actually being implemented, more personnel will view their work proactively. Such personnel create a constant stream of differentiated services that keep us half a step ahead of other companies." (Nippon Yusen Kaisha Line, 2017a) "The *DHL Innovation Center* in Bonn, Germany has been redesigned with a new concept and extended services. The new facilities offer customers as well as business and industry partners opportunities to meet, connect and exchange ideas with Deutsche Post DHL Group teams and trend experts. Additionally, with the launch of the *DHL Asia Pacific Innovation Center (APIC)* in December 2015 in Singapore, DHL provides a second customer-centric innovation platform to serve the needs of the Asian market." (DHL, 2017)
Criterion 2	Implements environmental reporting protocols to collect environmental information and disseminate to employees/customers	"To more completely disclose CSR performance of Evergreen Marine Corp. and the outcome of its communication with stakeholders, the report has been structured based on "Core" disclosures of *GRI (Global Reporting Initiative) G4.0*. The Company has engaged *PricewaterhouseCoopers Taiwan* to provide *external assurance* to the content of this report using Statement of Assurance Principles No. 1 – "Audit and Review of Non-Financial Information."." (Evergreen Marine Corporation, 2015) "Our environmental reporting covers greenhouse gas emissions as well as local air pollutants. The reporting of both our emissions and efficiency improvements adhere to or are based on recognized and proven calculation methods. Greenhouse gas emissions are calculated based on guidelines provided by the *Greenhouse Gas Protocol, the DIN EN 16258 standard* and the *Global Logistics Emissions Council*, as well as requirements outlined by the *European Emissions Trading System (EU-ETS)*. Carbon efficiency is measured in *Carbon Efficiency Index (CEX)*. The emissions produced by our fleet are also calculated using the methodologies of the *European Environment Agency (EEA)* and the *United States Environmental Protection Agency (EPA)*." (DHL, 2016a)
Criterion 3	Participates in R&D activities relevant to green innovation	"In the reporting year, we *joined forces with the Ellen MacArthur Foundation's CE100 initiative and Cranfield University* to publish a study on the significance of reverse logistics. We develop solutions for reverse logistics, waste management and extended producer responsibility. These are available through our DHL Envirosolutions product portfolio, for example, for a customer in the USA, we implemented a packaging system that produces individually sized packaging for each individual product. The solution has helped us reduce the amount of empty space inside the packages as well as the number of shipments required and the amount of packaging materials used." (DHL, 2016b)
Criterion 4	Participates in interorganizational collaborations to develop green innovations	"Matson has now formed a *partnership with the California State Lands Commission (CSLC) and Ecochlor, Inc.* to demonstrate a chlorine dioxide treatment system for ballast water aboard the bulk carrier Moku Pahu. The agreement with CSLC provides funding to offset the cost of retrofitting the Moku Pahu. In return, Matson is allowing a research team to gather data on the biological effectiveness and provides CSLC with information regarding the installation and system effectiveness, as well as operational and maintenance requirements." (Matson Navigation Company and Ecochlor Inc., 2017)

Table 21. Classification criteria of firms that adopt green technological innovation and selected examples

Green technological innovation - implementation of novel or significantly refined green technologies, information systems, and shipping equipment to guide and support the introduction of green services, processes, and management innovations.

Classification criterion		Selected examples
Criterion 1	Implements technological innovations to enhance operating efficiency	"*Intelligent Management System* has used the fuzzy control theory, multistage optimum decision-making theory, computer remote-control monitoring, computer emulation, network communication, database and modern information management and control technologies in the container production and management systems of the port. The *technical innovations* have lifted the level of container handling capacity and sharpened the core competitive edge of the container production in the Port of Shanghai…… After more than two years' production practices, this project has tremendously enhanced the container handling capacity of the Port of Shanghai, the *throughput capability per meter of waterfront has increased by 47.3%*, the *average berthing time at the port decreased by 17.38%*; the *utilization rate of major equipment went up by 11%* and the *failure rate went down from 6% to 2%*. The *profit growth of the demonstration points and the whole port was RMB83.93 million and RMB173.403 million respectively*." (Shanghai International Port Group, 2017) "To enhance fuel saving and improve fleet performance, OOCL and CargoSmart™ have been working closely together to utilize the *AIS signals* to monitor all OOCL vessels through *CargoSmart's Global Vessel Voyage Monitoring Centre* to tracking the movements of more than 6,500 container vessels and the status of over 1,300 container ports. The innovative tool would alert the container liners if speed deviation, route deviation or any abnormal activities of a vessel during the voyage is found." (Orient Overseas International Limited, 2015)
Criterion 2	Implements technological innovations to enhance environmental performance	"Real example of *weather routing system* used by Evergreen fleet: On April 7, 2015, Ever Envoy departed Ningbo Port, China and set sail for Port of Tacoma, US. The ship entered Bering Sea on April 12 as planned, and the weather report showed a low-pressure area moving quickly from western Pacific past the southern side of Aleutian Islands…… Based on analysis and calculation of the *weather routing system*, the captain decided to reduce the ship's speed, postpone its entry into Gulf of Alaska, and make adjustments for its arrival afterwards. Eventually, Ever Envoy was *able to avoid the rough seas* and *avoided the extra distance and the consumption of 277 tons fuel* it would have incurred." (Evergreen Marine Corporation, 2015) "Our *air-lubrication system* is an *energy-saving technology* that reduces friction between the hull and seawater by supplying air bubbles to the bottom of the vessel. In 2010, the NYK Group launched two module carriers, Yamato and Yamatai, which that became the world's first operational ocean vessels equipped with an air-lubrication system based on an air-blower…… The air-blower-based system *reduces CO_2 emissions by approximately 6 percent on average*, while the system using a main engine scavenging air bypass is expected to *reduce CO_2 emissions between approximately 4 percent and 8 percent*." (Nippon Yusen Kaisha Line, 2017b)
Criterion 3	Implements technological innovations to support the introduction of other green innovations	"*OOCL Lite App* is one of OOCL's *customer-focused and innovative IT products* developed by CargoSmart™, an independently-operated company with OOCL investing in the development of the solution platform. OOCL Lite allows users to: access real time sailing schedules, cargo and vessel tracking data, port schedules, rate of exchange for the selected voyage, detailed container specifications, carbon calculator functions, shipment details, and corporate news at their fingertips." (Orient Overseas International Limited, 2016) "*Big Data analyses using actual voyage data* gathered over half a year after the implementation of improvements in June 2014 were conducted by the NYK Group, and a *23% reduction in CO_2 emissions was confirmed*. The conversion was also verified not to affect the safe operation of the vessel or the operating condition of the engine." (Nippon Yusen Kaisha Line, 2015)

8.3. Dependent variables – ROA, ROE and asset turnover

Following Waddock and Graves (1997), Mahoney and Roberts (2007), and Makni et al., (2008), ROA and ROE were used to measure the economic performance of shipping firms. For robustness, asset turnover was also used as an additional measurement. ROA is a measure of the profitability of a firm in using assets to generate revenue and calculated by net income divided by total assets (Yu, 2008). ROE is a measure of the profitability of a firm in using shareholder funds to generate revenue and calculated as net income divided by shareholder equity (Garcia-Castro et al., 2009). Asset turnover is a measure of the efficiency of a firm in using assets to generate sales and calculated as sales divided by net operating assets (Soliman, 2004; Bodie et al., 2012). Such measures have been widely used in previous environmental and innovation studies as valid measurements for examining the relationship between the GI and economic performance of firms (e.g., García-Morales et al., 2012; Aguilera-Caracuel and Ortiz-de-Mandojana; 2013; Forsman, 2013; Martinez-del-Rio et al, 2015; Hojnik and Ruzzier, 2016a). Data on asset turnover, the ROA, and ROE of shipping firms from 2011 to 2013 were obtained from the Thomson Reuters Eikon database.

8.4. Data analysis and findings

To analyze the data, *t*-tests and Mann-Whitney *U*-tests were conducted to investigate if the firms that have adopted green management and technological innovations achieved better economic performance in comparison with their counterparts that do not adopt green management and technological innovations. The *t*-tests are parametric tests for testing the equality of means which assumes that the data are normally distributed and the groups have equal variances. The *U*-tests are nonparametric tests for testing the equality of the medians (Palepu, 1985). Before conducting the *t*-test and *U*-test analyses, extreme cases with values that differ from the rest of the sample called outliners were detected and removed by using SPSS.

Tables 22 and 23 show the results of the *t*-tests and the Mann-Whitney *U*-tests respectively. First, the results demonstrate that economic performance in terms of asset turnover, ROA, and ROE of the firms that have adopted green management innovation is significantly better over the period of 2011 to 2013. The results of asset turnover are $t = -2.2432$, $p < 0.05$ and $Z = -2.0362$, $p < 0.05$ in 2011; $t = -1.9711$, $p < 0.05$ and $Z = -2.0154$, $p < 0.05$ in 2012; and $t = -2.4989$, $p < 0.05$ and $Z = -1.9677$, $p < 0.05$ in 2013. The results of the ROA are t = -3.0324, $p < 0.01$ and Z = -2.6387, $p < 0.01$ in 2011; t = -3.6982, $p < 0.001$ and Z = -2.9545, $p < 0.01$ in 2012; and t = -2.2370, $p < 0.05$ and Z = -2.2838, $p < 0.05$ in 2013. Lastly, the results of the ROE are t = -1.9963, $p < 0.05$ and Z = -2.4822, $p < 0.05$ in 2011; t = -2.1742, $p < 0.05$ and Z = -2.1089, $p < 0.05$ in 2012; and t = -2.0725, $p < 0.05$ and Z = -2.3443, $p < 0.05$ in 2013.

Second, similar t-test and Mann-Whitney U-test results for asset turnover, ROA, and ROE were also obtained for the firms that have adopted green technological innovation. Significant performance differences were also found between those who have adopted green technological innovation versus those who do not adopt green technological innovation. The results of asset turnover are t = -2.1567, $p < 0.05$ and Z = -1.9616, $p < 0.05$ in 2011; t = -2.0421, $p < 0.05$ and Z = -2.0475, $p < 0.05$ in 2012; and t = -1.9821, $p < 0.05$ and Z = -2.3553, $p < 0.05$ in 2013. The results of the ROA are t = -2.9297, $p < 0.01$ and Z = -3.0133, $p < 0.01$ in 2011; t = -3.2886, $p < 0.001$ and Z = -2.8989, $p < 0.01$ in 2012; and t = -2.0348, $p < 0.05$ and Z = -2.3830, $p < 0.05$ in 2013. Lastly, the results of the ROE are t = -1.9676, $p < 0.05$ and Z = -2.2127, $p < 0.05$ in 2011; t = -1.9533, $p < 0.05$ and Z = -2.3138, $p < 0.05$ in 2012; and t = -2.1726, $p < 0.05$ and Z = -2.3039, $p < 0.05$ in 2013. Overall, as all of the t- and U-tests results indicated significant statistical differences, the firms who have adopted green management and technological innovations have a better economic performance in terms of asset turnover, ROA, and ROE in comparison with their counterparts who have not adopted green management and technological innovations. These results lend further support to the findings in the survey study, thus confirming that GI adoption is positively associated with economic performance.

Table 22.

t-test results of asset turnover: comparison between firms who have adopted GI vs. those who do not adopt GI

		Mean		*S.D.*		*t*-test		
Year	Green innovation	GI firms	Non-GI firms	GI firms	Non-GI firms	*d.f.*	*t*	*Sig.*
2011	GMI	0.6980	0.5112	0.4871	0.3910	114	-2.2432	*
(n=116)	GTI	0.7112	0.5217	0.4796	0.4046	114	-2.1567	*
2012	GMI	0.7217	0.5418	0.5138	0.4515	116	-1.9711	*
(n=118)	GTI	0.7459	0.5492	0.4864	0.4689	116	-2.0421	*
2013	GMI	0.7227	0.5120	0.5268	0.3850	116	-2.4989	*
(n=118)	GTI	0.7303	0.5430	0.4459	0.4476	116	-1.9821	*

t-test results of ROA: comparison between firms who have adopted GI vs. those who do not adopt GI

		Mean		*S.D.*		*t*-test		
Year	Green innovation	GI firms	Non-GI firms	GI firms	Non-GI firms	*d.f.*	*t*	*Sig.*
2011	GMI	0.0446	0.0216	0.0369	0.0385	112	-3.0324	**
(n=114)	GTI	0.0461	0.0227	0.0360	0.0388	112	-2.9297	**
2012	GMI	0.0503	0.0222	0.0426	0.0364	112	-3.6982	***
(n=114)	GTI	0.0509	0.0243	0.0456	0.0362	112	-3.2886	***
2013	GMI	0.0414	0.0251	0.0387	0.0352	112	-2.2370	*
(n=114)	GTI	0.0420	0.0262	0.0414	0.0347	112	-2.0348	*

t-test results of ROE: comparison between firms who have adopted GI vs. those who do not adopt GI

		Mean		*S.D.*		*t*-test		
Year	Green innovation	GI firms	Non-GI firms	GI firms	Non-GI firms	*d.f.*	*t*	*Sig.*
2011	GMI	0.0685	0.0406	0.0771	0.0666	108	-1.9963	*
(n=110)	GTI	0.0697	0.0415	0.0751	0.0684	108	-1.9676	*
2012	GMI	0.0718	0.0400	0.0668	0.0771	107	-2.1742	*
(n=109)	GTI	0.0735	0.0429	0.0713	0.0747	107	-1.9533	*
2013	GMI	0.0633	0.0360	0.0698	0.0650	110	-2.0725	*
(n=112)	GTI	0.0660	0.0365	0.0759	0.0620	110	-2.1726	*

Notes: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ (2-tailed sig.)

Table 23.

U-test results of asset turnover: comparison between firms who have adopted GI vs. those who do not adopt GI

		Mean Rank		Sum of Ranks		Mann-Whitney *U*	
Year	Green innovation	GI firms	Non-GI firms	GI firms	Non-GI firms	Z	*Sig.*
2011	GMI	67.26	53.89	2690.50	4095.50	-2.0362	*
(n=116)	GTI	68.21	54.64	2251.00	4535.00	-1.9616	*
2012	GMI	68.04	54.78	2857.50	4163.50	-2.0154	*
(n=118)	GTI	69.63	55.40	2367.50	4653.50	-2.0475	*
2013	GMI	67.53	54.72	2971.50	4049.50	-1.9677	*
(n=118)	GTI	72.20	55.17	2166.00	4855.00	-2.3553	*

U-test results of ROA: comparisons between firms who have adopted GI vs. those who do not adopt GI

		Mean Rank		Sum of Ranks		Mann-Whitney *U*	
Year	Green innovation	GI firms	Non-GI firms	GI firms	Non-GI firms	Z	*Sig.*
2011	GMI	69.23	51.86	2561.50	3993.50	-2.6387	**
(n=114)	GTI	72.69	51.83	2253.50	4301.50	-3.0133	**
2012	GMI	69.89	50.80	2795.50	3759.50	-2.9545	**
(n=114)	GTI	71.50	51.80	2359.50	4195.50	-2.8989	**
2013	GMI	67.65	52.62	2503.00	4052.00	-2.2838	*
(n=114)	GTI	69.78	53.11	2093.50	4461.50	-2.3830	*

U-test results of ROE: comparisons between firms who have adopted GI vs. those who do not adopt GI

		Mean Rank		Sum of Ranks		Mann-Whitney *U*	
Year	Green innovation	GI firms	Non-GI firms	GI firms	Non-GI firms	Z	*Sig.*
2011	GMI	65.46	49.81	2618.50	3486.50	-2.4822	*
(n=110)	GTI	65.13	50.82	2344.50	3760.50	-2.2127	*
2012	GMI	63.36	50.15	2534.50	3460.50	-2.1089	*
(n=109)	GTI	66.08	50.60	2048.50	3946.50	-2.3138	*
2013	GMI	66.13	51.15	2645.00	3683.00	-2.3443	*
(n=112)	GTI	66.96	51.75	2343.50	3984.50	-2.3039	*

Notes: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ (2-tailed sig.)

9. Conclusions

9.1. Discussion of research findings

9.1.1. Exploratory case study

An exploratory case study is conducted to examine the concept of GI and how GI is associated with firm performance in the shipping context. Based on a review of the related literature, GI is conceptualized in the shipping industry on the basis of four components, namely green management, green service/product, green process, and green technological innovations, which are related to the different domains of shipping operations. To verify the conceptualization of GI and its association with firm performance, a mixed method approach is used to analyze a case study (i.e., Maersk Line) and a sample of its major competitors in the liner shipping industry over a nine-year assessment period. Specifically, a qualitative analysis is conducted to identify the GI initiatives launched at Maersk Line and a quantitative analysis to compare the performance differences between Maersk Line and its competitors in view of the former's active pursuit of GI. The case study results support the view that the GI initiatives pursued by Maersk Line fall into four categories in line with the conceptualized components of GI. In terms of the performance implications of GI, the results of the quantitative analysis show that Maersk Line has achieved significant improvements in firm performance both environmentally and economically as a result of pursuing GI and making eco- and operational efficiency improvements.

In line with the findings of the previous literature in other fields, the results of the first part of this study suggest that GI in the shipping industry consists of four components.

- *Green management innovation*: A shipping firm needs to have the ability to initiate novel green shipping activities with proper configurations of the resource inputs, e.g., redesigning the internal organizational process to ensure internal efficiency, facilitating the implementation of various green shipping measures and substantially improving shipping services to comply with new environmental directives. Successful adoption of green management innovation requires careful planning in the acquisition of know-how and techniques, design of operations, and evaluation of the feasibility of the green management innovation initiatives concerned (Chen, 2008; Lin et al., 2013). Therefore, shipping firms should thoroughly evaluate and implement environmental management systems, establish dedicated functional units to direct the adoption of GI, and foster relevant environmental R&D activities. Moreover, as illustrated in the case study here, the innovation departments of Maersk Line (i.e., MMT) has successfully collaborated with external partners (e.g., universities and customers) to initiate R&D projects and enhance their GI activities, and in turn, achieve a better firm performance. This finding aligns with previous works (e.g., Lee et al., 2015; Wang et al., 2015; Dingler and Enkel, 2016; Rasiah et al., 2016) in that a high level of R&D collaboration facilitates the acquisition of external knowledge which can positively impact innovation deployment and firm performance.

- *Green service/product innovation*: Given the additional complexity of green services/products, the R&D or innovation unit of a shipping firm should routinely evaluate the degree of novelty and competitiveness of its green services/products (Tseng et al., 2013). To effectively recover and recycle "end-of-life" shipping products/equipment, and feasibly, economically, technically, and commercially (re-)design green shipping services, a shipping firm needs to accumulate and advance its own knowledge in many aspects, e.g., shipping technology, chemicals and materials, engineering, innovation management, and environmental regulations. Consequently, shipping firms should adopt an interdisciplinary approach to manage their green service/product innovation which spans shipping services, methods, and knowledge.
- *Green process innovation*: To develop innovative green processes, a shipping firm needs to develop the capability to conduct thorough and sound analyses of recycling, reusing, and reconfiguring of its shipping equipment. The firm should also focus on the amount of consumed resources (e.g., fuel, electricity, water) in its shipping operations, and use green technology to reduce energy consumption and pollutant emissions. Hence, innovative green shipping processes should be encouraged to reduce waste discharge and energy consumption, and improve environmental performance in general. Moreover, illustrative examples of green process innovation observed at Maersk Line (e.g. the Responsible Procurement Programme) align with findings in previous studies (Tseng et al. 2013), e.g., the utilization of an in-house auditing programme to assess environmental performance can lead to green process innovation.
- *Green technological innovation*: has a strategic role in guiding and supporting the other components of GI. Green information technology helps to track, collect, and supply the necessary environmental information for the development of a comprehensive resource saving plan, and supports the compilation of environmental reports. Moreover, it is crucial for the knowledge management process in terms of facilitating and supporting the acquisition, creation, utilization, and sharing of

knowledge (Lu and Kuo, 2014), all of which are essential to advancing GI. Hence, shipping firms could invest in novel green technologies to advance their green shipping activities, which will give them competitive advantages.

A quantitative analysis was conducted in the second part of the study to investigate the impact of the GI practices of Maersk Line on its firm performance. The performance of Maersk Line was compared with that of a sample of 11 major liner carriers. The results showed that there are positive relationships between GI, and environmental and economic performances. By adopting a spectrum of GI initiatives and measures, Maersk Line has progressively improved its environmental and economic performances. Specifically, improvements in eco-efficiency through the adoption of GI have a positive impact on the operational efficiency and cost-effectiveness of a firm. This finding is in line with strategic research that a firm can create long-term competitive advantages through a series of successful innovations (e.g., Dougherty and Hardy, 1996; Danneels, 2002; Chassagnon and Haned, 2015).

Moreover, although the use of the DEA cannot disentangle the impacts of increasingly larger vessel size, which affects the economies of scale, and consequently the operating profits of the DMU, the validity of results will generally not be affected. It is a fact that large-sized vessels currently deployed by different carriers actually combine and integrate GI into their system. Table 24 shows examples of GI initiatives applied in large-sized vessels. For example, these vessels are built in accordance with EEDI regulations, use SEEMP to manage the energy efficiency of vessels, and are equipped with a broad range of GIs such as a ship operation monitoring system, ballast water treatment systems, voyage optimization tools, innovative hull coatings, various green ship technologies, etc. In addition, large-sized vessels, in general, are designed specifically to slow steaming operations which particularly rely on the facilitation of GI (e.g., innovative ship design, eco-efficient engines and systems, etc.). Therefore, increasing the vessel size not only improves environmental efficiency, but at the same time, promotes the adoption of GI in the shipping industry. It is therefore reasonable to consider that increased vessel size improves environmental efficiency through the adoption of GI.

Table 24. Examples of GI initiatives applied in large-sized vessels

Carrier / Vessel	MOL Triumph[1]	MSC Oscar[2]	Maersk Triple-E Class[3]	CMA CGM Jules Verne[4]	OOCL New buildings[5]	Hapag-Lloyd Hamburg Express[6]	Yang Ming U-Type[7]
TEU	20,170	19,224	18,000	13,800	13,208	13,169	8,200
GI Initiatives							
- Advanced eco-efficient engines (e.g., engines for fuel optimization)	●	●	●	●	●	●	●
- Ballast water management systems	●	●	●	●	●	●	●
- Eco-friendly anti-fouling paint	●	●	●	●	●	●	●
- Energy efficiency design or management initiatives (e.g., EEDI, SEEMP)	●	●	●	●	●	●	
- Innovative ship design (e.g., optimized hull form and bulbous bow, enhanced fatigue design)	●	●	●	●	●	●	●
- Intelligent vessel control systems (e.g., ship operation monitoring system, navigation system for eco-speed operations, software tool for managing the propulsion and hull efficiency)	●	●	●	●	●	●	-
- Other green ship technologies (e.g., fuel switching technology, HFC/CFC free refrigerant, other energy saving devices)	●	●	●	●	●	●	●
- Ship recycling policies (e.g., green passport)	-	●	●	-	●	●	-

Sources

1 Mitsui O.S.K. Lines. 2018. "World's Largest Containerships: 20,000 TEU". Available at http://www.mol.co.jp/en/csr/environment/20000teu/index.html Accessed February 1, 2018.

2 Mediterranean Shipping Company. 2016. "Sustainability report 2016". Available at https://www.msc.com/getattachment/eab90d59-3000-46f5-8e1c-b24bcdbfe2c1/636481776372492999 Accessed February 1, 2018.

3 Maersk Line. 2018. "Triple-E". Available at https://www.maersk.com/explore/fleet/triple-e Accessed February 1, 2018.

4 CMA CGM. 2018. "CMA CGM Jules Verne: Innovation & Technology for the environment". Available at http://www.cma-cgm-blog.com/cma-cgm-jules-verne/csr-innovation-technology-environment/ Accessed February 1, 2018.

5 OOCL. 2018. "Environment Friendly Features on OOCL New Buildings – 13,208 TEU". Available at http://www.oocl.com/eng/aboutoocl/Environmentalcare/Documents/vsl1.jpg Accessed February 1, 2018.

6 Hapag-Lloyd. 2018. "Environmental Protection on Board our Ships". Available at https://www.hapag-lloyd.com/content/dam/website/images/all_areas/HLAG_Umweltflyer_engl_Hamburg_Express_02.jpg Accessed February 1, 2018.

7 Yang Ming. 2018. "Green Vessel". Available at http://www.yangming.com/about_us/Environment_Preservation/greenvessel.aspx Accessed February 1, 2018.

Furthermore, the results showed that there is a positive relationship between firm-level environmental performance and industry-level economic performance. Therefore, shipping firms can use GI as a strategic means to simultaneously advance their shipping operations, improve OP, and build diverse capabilities (e.g., green and innovation management, organizational learning, etc.).

9.1.2. Participatory survey study

9.1.2.1. Antecedents of GI adoption

Stakeholder pressures and GI adoption: In the structural model testing, the relationships between stakeholder pressures and the adoption of GI by shipping firms were first examined. It is suggested that stakeholder pressures are an important factor that motivates the decision of a firm to implement green initiatives (González-Benito and González-Benito, 2006). In this study, three types of stakeholder pressure were identified namely, regulatory, competitive, and customer pressures. It was posited that shipping firms that perceive these pressures are more likely to adopt GI, and thus the stakeholder pressures are positively related to the adoption of GI. The findings as shown in Table 14 support these hypotheses, which indicates that regulatory pressure (β = 0.369, $p < 0.001$), competitive pressure (β = 0.465, $p < 0.001$), and customer pressure (β = 0.169, $p < 0.01$) are positively related to GI adoption. While shipping firms perceive that stringent environmental regulations are relevant to their operations, they are expected to proactively adopt GI (e.g., retrofitting and green ship technologies) to comply with environmental regulations (e.g., MARPOL, EEDI requirements) and enhance the eco-efficiency of their shipping operations. Moreover, shipping firms nowadays face intense market competition. To improve operating efficiency, lower operating costs, meet customer requirements, and achieve greater legitimacy, similar types of GI can be commonly found among shipping firms. The competition and pressure from customers compel them to implement and regularly improve on GI in their shipping operations, so as to retain their competitiveness and respond to the environmental demands of their customers.

Environmental governance mechanisms and GI adoption: Environmental governance plays an important role in facilitating green operations. Shipping firms and their business partners can use environmental governance to specify the decision rights and accountability framework to mitigate the risks of exchange between business partners (e.g. opportunisms) and enhance the effectiveness of cooperation in introducing and implementing GI activities (Lun et al., 2015). In this study, environmental governance entails contractual, relational, and organizational governances. Contractual governance refers to the formal agreement between shipping firms and their business partners that incorporates the roles, responsibilities, and obligations of each party in the development of GI. Relational governance refers to the shared values or mutual understandings among shipping operators in terms of appropriate behavior that maintains and improves the inter-organizational relationships over the course of GI development. Organizational governance refers to the business process formulated within a shipping firm to direct the attention of organizational members to effectively develop and implement GI. In this study, it is hypothesized that contractual, relational, and organizational governance are positively related to the decision of shipping firms to adopt GI. Moreover, relational and organizational governances are posited to complement the relationship between contractual governance and GI adoption.

The findings of the participatory survey study support the hypotheses. First, H2a is validated as contractual governance is positively related to the adoption of GI by shipping firms ($\beta = 0.177$, $p < 0.01$), thus indicating that shipping firms are likely to use contracts to specify the rights and obligations of each party, and the expected performance outcomes of GI. By specifying the parameters of the cooperation, such as environmental requirements, regulations for compliance, and transaction-specific commitments (e.g., expertise and capital input into the GI project), the use of formal agreements between shipping firms and their business partners facilitates the effective adoption of GI.

Second, the results shown in Table 15 for H2b indicate that relational governance is also positively related to GI adoption ($\beta = 0.270$, $p < 0.001$). Shipping firms develop relational norms and trust through relational governance with their business partners as a result of the suppliers' engagement activities (e.g., training and workshops on environmental/innovation issues). Such activities foster information symmetry between shipping firms and their business partners, which in turn facilitate mutual trust and expectations. As a result, the improved cooperation relationship facilitates effective adoption of GI.

Third, the results support a positive relationship between organizational governance and GI adoption, ($\beta = 0.558$, $p < 0.001$). Introducing environmental policies, operating procedures, and reporting protocols allow shipping firms to consistently and systematically examine the environmental impacts of their shipping operations and utilize the performance outcomes to identify continuous improvement opportunities for green shipping operations.

Moreover, while the joint use of relational and organizational governances is recommended for overcoming the limitations of contractual governance (Lun et al., 2015), this study also tested their interrelationship to identify whether relational and organizational governance can complement the impacts of contractual governance on GI adoption. The findings of H2d and H2e show that the positive relationship between contractual governance and GI adoption is strengthened when incorporating relational and organizational governance as mediators. As shown in Table 16, with the incorporation of relational governance as a mediator, the effect of contractual governance on GI adoption is improved from (direct effect = 0.177, $P < 0.05$) to (total effect = 0.384, $p < 0.01$). With the incorporation of organizational governance as a mediator, the effect of contractual governance on GI adoption is improved from (direct effect = 0.177, $P < 0.05$) to (total effect = 0.594, $p < 0.01$). The results support the hypotheses that contractual, relational, and organizational governance are complementary in facilitating the GI adoption of firms.

9.1.2.2. Measurement validation

To operationalize GI adoption, GI constructs were developed and the measurement scales validated for evaluating the dimensions of GI adoption by employing a participatory survey of the shipping industry in the PRD region. The measurement items that underpinned the scale for GI adoption were classified into four a priori dimensions: green management, service, process, and technological innovations. Among the 19 items validated in the survey study, the construct of GI adoption adequately fits into the data collected. The validity and reliability of the scale for evaluating GI adoption are established with the systematic and scientific procedures used in this study. In the model testing, both the first- and second-order models are validated while the second-order model is considered to be a better predictor, which indicates that the GI construct should be treated as a higher order model that governs the covariance of the four dimensions of green management, service, process, and technological innovations. In the first-order model, green management, service, process, and technological innovations are correlated measurement factors for GI adoption. The estimated parameters of the second-order model are all significant and the second-order model is more restrictive with the provision of more information on the relationship between the higher-order GI adoption construct and the lower-order factors in path coefficients in addition to the correlated relationships. Thus, the second-order model appears to be a more appropriate predictor for studying GI adoption. This result reflects that GI adoption is multifaceted, and should not be limited to specific GI items.

9.1.2.3. GI and organizational performance

The relationships between GI and organizational performance (i.e., environmental, innovation, and economic performance) were examined. The results validated H3a-3d and are consistent with those of previous research studies (e.g., Chiou et al., 2011; Cheng et al., 2014a), thus confirming that GI and its sub-dimensions (i.e., green management, service, process, and technological innovations) are positively related to OP and its sub-dimensions (i.e., environmental, innovation, and economic performances). Moreover, the results are consistent with the contentions and findings in the literature (e.g., Naranjo-Gil, 2009; Cheng et al., 2014a), which show that firms should use a holistic approach to adopt GI (i.e., adopt all dimensions of GI, rather than a single dimension). An imbalance in focus on one dimension while neglecting the other dimensions can be devastating for the overall performance outcomes due to the complementary characteristics of GI adoption. As shown in Table 17, the estimated paths between GI (H4) and environmental, innovation, and economic performances are all significant at $p < 0.001$ with the highest β values, in comparison with the paths between green management (H3a), service (H3b), process (H3c), and technological (H3d) innovations.

9.1.2.4. Interrelationships among environmental, innovation, and economic performances

Crossan and Apaydin (2010) noted in their critique of recent innovation studies that many have not attempted to include both proximal and distal outcomes in their analysis. To fully understand the mechanisms behind the relationships between GI and OP, the mediating effects of environmental performance on the relationship between GI and OP (i.e. H5a) were further examined. The result indicated that the relationship between GI and economic performance is partially mediated by environmental performance; environmental performance as a mediator accounts for 65% of the total effect of the relationship between GI and economic performance. Likewise, in the result of H5b, the relationship between GI and economic performance is also partially mediated by innovation performance; innovation performance accounts for 79% of the total effect of the relationship between GI and economic performance. A plausible explanation for these results is that greater emphasis placed on GI adoption will mean that a firm is better able to exploit the opportunities by improving eco-efficiency or cultivating innovativeness, to increase its economic performance. If the significant mediating effects of environmental and innovation performances are discounted, the contribution of GI adoption on economic performance is somewhat limited with direct effect $\beta = 0.244$ and 0.143 respectively. The implication of these results is that strategizing for GI adoption should be encouraged as improved environmental and innovation performances can generate considerable economic benefits for shipping firms.

9.1.2.5. Moderating role of environmental uncertainty

To examine the moderating role of environmental uncertainty on the relationship between GI and OP, the contingency theory was used and empirical data collected from shipping managers. As posited in H6a-6d, the results showed that when environmental uncertainty is considered, the relationships between GI and OP (i.e., environmental, innovation, and economic performances) differ significantly. On the one hand, the positive relationships between GI and both environmental and innovation performances will be strengthened in uncertain environments as opposed to stable environments. On the other hand, the positive relationship between GI and economic performance will not be strengthened. Among the sub-dimensions of GI, the effectiveness of adopting green process innovations on the outcomes of OP is greater than that of green management, service, and technological innovations in uncertain environments. These results align with the findings of previous studies (e.g., Horbach et al., 2012), thus demonstrating that firms tend to adopt GI to respond to uncertain business situations. The environmental and innovation performances of shipping firms improve with increased GI adoption, however, the high capital investments (e.g., costs for developing novel green technologies or retrofitting vessels) and the lengthy payback period cannot be sufficiently justified with only the potential gains (e.g., cost savings in fuel or waste treatment) from GI adoption in the short term. Thus, shipping firms will not achieve a better economic performance by proactively introducing GI under uncertain environments; in other words, the positive relationships between GI (and its underlying components) and economic performance will not be strengthened. In addition, there is no support found for the moderating role of environmental uncertainty on the relationship between green management innovation and OP. The strength of the impacts of green management innovation on environmental and innovation performances holds across different levels of environmental uncertainty. Specifically, the impact of adopting green management innovation on environmental and innovation performances is neither better nor worse off under any environmental condition. This result seems surprisingly reasonable because conceptually, the implementation of green management innovation requires high capital inputs in R&D activities and considerable organizational restructuring (e.g., developing an innovation department, functional team), which contribute to green service and process innovation development and promote green knowledge, thus compelling firms to routinely introduce novel and technologically advanced shipping equipment to accommodate the rapidly increasing demand for green shipping operations and thus, to improve OP. Such investment in green management innovation adoption in the short-run has connotations of high financial risk, high levels of uncertainty of effectiveness, and the potential benefits for OP may not as impactful as green service and process innovation activities. Thus, shipping managers need to thoroughly examine the status quo of their firm in the adoption of green management innovation, particularly if they perceive a great deal of environmental uncertainty. In sum, these results are consistent with the contingency theory in that organizational capabilities are not equally effective under all conditions.

9.1.3. Secondary data analysis study

Based on analyses of the financial data of publicly listed shipping firms on the major stock exchanges worldwide, the results of the secondary data analysis revealed that shipping firms that have adopted GI achieve better economic performance in terms of ROA, ROE, and asset turnover. In the participatory survey study, the findings suggested that the direct positive impacts of GI adoption on economic performance are limited when discounting the significant mediating effects of environmental and innovation performances. The results of this study substantiate a plausible explanation for such findings in that shipping firms that give priority to GI are more capable of exploiting opportunities for improving eco- and operating efficiencies or cultivating innovativeness to enhance their economic performance. In this study, two fundamental components of GI (i.e. green management and technological innovations) are specifically used as the independent variables to examine the economic performance outcomes of shipping firms. These two components of GI play an essential and supporting role in directing the implementation of other components of GI (e.g., green process and service innovations). If shipping firms are not capable of transforming such innovation efforts into the introduction of green process and service innovations, adopting green management or technological innovations alone generally would only constitute as a financial burden to business. For example, shipping firms have to be capable of utilizing their obtained environmental knowledge from green management innovation or implementing the particular weather routing technology or waste-heat recovery systems into their green shipping process, so as to improve their eco- and operating efficiencies and as a result, achieve better economic performance (e.g., generate profit from saving on fuel costs). Overall, the results of this study show that shipping firms that have adopted green management and technological innovations can attain better economic performance in terms of ROA, ROE, and asset turnover in comparison with firms that do not adopt green management and technological innovations. It can be reasonably assumed that such significant economic benefits are in part due to the successful and effective transformation of innovation efforts into the introduction of new green services or advancement of green shipping processes.

9.2. Academic implications

This study has four important implications for research on GI adoption.

- First and foremost, the findings of this study provide firms with the theoretical means of achieving sustainable competitive advantages through the active pursuit of GI. In the course of doing so, firms need to commit to a proper set of tangible (e.g., experts, R&D investment, technological innovation infrastructures, etc.) and intangible (e.g., environmental information, knowledge, know-how, social capital, etc.) resources. These resources enable firms to effectively and efficiently meet the increasing demands for novel green shipping services that originate from environmental threats, stringent regulations, and customer demands. The effective pursuit of GI requires firms to continually review, integrate, and reconfigure their internal and external competencies to adapt to an uncertain and volatile environment. However, success in addressing these challenges provides opportunities to achieve sustainable competitive advantages through the development and acquisition of a unique set of resources and competencies.

- Second, the multidimensional conceptualization of the GI adoption model provides insights into the construct of GI adoption and its relationships with the underlying dimensions. The related items and sub-dimensions of GI are adapted specifically to the context of the shipping industry; therefore, they provide feasible suggestions for GI adoption. The conceptualization of the GI construct assists shipping firms to see GI adoption at an advanced level of abstraction beyond the individual items. With individual items, shipping firms may use GI as a tool for evaluating the need for improvement in particular aspects of their green shipping operations. The measurement items validated in this study provide shipping firms with a systematic guideline to evaluate their strengths and weaknesses in GI adoption and also identify the opportunities for improvement.

- Third, this study has systematically investigated the relationships among the antecedents (stakeholder pressures and environmental governance mechanisms), GI adoption, environmental uncertainty, and OP in shipping firms. The results of this study extend the findings in the green shipping literature by providing evidence that 1) stakeholder pressures and environmental governance mechanisms are positively related to GI adoption. Competitive pressure is a major external factor that compels shipping firms to introduce GI activities. Moreover, by developing standard operating procedures and environmental policies and reporting protocols, the results of this study suggest that organizational governance is the primary mechanism that effectively guides GI adoption in the shipping industry. The relationship between contractual governance and GI adoption is significantly mediated by relational and organizational governance. 2) GI adoption is positively related to OP; 3) in an uncertain business environment, firms would not obtain a better economic performance through GI adoption; likewise, adopting green management innovation alone will not facilitate improvement in environmental, innovation, and economic performances; and 4) the positive impacts of GI adoption on economic performance are mainly due to improved environmental and innovation performances. Examining the relationships between these factors add to the understanding of how and what kinds of GI occurs, and their driving factors and implications on performance outcomes.

- Fourth, this study has explored the relationship between GI and OP from the contingency perspective. The results reveal that this relationship is not equally positive. Environmental uncertainty is an important contextual factor that enhances the positive relationship between GI and OP. As the perceived environmental uncertainty increases, the adoption of green service, process, and technological innovations increasingly enhances environmental and innovation performances but not economic performance. In addition, the results respond to and confirm the contentions of previous GI studies (Naranjo-Gil, 2009; Cheng et al., 2014a) in that employing a holistic approach to adopt GI in a highly uncertain environment will be more beneficial for OP, rather than adopting a single dimension of GI. Thus, considering the contingent role of EU can provide a better understanding of the value of GI, its underlying dimensions, and performance implications.

9.3. Managerial implications

The results of this study have four primary managerial implications for shipping managers.

- First, by focusing on the concept of innovation, this study has identified that GI in the shipping industry consists of four key components. Second, with the conceptualization of GI and demonstration of its relationships between different driving factors and performance implications, the findings can be used as a reference for shipping managers when considering the undertaking of GI.
- Second, the findings of this study suggest that using contractual governance alone is not sufficient for effectively guiding GI adoption. Given the complementary characteristics of contractual, relational, and organizational governance, shipping managers should use a combination of different governance mechanisms to manage the development of GI activities.
- Third, given the moderating role of environmental uncertainty on the relationships between GI and OP, shipping managers should align their GI strategies with the conditions of the external environment, so as to attain the full extent of performance improvement. For instance, in an uncertain environment, managers should consider a high level of GI to respond to the changing environmental conditions (e.g., routinely refining shipping processes to improve eco-efficiency, actively introducing green equipment for energy saving, reducing emissions, and complying with environmental regulations), as this strategy enables them to seize the potential advantages of environmental changes and achieve exceptional performance outcomes. In contrast, in circumstances where there is little environmental uncertainty, managers should just maintain an adequate level of GI adoption, as the impacts will be minimal and may even reduce the efficiency and effectiveness of resource utilization (e.g., human and capital costs for acquiring new knowledge and technologies) in implementing GI activities. Thus, managers should focus on an optimal mix of strategies and capabilities to effectively allocate resources for GI adoption.
- Fourth, the discussed variables in this study are interrelated with other organizational variables, resources, and strategies. For example, the effectiveness of green management innovation on OP not only depends on how much green knowledge is acquired, integrated, stored, and disseminated, but also on the ease of retaining such

information and knowledge. Hence, shipping managers need to recognize the interaction between the linkages explored in this study with other organizational phenomena before deciding on GI strategies.

9.4. Policy implications

This study provides three policy implications for GI in shipping.

- First, the findings highlight the essential role of knowledge exchange in facilitating GI adoption. Shipping firms actively participate in R&D efforts with universities and partnerships with other firms to produce GI and technologies for shipping. Policy makers may initiate relevant supporting policies for R&D to encourage cooperation in the shipping industry for innovative purposes (for e.g. providing funding to encourage R&D partnerships and technology transfer for GI).
- Second, some shipping firms currently provide different environmental and innovation training and workshops to their business partners or customers. Such workshops allow shipping firms and their partners or customers to generate green knowledge through the active exchange of trends, information, and experience in GI adoption, which in turn, advances the development of GI in the shipping industry. Therefore, policy makers may take a direct role in facilitating green knowledge exchange (for e.g., introducing an official green knowledge exchange platform for shipping firms to facilitate the sharing of best practices in GI adoption in the shipping industry).
- Third, the findings suggest that GI adoption may come with financial losses, which are due to the high capital investment (e.g., costs for developing novel green technologies and acquiring expertise) and the lengthy payback period might not be sufficiently justified by the potential gains (e.g., cost savings in fuel or waste treatment). To encourage GI adoption, policy makers may wish to consider the provision of guidelines and financial subsidies for shipping firms to develop GI.

9.5. Limitations of study

This study has four major limitations.

- First, in the survey study, the sample of respondents is taken from shipping firms and the study assesses information only from the perspective of the shipping industry. Consequently, it offers a self-reported, one-dimensional focus. The study results could be different if the questionnaire data are collected from other transportation sectors (e.g., air, land, and rail transport) and stakeholders (e.g., shippers and consignees) within the transportation chain. Further research will benefit from testing the instrument with different parties in the transportation chain to triangulate the findings.

- Second, t-tests were conducted to test for non-response bias and identify whether there is any significant difference with GI adoption among the three waves of respondents. Although the test results confirmed that there is no non-response bias, it is entirely possible that non-response bias may exist with the non-respondents who have not adopted GI but achieved superior organizational performance. This study, however, is unable to determine the statistical differences between the non-respondents and the 226 respondents in the sample.
- Third, this study focuses on evaluating the moderating effects of environmental uncertainty on the relationships between GI and OP without a more in-depth investigation by separately examining the individual components of EU (e.g., demand, supply, technological uncertainty, competition intensity, etc.). Future empirical research that examines the moderating effects of specific kinds of environmental uncertainties on the relationships between GI and OP is encouraged.
- Forth, this study focuses on verifying the relationship between GI and OP, and suggests that the adoption of GI is one of the strategic means to improve the eco- and operational efficiencies of shipping operations, which in turn, will benefit environmental, innovation, and economic performances. While the factors that influence the firm performance of shipping firms are complex, other factors such as the global economic situation, freight rate, bunker price, market segments, risk profiles, and types and management of shipping firms are also worth considering in future GI studies.

9.6. Future research directions

GI is an emerging topic in research work on shipping and innovation management, and there are a number of different areas that can be examined in future research such as radical vs. incremental innovation and the related issues, open vs. closed innovation, the role of organizational learning in GI adoption, the notion of ambidexterity, etc. Richer insights can be obtained if future studies consider these concepts to further investigate the relationships between GI and OP, which allow both academic researchers and practitioners to determine the effectiveness of different types of GI for producing exceptional performance outcomes.

9.7. Concluding remarks

To respond to stringent environmental regulations and improve the eco- and operating efficiencies of shipping operations, the shipping industry has been placing increasing emphasis on greening issues. However, the concept of GI has been largely ignored in the extant shipping literature. This study uses a mixed methods research approach, which consists of a qualitative study (i.e. exploratory case study) and two quantitative studies (i.e., participatory survey study and a post-hoc analysis study). The aim is to provide a comprehensive picture of GI adoption in the shipping industry by empirically and systematically examining the relationships among the antecedents, adoption, and performance outcomes of GI.

In this study, first, an exploratory case study is conducted to illustrate the key components and the pursuit of GI by shipping firm and preliminarily examine the influence of GI adoption on the environmental and economic performances of a firm. Second, a participatory survey study that focuses on PRD-based shipping firms is conducted to empirically validate the theory-driven conceptual framework and show the relationships among the antecedents, GI adoption, and performance implications of GI adoption. Lastly, to ensure that the findings of the participatory survey can be generalized to international shipping firms, a post-hoc analysis is conducted with secondary data to explore whether the publicly-listed international shipping firms in this study can achieve better economic performance through GI adoption. Together, the exploratory case study, participatory survey, and post-hoc analysis ensure the validity and generalizability of the findings in this study.

As there is a serious lack of research that focuses on GI in the shipping industry, this study conceptualizes and validates GI and its sub-dimensions in the shipping context. The findings of this study show that GI adoption by shipping firms is driven by stakeholder pressures (i.e., regulatory, competitive, and customer pressures) and compelled by environmental governance mechanisms (i.e., contractual, relational, and organizational governances). The influence of contractual governance on GI adoption is mediated by relational and organizational governance. Moreover, the findings support the hypotheses that GI adoption is positively related to the OP (i.e., environmental, innovation, and economic performances) of a firm. The positive effect of GI adoption on economic performance, to a large extent, is mediated by the environmental and innovation performances of a firm. Furthermore, environmental uncertainty plays a significant moderating role between GI adoption and OP. Under an uncertain business environment, the adoption of green service, process, and technological innovations increasingly enhance environmental and innovation performances but not economic performance.

In general, by focusing on the shipping firms in the PRD region, this study contributes to the shipping and operations management literature by validating the measurement scales for GI adoption; illuminating the contingent value of GI and its underlying components for OP under different levels of environmental uncertainty; as well as uncovering the interrelationships among the antecedents, GI adoption, and OP and their underlying components. This research work sheds new light on the crucial role of GI in the shipping industry and provides the groundwork for future GI studies on green shipping.

THE HONGKONG
POLYTECHNIC UNIVERSITY
香港理工大學

Appendix A. Cover Letter (ENG)

<<Date>>

Dear Sir/Madam,

Shipping companies in recent years have implemented green innovation to mitigate the environmental impacts caused by the shipping activities. Your company may be pondering over the following pressing questions concerning the adoption of green innovation in shipping operations: What are the role and value of your company’s green innovation in promoting organizational performance? How to evaluate your company’s green innovativeness? Can your company’s green innovation sufficiently meet the market demands and support the business needs in the ever-changing environment?

To address such imperative questions, we are conducting a study to examine the relationship between the determining factors and performance outcomes of the shipping company’s green innovation adoption. The purpose of this questionnaire survey is to gather necessary data for our study from practitioners and professionals in the shipping industry.

You are cordially invited to participate in this survey, which should take about 10 to 15 minutes to complete. You may complete either the English or Chinese version of questionnaire. The content on both questionnaires are the same.

As has always been the policy of the research conducted by The Hong Kong Polytechnic University, all information you provided will be treated in strict confidence and will not be divulged to anyone. All information collected will be used only for research purposes. The research results will be written for industrial levels and there will be no possibility of identity disclosure.

We appreciate your return of the completed questionnaire ***within two weeks*** by post using the enclosed pre-paid envelope, or by e-mail to XXXXXXXXX. If you have any question about this survey, please contact the project researcher, Mr. Michael Ng at XXXX XXXX or the project supervisor, Dr. Venus Lun at XXXX XXXX.

Your contribution to the success of this study is greatly appreciated. We look forward to receiving your completed survey soon. Thank you very much in advance for your time and support.

Yours Faithfully,

Michael Ng
PhD Candidate
Department of Logistics and Maritime Studies
The Hong Kong Polytechnic University

敬啟者：

航運物流操作對環境造成的污染問題近年備受政府及社會關注，促使航運物流業界相繼引進綠色創新以改善環境問題及提升組織績效。貴公司或正迫切探究以下與綠色航運操作有關的問題：綠色創新的採行如何影響組織績效？如何評估綠色創新性？隨著營運環境的不斷演變，綠色創新能否充分地滿足市場需求及支援業務需要？

為解答這些重要的問題，我們正開展一項探討航運物流業綠色創新採用的前因及對組織績效之關聯性的研究。是次問卷調查的對象針對航運物流業界的從業員和專業人士，旨在為研究項目蒐集必要的數據。

本問卷只需十至十五分鐘便可完成，我們誠摯邀請閣下撥冗參與是次調查，中英文問卷內容相同，您可以選擇以英文或中文問卷作答。

按照香港理工大學一貫的研究方針，您所提供的所有資料將嚴格保密，不會洩露予任何人士。所蒐集的資料將只作研究目的。研究結果將只對航運物流業作整體性的分析，並不作任何的身份識別。

煩請於***兩個星期內***使用隨函的預付郵費信封，將已填妥的問卷寄回或電郵至 XXXXXXXX。如您對本調查有任何疑問，請與項目研究員－吳文傑先生（電話：XXXXXXXX）或項目主管－倫婉霞博士（電話：XXXXXXXX）聯絡。

您的參與對本研究項目的成功尤為重要，我們熱切期待收到您完成的問卷。衷心感謝您的寶貴時間和支持。

此致

吳文傑
博士研究生
物流及航運學系
香港理工大學

年　月　　　日

敬启者：

航运物流操作对环境造成的污染问题近年备受政府及社会关注，促使航运物流业界相继引进绿色创新以改善环境问题及提升组织绩效。贵公司或正迫切探究以下与绿色航运操作有关的问题：绿色创新的采行如何影响组织绩效？如何评估绿色创新性？随着营运环境的不断演变，绿色创新能否充分地满足市场需求及支援业务需要？

为解答这些重要的问题，我们正开展一项探讨航运物流业绿色创新采用的前因及对组织绩效之关联性的研究。是次问卷调查的对象针对航运物流业界的从业员和专业人士，旨在为研究项目搜集必要的数据。

本问卷只需十至十五分钟便可完成，我们诚挚邀请阁下拨冗参与是次调查，中英文问卷内容相同，您可以选择以英文或中文问卷作答。

按照香港理工大学一贯的研究方针，您所提供的所有资料将严格保密，不会泄露予任何人士。所搜集的资料将只作研究目的。研究结果将只对航运物流业作整体性的分析，并不作任何的身份识别。

烦请于***两个星期内***使用随函的预付邮费信封，将已填妥的问卷寄回或电邮至 XXXXXXXX。如您对本调查有任何疑问，请与项目研究员－吴文杰先生（电话：XXXX XXXX）或项目主管－伦婉霞博士（电话：XXXX XXXX）联络。

您的参与对本研究项目的成功尤为重要，我们热切期待收到您完成的问卷。衷心感谢您的宝贵时间和支持。

此致

吴文杰
博士研究生
物流及航运学系
香港理工大学

年　月　　日

Green Innovation Adoption in the Shipping Industry

INSTRUCTION:

- Please answer all the questions and choose the most appropriate answer for each question.
- Please be reminded that the questionnaire can be answered by Operations Manager, Environmental Management Manager, Quality Assurance Manager, or a member of Senior Management of the responding company.

Shipping refers to the business of transporting goods. Key sectors of the shipping industry include *transport carrier, terminal operator*, *3PL/freight forwarder*, and *midstream operator.*

In this study, green shipping innovation is defined as "*the use of novel solutions or significantly improved operations to perform shipping related activities to pursue environmental objectives*". It involves green management innovation, green service innovation, green process innovation, and green technological innovation.

PART I: The adoption of green shipping innovation

Please describe your company in relation to competing companies in the shipping industry over the past *three* years on the extent to which …

	0-20% Very Low	21-40% Low	41-60% Moderate	61-80% High	81-100% Very High
Green Management Innovation – Your company …					
1. Implements environmental management systems (e.g., ISO14001, EMAS) to manage shipping operations	1	2	3	4	5
2. Collects updated information on green innovation relevant to the shipping industry	1	2	3	4	5
3. Participates in research and development activities relevant to green innovation (e.g., R&D collaboration with research institutes/universities)	1	2	3	4	5
4. Communicates green innovation information with employees/customers (e.g., environmental trainings/seminars)	1	2	3	4	5
5. Shares green shipping experience among various departments involved in the implementation of green innovation	1	2	3	4	5
Green Service Innovation – Your company …					
6. Initiates shipping services to prevent pollution	1	2	3	4	5
7. Initiates shipping services to save energy/resources	1	2	3	4	5
8. Introduces novel shipping services to prevent pollution	1	2	3	4	5
9. Introduces novel shipping services to save energy/resources	1	2	3	4	5
10. Redesigns green shipping services to enhance environmental operations	1	2	3	4	5
11. Introduces recovery/recycling "end-of-life" shipping equipment	1	2	3	4	5
Green Process Innovation – Your company …					
12. Reviews and modifies shipping processes to prevent pollution	1	2	3	4	5
13. Reviews and modifies shipping processes to save energy/resources	1	2	3	4	5
14. Uses novel shipping processes to prevent pollution	1	2	3	4	5
15. Uses novel shipping processes to save energy/resources	1	2	3	4	5
16. Incorporates recovery/recycling systems into shipping processes	1	2	3	4	5
Green Technological Innovation – Your company …					
17. Reviews and adopts technologies to support green management, service, and process innovation	1	2	3	4	5
18. Uses novel technologies or equipment to support green management, service, and process innovation	1	2	3	4	5
19. Uses novel technologies to manage shipping documentation and information, and provide relevant environmental information	1	2	3	4	5

PART II: Influence of stakeholders' pressures on the adoption of green shipping innovation
Please provide the most appropriate descriptions for your company

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Regulatory Pressure and Incentive – Your company …					
1. Adopts green shipping innovation to comply with the regulations/restrictions imposed by government on the industry sector	1	2	3	4	5
2. Adopts green shipping innovation to cope with the future government environmental legislation	1	2	3	4	5
3. Experiences frequent inspections or audits in relation to compliance with the environmental rules and regulations from relevant governing bodies	1	2	3	4	5
4. Incentives offered by government (e.g., grants, subsidies, and tax/fee reductions) are significant motivators for the adoption of green shipping innovation	1	2	3	4	5
Competitive Pressure – Your competitors …					
5. Adopt green shipping innovation to improve company image	1	2	3	4	5
6. Adopt green shipping innovation to achieve business objectives	1	2	3	4	5
7. Adopt green shipping innovation to enhance organizational performance (e.g., environmental performance, innovation performance, and economic performance)	1	2	3	4	5
8. Generally believe that the benefits of green shipping innovation adoption outweigh the costs incurred	1	2	3	4	5
Customer Pressure – Your customers …					
9. Expect your company to adopt green shipping innovation	1	2	3	4	5
10. Will switch to competitors who adopt green shipping innovation	1	2	3	4	5
11. Will withhold their contracts if your company does not meet their environmental requirements	1	2	3	4	5
12. Have a clear environmental policy statement	1	2	3	4	5

PART III: Influence of environmental governance on the adoption of green shipping innovation
Please select from the following the most appropriate descriptions for your company

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Organizational Mechanism - Your company …					
1. Incorporates organizational environmental policies and procedures into business operations (e.g., shipping operations, staff training activities)	1	2	3	4	5
2. Initiates a dedicated department to manage environmental affairs	1	2	3	4	5
3. Implements cross-functional co-operation to facilitate the development of green shipping operations	1	2	3	4	5
4. Introduces and documents operating procedures to regularly track and monitor the latest information and trends relevant to green shipping	1	2	3	4	5
5. Introduces and documents operating procedures to periodically track and evaluate the internal environmental performance	1	2	3	4	5
6. Introduces and documents operating procedures to identify and resolve the environmental problems and non-conformance	1	2	3	4	5
Contractual Mechanism - Your company has formal written agreements (e.g., contracts) specifying…					
7. Business partners' environmental requirements of shipping operations (e.g., service level, energy efficiency, CO_2 emission level)	1	2	3	4	5
8. Rights and obligations of both parties in the implementation of green shipping operations	1	2	3	4	5
9. Methods of monitoring or assessing the environmental performance of business partners	1	2	3	4	5
10. Methods of handling complaints and disputes in green shipping operations	1	2	3	4	5
11. Methods of handling contingencies in green shipping operations	1	2	3	4	5

Relational Mechanism - Your company and business partners…	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
12. Frequently and informally share and exchange information (e.g., ideas, environmental knowledge and initiatives) that support the implementation of green shipping operations	1	2	3	4	5
13. Notify each other about events or changes that might impact the green shipping operations	1	2	3	4	5
14. Are flexible to co-operatively respond to the requests for changes, and make necessary adjustments in green shipping services (e.g., service level, environmental requirements) to cope with the changing circumstances	1	2	3	4	5
15. Commit to environmental improvements that enable bilateral benefits rather than individual benefits	1	2	3	4	5

PART IV: Perceived environmental uncertainty

Please select from the following the most appropriate descriptions for your company

1. Business partners consistently meet the environmental requirements of your company	1	2	3	4	5
2. Business partners provide green shipping services with consistent quality	1	2	3	4	5
3. Customers' needs for green shipping services are difficult to assess	1	2	3	4	5
4. Green shipping technologies are difficult to implement due to the high degree of technological complexity and rapid technological changes	1	2	3	4	5

PART V: Performance outcomes of the adoption of green shipping innovation

Please describe your company's organizational performance in relation to competing companies in the shipping industry on the following performance measures over the past *three* years.

Environmental Performance	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Generates less air pollutants/carbon emissions	1	2	3	4	5
2. Discharges less waste water	1	2	3	4	5
3. Produces less solid wastes	1	2	3	4	5
4. Consumes less hazardous materials	1	2	3	4	5
5. Increases materials or equipment recycling/recovery	1	2	3	4	5
Innovation Performance					
6. Performs better in introducing novel shipping services and processes to meet customers' needs	1	2	3	4	5
7. Is perceived by customers to be more innovative	1	2	3	4	5
8. Increases number of green innovations in the shipping service portfolio of your company	1	2	3	4	5
9. Consumes less time between the conception of a green innovation and its introduction into the market place	1	2	3	4	5
Economic Performance					
10. The adoption of green innovation has a positive impact on the financial performance of your company	1	2	3	4	5
11. Please indicate the extent to which your company has experienced any of the following benefits from the adoption of green shipping innovation over the past *three* years:					
− Reduces costs for energy consumption	1	2	3	4	5
− Reduces costs for waste treatment	1	2	3	4	5
− Reduces fee for waste discharge	1	2	3	4	5
− Reduces fine for environmental accident	1	2	3	4	5
− Improves corporate image	1	2	3	4	5
− Improves productivity	1	2	3	4	5
− Improves quality of shipping services	1	2	3	4	5
− Increases sales volume (by attracting more customers)	1	2	3	4	5
− Improves market share	1	2	3	4	5
− Improves profit margin	1	2	3	4	5
− Achieves higher return on assets	1	2	3	4	5

PART VI: General Information

Please evaluate the level of your knowledge and familiarity with…	Very Little	Little	Moderate	Good	Very Good
1. The business operations of your company	1	2	3	4	5
2. The company's activities involved in green shipping innovation	1	2	3	4	5
3. Your involvement in the company's green shipping innovation	1	2	3	4	5

4. The type of ownership of your company:
   ☐ Stated-owned ☐ Privately-owned ☐ Collectively-owned (subsidized by government)
   ☐ Publicly-listed ☐ Foreign joint venture ☐ Others (please specify: ________________________)

5. The industry sector in which your company competes:
   ☐ Transport carrier ☐ Terminal operator ☐ 3PL/Freight forwarder
   ☐ Midstream operator ☐ Others (please specify: ________________________)

6. Number of years your company has been in business:
   ☐ 1-5 ☐ 6-10 ☐ 11-15 ☐ 16-20
   ☐ 21-25 ☐ 26-30 ☐ 31-35 ☐ 36 or longer

7. Number of employees in your company:
   ☐ 1-10 ☐ 11-50 ☐ 51-100 ☐ 101-500 ☐ > 500

8. The turnover of your company in the last fiscal year (HKD$):
   ☐ Under 10 million ☐ 10-19 million ☐ 20-29 million
   ☐ 30-39 million ☐ 40 million or more

9. Please indicate the business scope of your company:
   ☐ For Hong Kong only ☐ For China only ☐ For Hong Kong and China
   ☐ International ☐ Others (please specify: ________________________)

10. Please kindly provide your contact information or attach your business card for further discussion or follow-up.

Name:	
Title:	
Company:	
Address:	
Phone Number:	
E-mail:	

Please provide any comments about this survey (additional sheet can be attached), if any:

☐ I would like to receive a copy of the study results.

We appreciate your return of the completed questionnaire ***within two weeks*** by post using the enclosed pre-paid envelope or by e-mail to XXXXXXXX.

If you have any questions about this survey, please contact the following:
Project Researcher: Mr. Michael Ng (Tel: XXXXXX, E-mail: XXXXXX)
Project Supervisor: Dr. Venus Lun (Tel: XXXXXX, E-mail: XXXXXX)

<End of questionnaire>

Thank you very much for your participation in this study.

航運業綠色創新的採行

說明：
- 請選擇最合適的答案，並回答所有問題。
- 此調查問卷可由貴公司的營運經理、環境管理經理、質量保證經理或高級管理層成員回答。

航運是指貨物運輸的業務。航運業的主要業界類別包括*運輸承運商*、*碼頭營運商*、*第三方物流服務供應商/貨運代理*、以及*中流作業營運商*。

綠色航運創新在本研究項目中定義為：*利用新穎的解決方案或有顯著改善的操作方式來執行與航運相關的活動，以達致環境目標*。綠色航運創新包括：綠色管理創新、綠色服務創新、綠色流程創新、以及綠色科技創新。

第一部分：綠色航運創新的採行
請描述在過去三年，貴公司在航運業內相對於競爭對手在採行綠色創新程度。

綠色管理創新 – 貴公司…	0-20% 非常低	21-40% 低	41-60% 中等	61-80% 高	81-100% 非常高
1. 執行環境管理系統（例如： ISO 14001、EMAS），以管理航運操作	1	2	3	4	5
2. 收集與航運業相關的綠色創新最新信息	1	2	3	4	5
3. 參與綠色創新相關的研究和開發活動（例如：與研究機構/大學合作研發活動）	1	2	3	4	5
4. 與員工/客戶交流綠色創新信息（例如：環保培訓/講座）	1	2	3	4	5
5. 與各個參與執行綠色創新的部門共享綠色航運經驗	1	2	3	4	5
綠色服務創新 – 貴公司…					
6. 開展航運服務，以防止污染	1	2	3	4	5
7. 開展航運服務，以節省能源/資源	1	2	3	4	5
8. 引進新穎的航運服務，以防止污染	1	2	3	4	5
9. 引進新穎的航運服務，以節省能源/資源	1	2	3	4	5
10. 重新設計綠色航運服務，以優化環保操作	1	2	3	4	5
11. 引進回收/循環再用的報廢船舶設備	1	2	3	4	5
綠色流程創新 – 貴公司…					
12. 檢討和改進航運流程，以防止污染	1	2	3	4	5
13. 檢討和改進航運流程，以節省能源/資源	1	2	3	4	5
14. 採納新穎的航運流程，以防止污染	1	2	3	4	5
15. 採納新穎的航運流程，以節省能源/資源	1	2	3	4	5
16. 把回收/循環再用系統納入航運流程	1	2	3	4	5
綠色科技創新 – 貴公司…					
17. 檢討和採納科技，以支援綠色管理、服務、以及流程創新	1	2	3	4	5
18. 採用新穎的科技或設備，以支援綠色管理、服務、以及流程創新	1	2	3	4	5
19. 採用新穎的科技來管理航運文件和資料，並提供相關的環境信息	1	2	3	4	5

第二部分：利益相關者的壓力與採行綠色航運創新的關係
請提供最合適的描述。

法規壓力及誘因 – 貴公司	非常不同意	不同意	中立	同意	非常同意
1. 採行綠色航運創新，以遵守政府對業界所施行的相關法規/限制	1	2	3	4	5
2. 採行綠色航運創新，以符合政府未來的環保法規	1	2	3	4	5
3. 頻繁接受相關監管機構按環保法規進行的巡查或審計	1	2	3	4	5
4. 政府提供的誘因（例如：補助、津貼及稅務/費用減免）是採行綠色航運創新的重要動機	1	2	3	4	5

競爭壓力－貴公司的競爭對手

		1	2	3	4	5
5.	採行綠色航運創新，以提升企業形象	1	2	3	4	5
6.	採行綠色航運創新，以達成業務目標	1	2	3	4	5
7.	採行綠色航運創新，以提升組織在環境、創新及經濟方面的績效	1	2	3	4	5
8.	一般相信採行綠色航運創新所帶來的效益遠超成本	1	2	3	4	5

客戶壓力－貴公司的客戶

9.	期望貴公司採行綠色航運創新	1	2	3	4	5
10.	將會轉換到採行綠色航運創新的競爭對手	1	2	3	4	5
11.	如果貴公司沒有達到他們的環保要求，他們將中止合同	1	2	3	4	5
12.	有明確的環境政策聲明	1	2	3	4	5

第三部分：環境治理與採行綠色航運創新的關係

請從下列各項中選擇最合適的描述。

組織機制－貴公司

		非常不同意	不同意	中立	同意	非常同意
1.	把組織環保方針及程序納入業務操作（例如：航運操作、員工培訓活動）	1	2	3	4	5
2.	成立專責部門，以管理環境事務	1	2	3	4	5
3.	實施跨部門合作，以促進綠色航運操作的發展	1	2	3	4	5
4.	實施並以書面形式記錄操作程序，定期追踪及監察與綠色航運相關的最新信息和發展趨勢	1	2	3	4	5
5.	實施並以書面形式記錄操作程序，定期追踪及評估公司內部的環境績效	1	2	3	4	5
6.	實施並以書面形式記錄操作程序，找出及解決衍生的環境問題與不合規情況	1	2	3	4	5

契約機制－貴公司與商業夥伴的正式書面協議（例如：合同）訂明

7.	商業夥伴對航運操作的環境要求（例如：服務水平、能源效率、二氧化碳排放水平）	1	2	3	4	5
8.	雙方在執行綠色航運操作時的權利和義務	1	2	3	4	5
9.	監察或評估商業夥伴環境績效的方法	1	2	3	4	5
10.	在綠色航運操作中，處理投訴和糾紛的方法	1	2	3	4	5
11.	在綠色航運操作中，處理突發事件的方法	1	2	3	4	5

關聯機制－貴公司與商業夥伴

12.	頻密地和透過非正式的渠道共享和交換有助於執行綠色航運操作的信息（例如：相關建議、環境知識及措施）	1	2	3	4	5
13.	告知對方對綠色航運操作有潛在影響的事件或變化	1	2	3	4	5
14.	能因應情況的變化，靈活地共同應對變更要求，並為綠色航運服務作必要的調整（例如：服務水平、環境要求）	1	2	3	4	5
15.	為雙方利益而非單方利益，致力於環境的改善	1	2	3	4	5

第四部分：感知的環境不確定性

請從下列各項中選擇最合適的描述。

		非常不同意	不同意	中立	同意	非常同意
1.	商業夥伴一貫能滿足貴公司的環保要求	1	2	3	4	5
2.	商業夥伴提供質量穩定的綠色航運服務	1	2	3	4	5
3.	客戶對綠色航運服務的需求難以評估	1	2	3	4	5
4.	由於技術複雜性高及變化迅速，綠色航運科技難以施行	1	2	3	4	5

第五部分：綠色航運創新與績效成果

請描述在過去三年，貴公司相對於航運業內競爭對手的組織績效，在以下績效量度指標上表現。

	非常不同意	不同意	中立	同意	非常同意
環境績效					
1. 減少空氣污染物/碳排放	1	2	3	4	5
2. 減少廢水排放	1	2	3	4	5
3. 減少固體廢物產生	1	2	3	4	5
4. 減少有害物質消耗	1	2	3	4	5
5. 增加物料或設備循環再造/回收的數量	1	2	3	4	5
創新績效					
6. 為滿足客戶需求而引進新穎的航運服務和流程時，有更好的表現	1	2	3	4	5
7. 客戶均認為貴公司具較強的創新性	1	2	3	4	5
8. 在貴公司的航運服務組合中，已增加更多的綠色創新	1	2	3	4	5
9. 耗費較少的時間把綠色創新概念引入市場	1	2	3	4	5
經濟績效					
10. 採行綠色創新對貴公司的財務績效有正面的影響	1	2	3	4	5
11. 請指出在過去三年，貴公司因採行綠色創新而體驗到下列各項效益的程度：					
－ 降低能源消耗成本	1	2	3	4	5
－ 降低廢物處理成本	1	2	3	4	5
－ 減少廢物排放費用	1	2	3	4	5
－ 減少環保事故罰款	1	2	3	4	5
－ 改善企業形象	1	2	3	4	5
－ 提高生產力	1	2	3	4	5
－ 提高航運服務質素	1	2	3	4	5
－ 增加銷量（通過吸引更多的客戶）	1	2	3	4	5
－ 提高市場份額	1	2	3	4	5
－ 提高邊際利潤	1	2	3	4	5
－ 提高資產收益率	1	2	3	4	5

第六部分：一般資料

請評估您對貴公司業務運作的認識和熟悉水平。	非常少	少	中等	好	非常好
1. 您對貴公司業務運作的認識	1	2	3	4	5
2. 您對貴公司所涉及綠色航運創新的認識	1	2	3	4	5
3. 您對貴公司綠色航運創新的參與是	1	2	3	4	5

4. 貴公司的企業類型：
   ☐ 國有企業　☐ 私營企業　☐ 集體企業（政府補貼）
   ☐ 上市企業　☐ 中外合資企業　☐ 其他 (請註明：__________________)

5. 貴公司的業界類別：
   ☐ 運輸承運商　☐ 碼頭營運商　☐ 第三方物流服務供應商/貨運代理
   ☐ 中流作業營運商　☐ 其他 (請註明：__________________)

6. 貴公司的業務資歷：
   ☐ 1-5 年　☐ 6-10 年　☐ 11-15 年　☐ 16-20 年
   ☐ 21-25 年　☐ 26-30 年　☐ 31-35 年　☐ 36 年或以上

7. 貴公司的員工人數：
☐ 1-10 人　☐ 11-50 人　☐ 51-100 人　☐ 101-500 人
☐ 多於 500 人

8. 貴公司在上個財政年度的營業額（港幣）：
☐ 少於 1,000 萬元　☐ 1,000-1,999 萬元　☐ 2,000-2,999 萬元　☐ 3,000-3,999 萬元
☐ 4,000 萬元或以上

9. 貴公司的業務範圍集中於：
☐ 香港市場　☐ 中國市場　☐ 香港及中國市場　☐ 國際市場
☐ 其他 (請註明： ___________________)

10. 請提供您的聯絡資料或附上名片以便作進一步討論或跟進。

姓名：	
稱謂：	
公司名稱：	
地址：	
電話號碼：	
電子郵件：	

請在以下的空格提出您對本調查的任何意見：

☐ 閣下希望收到調查研究結果的副本。

煩請於***兩個星期內***使用隨函的預付郵費信封將已填妥的問卷寄回或電郵至 XXXXXXXX.

如您對本調查有任何疑問，請聯絡：
項目研究員： 吳文傑先生　電話：XXXXXXXX　電郵：XXXXXXXX
項目主管：　倫婉霞博士　電話：XXXXXXXX　電郵：XXXXXXXX

<調查問卷結束>

非常感謝您對是次研究的參與。

航运业绿色创新的采行

说明：

- 请选择最合适的答案，并回答所有问题。
- 此调查问卷可由贵公司的营运经理、环境管理经理、质量保证经理或高级管理层成员回答。

航运是指货物运输的业务。航运业的主要业界类别包括运输承运商、码头营运商、第三方物流服务供应商/货运代理、以及中流作业营运商。

绿色航运创新在本研究项目中定义为：*利用新颖的解决方案或有显著改善的操作方式来执行与航运相关的活动，以达致环境目标*。绿色航运创新包括：绿色管理创新、绿色服务创新、绿色流程创新、以及绿色科技创新。

第一部分：绿色航运创新的采行

请描述在过去三年，贵公司在航运业内相对于竞争对手在采行绿色创新程度。

绿色管理创新－贵公司…	0-20% 非常低	21-40% 低	41-60% 中等	61-80% 高	81-100% 非常高
1. 执行环境管理系统（例如： ISO 14001、EMAS），以管理航运操作	1	2	3	4	5
2. 收集与航运业相关的绿色创新最新信息	1	2	3	4	5
3. 参与绿色创新相关的研究和开发活动（例如：与研究机构/大学合作研发活动）	1	2	3	4	5
4. 与员工/客户交流绿色创新信息（例如：环保培训/讲座）	1	2	3	4	5
5. 与各个参与执行绿色创新的部门共享绿色航运经验	1	2	3	4	5
绿色服务创新－贵公司…					
6. 开展航运服务，以防止污染	1	2	3	4	5
7. 开展航运服务，以节省能源/资源	1	2	3	4	5
8. 引进新颖的航运服务，以防止污染	1	2	3	4	5
9. 引进新颖的航运服务，以节省能源/资源	1	2	3	4	5
10. 重新设计绿色航运服务，以优化环保操作	1	2	3	4	5
11. 引进回收/循环再用的报废船舶设备	1	2	3	4	5
绿色流程创新－贵公司…					
12. 检讨和改进航运流程，以防止污染	1	2	3	4	5
13. 检讨和改进航运流程，以节省能源/资源	1	2	3	4	5
14. 采纳新颖的航运流程，以防止污染	1	2	3	4	5
15. 采纳新颖的航运流程，以节省能源/资源	1	2	3	4	5
16. 把回收/循环再用系统纳入航运流程	1	2	3	4	5
绿色科技创新－贵公司…					
17. 检讨和采纳科技，以支援绿色管理、服务、以及流程创新	1	2	3	4	5
18. 采用新颖的科技或设备，以支援绿色管理、服务、以及流程创新	1	2	3	4	5
19. 采用新颖的科技来管理航运文件和资料，并提供相关的环境信息	1	2	3	4	5

第二部分：利益相关者的压力与采行绿色航运创新的关系

请提供最合适的描述。

法规压力及诱因－贵公司	非常不同意	不同意	中立	同意	非常同意
1. 采行绿色航运创新，以遵守政府对业界所施行的相关法规/限制	1	2	3	4	5
2. 采行绿色航运创新，以符合政府未来的环保法规	1	2	3	4	5
3. 频繁接受相关监管机构按环保法规进行的巡查或审计	1	2	3	4	5
4. 政府提供的诱因（例如：补助、津贴及税务/费用减免）是采行绿色航运创新的重要动机	1	2	3	4	5

竞争压力 – 贵公司的竞争对手

5.	采行绿色航运创新，以提升企业形象	1	2	3	4	5
6.	采行绿色航运创新，以达成业务目标	1	2	3	4	5
7.	采行绿色航运创新，以提升组织在环境、创新及经济方面的绩效	1	2	3	4	5
8.	一般相信采行绿色航运创新所带来的效益远超成本	1	2	3	4	5

客户压力 – 贵公司的客户

9.	期望贵公司采行绿色航运创新	1	2	3	4	5
10.	将会转换到采行绿色航运创新的竞争对手	1	2	3	4	5
11.	如果贵公司没有达到他们的环保要求，他们将中止合同	1	2	3	4	5
12.	有明确的环境政策声明	1	2	3	4	5

第三部分：环境治理与采行绿色航运创新的关系

请从下列各项中选择最合适的描述。

组织机制 – 贵公司

		非常不同意	不同意	中立	同意	非常同意
1.	把组织环保方针及程序纳入业务操作（例如：航运操作、员工培训活动）	1	2	3	4	5
2.	成立专责部门，以管理环境事务	1	2	3	4	5
3.	实施跨部门合作，以促进绿色航运操作的发展	1	2	3	4	5
4.	实施并以书面形式记录操作程序，定期追踪及监察与绿色航运相关的最新信息和发展趋势	1	2	3	4	5
5.	实施并以书面形式记录操作程序，定期追踪及评估公司内部的环境绩效	1	2	3	4	5
6.	实施并以书面形式记录操作程序，找出及解决衍生的环境问题与不合规情况	1	2	3	4	5

契约机制 – 贵公司与商业伙伴的正式书面协议（例如：合同）订明

7.	商业伙伴对航运操作的环境要求（例如：服务水平、能源效率、二氧化碳排放水平）	1	2	3	4	5
8.	双方在执行绿色航运操作时的权利和义务	1	2	3	4	5
9.	监察或评估商业伙伴环境绩效的方法	1	2	3	4	5
10.	在绿色航运操作中，处理投诉和纠纷的方法	1	2	3	4	5
11.	在绿色航运操作中，处理突发事件的方法	1	2	3	4	5

关联机制 – 贵公司与商业伙伴

12.	频密地和透过非正式的渠道共享和交换有助于执行绿色航运操作的信息（例如：相关建议、环境知识及措施）	1	2	3	4	5
13.	告知对方对绿色航运操作有潜在影响的事件或变化	1	2	3	4	5
14.	能因应情况的变化，灵活地共同应对变更要求，并为绿色航运服务作必要的调整（例如：服务水平、环境要求）	1	2	3	4	5
15.	为双方利益而非单方利益，致力于环境的改善	1	2	3	4	5

第四部分：感知的环境不确定性

请从下列各项中选择最合适的描述。

		非常不同意	不同意	中立	同意	非常同意
1.	商业伙伴一贯能满足贵公司的环保要求	1	2	3	4	5
2.	商业伙伴提供质量稳定的绿色航运服务	1	2	3	4	5
3.	客户对绿色航运服务的需求难以评估	1	2	3	4	5
4.	由于技术复杂性高及变化迅速，绿色航运科技难以施行	1	2	3	4	5

第五部分：绿色航运创新与绩效成果

请描述在过去三年，贵公司相对于航运业内竞争对手的组织绩效，在以下绩效量度指标上表现。

环境绩效	非常不同意	不同意	中立	同意	非常同意
1. 减少空气污染物/碳排放	1	2	3	4	5
2. 减少废水排放	1	2	3	4	5
3. 减少固体废物产生	1	2	3	4	5
4. 减少有害物质消耗	1	2	3	4	5
5. 增加物料或设备循环再造/回收的数量	1	2	3	4	5
创新绩效					
6. 为满足客户需求而引进新颖的航运服务和流程时，有更好的表现	1	2	3	4	5
7. 客户均认为贵公司具较强的创新性	1	2	3	4	5
8. 在贵公司的航运服务组合中，已增加更多的绿色创新	1	2	3	4	5
9. 耗费较少的时间把绿色创新概念引入市场	1	2	3	4	5
经济绩效					
10. 采行绿色创新对贵公司的财务绩效有正面的影响	1	2	3	4	5
11. 请指出在过去三年，贵公司因采行绿色创新而体验到下列各项效益的程度：					
－ 降低能源消耗成本	1	2	3	4	5
－ 降低废物处理成本	1	2	3	4	5
－ 减少废物排放费用	1	2	3	4	5
－ 减少环保事故罚款	1	2	3	4	5
－ 改善企业形象	1	2	3	4	5
－ 提高生产力	1	2	3	4	5
－ 提高航运服务质素	1	2	3	4	5
－ 增加销量（通过吸引更多的客户）	1	2	3	4	5
－ 提高市场份额	1	2	3	4	5
－ 提高边际利润	1	2	3	4	5
－ 提高资产收益率	1	2	3	4	5

第六部分：一般资料

请评估您对贵公司业务运作的认识和熟悉水平。	非常少	少	中等	好	非常好
1. 您对贵公司业务运作的认识	1	2	3	4	5
2. 您对贵公司所涉及绿色航运创新的认识	1	2	3	4	5
3. 您对贵公司绿色航运创新的参与是	1	2	3	4	5

4. 贵公司的企业类型：
   ☐ 国有企业　☐ 私营企业　☐ 集体企业（政府补贴）
   ☐ 上市企业　☐ 中外合资企业　☐ 其他 (请注明： ____________________)

5. 贵公司的业界类别：
   ☐ 运输承运商　☐ 码头营运商　☐ 第三方物流服务供应商/货运代理
   ☐ 中流作业营运商　☐ 其他 (请注明： ____________________)

6. 贵公司的业务资历：
   ☐ 1-5 年　☐ 6-10 年　☐ 11-15 年　☐ 16-20 年
   ☐ 21-25 年　☐ 26-30 年　☐ 31-35 年　☐ 36 年或以上

7. 贵公司的员工人数：
☐ 1-10 人 ☐ 11-50 人 ☐ 51-100 人 ☐ 101-500 人
☐ 多于 500 人

8. 贵公司在上个财政年度的营业额（人民币）：
☐ 少于 800 万元 ☐ 800-1,599 万元 ☐ 1,600-2,399 万元 ☐ 2,400-3,199 万元
☐ 3,200 万元或以上

9. 贵公司的业务范围集中于：
☐ 香港市场 ☐ 中国市场 ☐ 香港及中国市场 ☐ 国际市场
☐ 其他(请注明： ___________________)

10. 请提供您的联络资料或附上名片以便作进一步讨论或跟进。

姓名：	
称谓：	
公司名称：	
地址：	
电话号码：	
电子邮件：	

请在以下的空格提出您对本调查的任何意见：

☐ 阁下希望收到调查研究结果的副本。

烦请于***两个星期内***使用随函的预付邮费信封将已填妥的问卷寄回或电邮至 XXXXXXXX.

如您对本调查有任何疑问，请联络：
项目研究员： 吴文杰先生 电话：XXXXXXXX 电邮：XXXXXXXX
项目主管： 伦婉霞博士 电话：XXXXXXXX 电邮：XXXXXXXX

<调查问卷结束>

非常感谢您对是次研究的参与。

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