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Environmental Goal Misalignment between Logistics Service Providers and Shippers

S.M. Mehdi Jourabchi
sjourabchi@wlu.ca

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by

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- ## Faculty Supervisors
  - **Michael Haughton**[a]

    Professor and CN Fellow in Supply Chain Management
  - **D. Marc Kilgour**[b]

    Professor; Research Area Coordinator of Operations and Decision Science Division at MS2Discovery Institute; Member of Conflict Analysis Group, University of Waterloo
- ## Committee Members
  - **Hamid Noori**[a]

    Professor and Director of Lazaridis Executive Master's in Technology Management (EMTM) Program
  - **Michael Pavlin**[a]

    Associate Professor and Director of Master of Science in Management Analytics Program
- ## External Examiner
  - **David Gillen**[c]

    Professor and Director of Centre for Transportation Studies

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[a] *Operations and Decision Sciences Area, Lazaridis School of Business and Economics*

[b] *Department of Mathematics, Wilfrid Laurier University*

[c] *Operations and Logistics Division, Sauder School of Business, University of British Columbia*

Abstract

The ongoing debate about who, ultimately, should pay for greening the transportation industry has exposed a *gap* (i.e. *misalignment*) between logistics companies and their clients (shippers). This thesis examines this gap in detail.

Study 1 utilizes conceptual theory building to discuss the conditions under which closer environmental collaboration between logistics service provider (LSP) and shipper can be realized within the supply chain. Our theoretical framework discusses the *misalignment* of LSPs' and shippers' incentives regarding green initiatives. Our conceptual framework aims to address the general dependency of LSPs on shippers and to assess whether and when it can be converted to inter-dependency, thereby facilitating closer coordination on environmental sustainability. To this end, market pressures can *moderate* the parties' negotiation deadlock over green initiatives. In addition, we shed light on *mediating* impact of agency problems and transaction costs on sustainability-related interactions. We summarize our findings by providing propositions about how practitioners and policy makers should approach green logistics issues.

Game-theoretic modeling makes it possible to understand the behavior of LSPs and shippers as economic agents. In **Study 2**, we assess to what extent the emissions reductions goals of LSPs and shippers are aligned or misaligned. In particular, we explain how factors such as consumer preferences and carbon tax policy determine the parties' relative emissions preferences, and propose a modeling approach that simultaneously considers both the shipper's and the LSP's interests. Our notion of the *environmental gap* between the shipper's and LSP's environmental performance levels enables us to provide methodologically rigorous

analytical explanations for existing empirical studies. Can LSPs and shippers fully agree on matters such as how to share the responsibility for environmental initiatives or who should be responsible for carbon tax?

In **Study 3**, we develop game-theoretic models to analyze whether and how LSPs and shippers can reach a mutually beneficial consensus on improved environmental performance. First, we develop a non-cooperative model in which the LSP is responsible for greening costs but the shipper determines environmental performance, taking monitoring costs and consumers' environmental preferences into account. Under the non-collaborative setting, we characterize the LSP's preferred environmental target to find conditions under which the LSP's environmental target exceeds the shipper's, i.e., the shipper's environmental target is suboptimal from the LSP's point of view. Then we study *collaboration* under two innovative contracts, Sharing Cost Savings and Sharing Monitoring Cost. We characterize the conditions under which collaboration between the two parties can result in a *win-win-win* outcome covering not only the parties' profits, but also the green efficiency of product logistics.

This dissertation is lovingly dedicated to my wonderful wife **Tina**, for her constant love, care, and never-ending support over the past years, and to my parents and parents-in-law for their support and encouragement which have sustained me during my PhD journey.

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Statement of contribution

I, S.M. Mehdi Jourabchi, declare that this dissertation titled "Environmental Goal Mislignment between Logistics Service Providers and Shippers" and the work presented in it are my own. Confirm that:

- This work was done wholly or mainly while in candidature for a Doctoral degree at Wilfrid Laurier University.
- Where any part of this dissertation has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this dissertation is entirely my own work.
- I have acknowledged all main sources of help.

Signed ***S.M. Mehdi Jourabchi***

Date: **Wednesday 30th September, 2020**

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List of abbreviations

3PL	Third Party Logistics
(CSR)	Corporate Social Responsibility
GSCM	Green Supply Chain Management
ICT	Information and Communication Technology
(IoT)	Internet of Things
KPI	Key Performance Indicator
LSP	Logistics Service Provider
SSCM	Sustainable Supply Chain Management
SSD	Sustainable Supplier Development.

Chapter 1

Introduction

There are many reasons to believe that logistics must make a large contribution to the drastic reductions in CO_2 emissions that are required by 2050 in order to realize the Paris Climate Agreement's goal of limiting global temperature increase in 2100 to 2°C. In the transport sector, CO_2 emissions are projected to be 80 percent higher by 2030 (IPCC, 2007). Logistics activities are responsible for about 10 percent of global energy-related greenhouse gas (GHG) emissions (Maas et al., 2014), freight emissions account for 8 percent (McKinnon, 2010), and the amount of energy used for logistics is expected to double by 2050 (WBCSD, 2004).

Without emission-reduction action, CO_2 emissions from freight transport will rise by 76 percent by 2050 compared to 2015: a reduction by 65 percent is required to realize the aforementioned goal of the Paris Climate agreement. (SmartFreight Leadership, 2017). Moreover, studies have suggested that up to 75 percent of an organization's carbon emissions are generated in logistics activities along the supply chain (Dey et al., 2011; Sustainability Watch, 2011). On a side note, ahead of the United Nations Climate Change Conference in Paris (COP21, 2015), a new Conference Board of Canada report finds that Canada's transport sector is unlikely to achieve an 80 percent reduction in greenhouse gas emissions in its transportation from 1990 levels by 2050. Even when taking into account reduced distances traveled per vehicle, improvements in fuel efficiency, and greater market penetration of alternative technology vehicles, Canada falls short of the 80-by-50 target.

The recent calls for more rigid environmental regulations and the emergence of environmentally conscious consumers, will force supply chain members to account for the associated emissions costs of their activities on the community and ecosystem. The results from the Green Trends Survey carried out by DHL in 2010 confirm that sustainability will ultimately become a key buying criterion: 51 percent of end consumers would prefer products from a company with green logistics/transport solutions over a cheaper provider. Also, 59 percent of business customers (i.e. shippers) estimated that the green logistics of their products would be a crucial factor in winning end-consumers. In an effort to take serious action against contributing to the effects of climate change, and to remain in adherence to the Paris Agreement, a number of contributing countries have started to impose regulatory measures on the freight transport industry. In particular, effective April 1st, 2019, the government of Canada enacted carbon pricing (a "Carbon Tax") that affects trucking industry. This obliges polluting Logistics Service Providers (LSPs) to account for the emissions costs of their activities in Canada.

LSPs and their clients (shippers), are currently under pressure from consumers and governments to reduce the environmental impact of their operations. Nevertheless, the debate on who will ultimately be responsible for green initiatives implies that there is a gap between logistics companies and their customers in responsibility for managing environmental issues

(Insight, 2008). *Environmental goal misalignment* (the "environmental gap") refers to the parties' lack of alignment on green targets; i.e., their target levels of environmental performance are often quite different. In the context of this research, *environmental performance level* means an emissions target that is economically optimal from LSP's or shipper's point of view. Thus, the shipper's profit maximization environmental target is not necessarily in line with the target level that maximizes the profit for the LSP.

Leading LSPs have announced ambitious carbon intensity reduction targets (Lieb and Lieb, 2010). However, more recent surveys of LSPs indicate that most of their customers are reluctant to spend more for green logistics services offerings (Colicchia et al., 2013; Oberhofer and Dieplinger, 2014). Traditional performance objectives (such as price, quality requirements, service performance/reliability, and timely delivery) continue to dominate purchasing decisions for third-party logistics (3PL) services (Selviaridis and Spring, 2007; Marasco, 2008; and Wolf and Seuring, 2010; Björklund and Forslund, 2013; Lammgård and Andersson, 2014; Abbasi and Nilsson, 2016; Bask et al., 2018; Bahr and Sweeney, 2019; Jazairy and Haartman, 2020).

According to Lammgård and Andersson (2014), environmental efficiency was rated lower than other logistical and purchasing criteria such as price and delivery time; while some companies placed no importance on environmental efficiency at all. Moreover, shippers must sometimes implement costly controls (e.g. direct supervision and external audits) to discourage LSPs' opportunistic behavior (Kudla and Klass-Wissing, 2012), making green logistics offerings less attractive. In other words, integrating environmental concerns into LSPs' offerings appears to create a mismatch of supply and demand (Wolf and Seuring, 2010; Martinsen and Björklund, 2012; Isaksson and Huge-Brodin, 2013) in that the parties lack alignment on green targets (Jazairy, 2020). In fact, many organizational strategies to improve sustainability in the supply chain are based on a short-term perspective that has little impact on processes and cost structure (Colicchia, 2013). The potential for synergy between economy and ecology is not well understood by the parties (Wolf and Seuring, 2010; Sallnäs, 2016); it is difficult for shippers to discern what is optimal from both the environmental and the economic points of view (Colicchia, 2013).

The lack of deep insight into the environmental facet of LSP-shipper interface and thus the need for theory building have been underscored by recent studies (Wolf and Seuring, 2010; Kudla and Klass-Wissing, 2012; Centobelli et al., 2017); and Evangelista et al., 2018). Moreover, even though recent reviews of green supplier selection/supply chain management literature underscore the importance of a supplier's environmental performance for buying firms (e.g. Genovese et al., 2013; Govindan et al., 2015; Zimmer et al., 2016), little attention has been paid to: (1) the role of LSPs in the research on green supply chain management (Martinsen and Björklund, 2012); and (2) the inclusion of suppliers of logistics into the supply chain decision-making process with respect to the environmental performance (Konur, 2017). There are two possible explanations. First, most global shippers focus their attention on the environmental practices of raw material suppliers, not on service suppliers such as LSPs (Wolf and Seuring, 2010). The lack of shippers' engagement in green logistics purchasing is ascribed to the dominant regulatory, market and competitive pressures on shippers' internal, industry-related activities as opposed to green logistics (Jazairy and Haartman, 2020). Second, LSPs are recognized to be the least integrated link in the supply chains (Lemoine and Skjoett-Larsen, 2004); they merely play a supportive role (Spens and Bask, 2002).

In practice it has been observed that, when the shipper is the party who holds power over the environmental performance of the logistics service, disagreement over the inclusion of environmental content in the LSP-shipper often arises. This suggests a hierarchical relationship between LSPs and shippers (Wolf and Seuring, 2010) with the LSP depending on the shipper's collaboration to lessen the environmental impacts of logistics. In particular, the shipper is the party who initiates the request for the green logistics services and sets the conditions for coordination of green initiatives (Sallnäs, 2016). The general dependency of LSP's on shipper's decisions on logistics services places LSPs in a "henchman" position" (Wolf and Seuring, 2010), binding them to shipper's lack of interest in environmental protection.

This study seeks to address the following critical questions that arise in the context of mounting pressures to improve environmental outcomes in freight transportation activities:

- How can environmental gaps in the dyadic LSP-shipper relationships be explained and conceptualized using inter-organizational and institutional theories?
- To what extent are the environmental (emissions reductions) goals of LSPs aligned (or misaligned) with those of shippers?
- How do factors such as consumer preferences and carbon tax policy determine which of these parties prefers better (lower) environmental targets (emissions levels) than the other?
- What can be done to achieve mutually beneficial LSP-shipper consensus on improved environmental performance levels (emissions levels)?

Under this general theme, the research is classified my research into two streams: Theoretical and Conceptual (Chapter 2), and Analytical (Chapters 3 and 4). The research project is important for three reasons:

First, it responds to recent calls for CO_2 reduction in the transport sector aimed at achieving the 2050 emission target in order to contain the global temperature increase to within 2°C by 2100.

Second, it takes into account that shippers and LSPs are now investing in their strategic relationship which, as the 2017 Eye for Transport report makes clear, is being transformed toward greater solution orientation and increased collaboration.

Third, it reflects recent discussions on policy measures, for example at the *Upcoming Carbon Tax and its Implications for Transport Sector* session in 30th Annual Transport Conference, Toronto, Canada, 2016.

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Chapter 2

Environmental Gap in the Logistics Service Provider-Shipper Interface: Towards A Conceptual Framework

2.1 Introduction

Driven by unsustainable business practices and uncontrolled utilization of natural resources, economic activity is accelerating climate change and causing increasingly frequent natural disasters, which in turn are disrupting supply chains. But the recent trend to the imposition of more rigid limits on environmental impacts, as well as the emergence of environmentally conscious consumers, will force supply chain members to account for the ecological costs of their activities, rather than simply manage their supply chain so as to maximize profit (Seuring and Müller, 2008b).

Emissions of CO_2 from freight transport will rise 76 percent between 2015 and 2050 unless action is taken. A reduction by 65 percent is required to meet the objective of the Paris Climate Agreement to hold the global temperature increase to at most 2 degrees Celsius by 2100 (SmartFreight Leadership, 2017). Analyses show that logistics activities are responsible for about a tenth of global energy usage and global energy-related greenhouse gas (GHG) emissions (Maas et al., 2014) from which freight emissions account for 8 per cent (McKinnon, 2010). Studies on various case studies have shown that upwards 75 percent of an organization's carbon footprint can be found in their logistics functions (Dey et al., 2011). Given the carbon intensity of logistics operations and the increasing use of freight transport along the supply chain, both Logistics Service Providers (LSPs) and shippers (users of logistics services)[1] are being pressured by governments, customers, and others to reduce the "negative externality" of their operations (McKinnon and Piecyk, 2009; Wolf and Seuring, 2010; Martinsen and Björklund, 2012). World-leading LSPs have announced ambitious carbon intensity targets (Lieb and Lieb, 2010; McKinnon and Piecyk, 2012), but nonetheless the majority of LSPs still hesitates to proactively invest in sustainability (Perotti et al., 2012) and, indeed, they are sometimes simply unable to achieve green standards (Kudla and Klass-Wissing, 2012).

Recent surveys indicate that most shippers (i.e. buyers of logistics services) are not committed to spend more for sustainable logistics services offerings (Colicchia et al., 2013; Oberhofer and Dieplinger, 2014), and that traditional performance objectives (such as price,

[1] The interface between LSPs and shippers can be considered as supply and demand in a logistics market where LSPs supply and shippers consume freight transportation services (Sheffi, 1986; Wandel et al., 1992). In this context, the development of green logistics services is an on-going interaction of demand and supply sides, where both sides pressure and respond to each other (Martinsen and Huge-Brodin, 2010).

quality requirements, service performance/reliability, and timely delivery) continue to dominate purchasing decisions for third-party logistics (3PL)[2] services (Selviaridis and Spring, 2007; Marasco, 2008; and Wolf and Seuring, 2010; Björklund and Forslund, 2013; Lammgård and Andersson, 2014; Abbasi and Nilsson, 2016; Bask et al., 2018; Bahr and Sweeney, 2019; Jazairy and Haartman, 2020). According to Lammgård and Andersson (2014), environmental efficiency was rated lower than any other criterion, logistical and purchasing, such as price and delivery time; while some companies put no importance on environmental efficiency at all. In fact, despite growth in shippers' request for environmentally adapted logistics (Wolf and Seuring, 2010; Bahr and Sweeney, 2019), once the question of price and/or associated costs comes up in the negotiation/contracting phase, they put environmental criteria aside (Bask et al., 2018). Moreover, shippers must sometimes implement costly controls (e.g. direct supervision and external audits) to discourage LSPs' opportunistic behavior (Kudla and Klass-Wissing, 2012; Sallnäs, 2016), making green logistics offerings less attractive. Although shippers have a great responsibility for the natural environment when purchasing logistics services (Björklund, 2011), apparent paradoxes, such as low shipper's priority for ecological considerations despite the high ecological awareness of consumers, are puzzling. In other words, integrating environmental concerns into LSPs' offerings appears to create a mismatch of supply and demand (Wolf and Seuring, 2010; Martinsen and Björklund, 2012; Isaksson and Huge-Brodin, 2013) in that the parties lack *alignment* on green targets (Jazairy, 2020). The central purpose of this paper is to provide explanations and insights by drawing on multiple theories of inter-organizational relationships.

The ability of logistics to provide low carbon products constitutes a huge opportunity for

[2]The terms 3PL and LSP are interchangeably used in this study. According to Evangelista (2014), a 3PL (i.e. LSP) is defined as an external provider who manages to carry out logistics activities on behalf of a shipper.

LSPs to assist other sectors to reduce their carbon footprints in the supply chain by expediting the greening process of their logistics functions (WEF, 2009; Martinsen and Huge-Brodin, 2014). Moreover, the fact that the demand for logistics services depends on shipping volumes underlines the importance of integrating related services into inter-organizational sustainability management (Kudla and Klaas-Wissing, 2012). The reliance of shippers on LSPs has increased in order to green their supply chains, since LSPs play central position and orchestrating role in supply chains and possess higher competencies in developing green logistics solutions (Rossi et al., 2013; Colicchia et al., 2013; Bask et al., 2018). The global trend toward outsourcing third-party logistical services underscores the critical role of stronger relationships between LSPs and others in the supply chains (Seth et al., 2006). However, many organizational strategies to improve sustainability in the supply chain are based on a short-term perspective that has a little impact on processes and cost structure (Colicchia, 2013). The potential for synergy between economy and ecology is not well understood by the parties (Wolf and Seuring, 2010; Sallnäs, 2016); it is difficult for shippers to discern what is optimal from the both the environmental and the economic point of view (Colicchia, 2013).

Likewise, recognizing customers as a major driver for environmental responsibility, 3PLs have considered partnerships with them, searching for a joint strategic direction that includes a common effort to improve the sustainability of the supply chain by sharing risks and opportunities (Piecyk et al., 2015). Recent studies show how collaboration between LSPs and shippers may contribute to increasing awareness of the impact that greening logistics may have on operational metrics (Wolf and Seuring, 2010; Isaksson and Huge-Brodin, 2013). Thus, LSPs and shippers seem to be mutually dependent with regard to the incorporation of environmental practices into their practices (Lun et al., 2015, Sallnäs, 2016). The LSP depends on the shipper's collaboration to reduce the ecological impacts of logistics. In fact, the shipper must initiate the request for the green logistics services, and set the conditions for the inclusion of environmental practices[3]. On the other hand, even though the LSP is responsible for the logistics, the shipper with high environmental ambition depends on the LSP to implement the desired environmental practices (Sallnäs, 2016).

It has been claimed that Green Supply Chain Management (GSCM) is a *win-win* strategy through which economic benefits, such as long-term profits, can be achieved while maintaining ecological efficiencies (Zhu and Cote 2004; Zhu et al., 2008(a); Zhu et al., 2008(b)). Research on GSCM was influenced by environmental practices aimed at end-to-end sustainable manufacturing (Centobelli et al, 2017), in which little attention was paid to logistics purchasing/providing decisions (Lieb and Lieb, 2010; Lin and Ho, 2011; Davarzani et al., 2016; Jazairy and Haartman; 2020) and in particular to the interface between shippers and LSPs (Martinsen and Björklund, 2012; Martinsen and Huge-Brodin, 2014; Jørsfeldt et al., 2016). There are two possible explanations: (1) Most supply chain partners focus their environmental sustainability initiatives on raw material suppliers but not LSPs (Wolf and Seuring, 2010); and (2) LSPs are the least integrated link in supply chain (Lemoine and Skjoett-Larsen, 2004); their role is to support other members (Spens and Bask, 2002; Kovács, 2008).

After many years of neglect, research into the environmental practices of LSPs is now gaining greater prominence (Isaksson and Huge-Brodin, 2013; Marchet et al., 2014; Sallnäs, 2016). Nevertheless, most of this research presents a one-sided, rather than dyadic, perspective (Martinsen and Björklund, 2012; Jazairy, 2020). Specifically, 3PLs' environmental practices (see, e.g. Perotti et al., 2012), referring to actions unilaterally adopted by LSPs,

[3] According to Wolf and Seuring (2010), this suggests a hierarchical relationship between LSPs and shippers placing LSPs in a "Henchman Position" in their interactions with shippers on environmental issues.

are the most studied aspect (Colicchia et al., 2013). These studies make a significant contribution to the green logistics literature, but unfortunately, they exclude the customers, i.e. shippers (Sallnäs, 2016). In fact, few studies seem to simultaneously incorporate both actors' viewpoints, understanding the main drivers for facilitating green logistics (Jazairy and Haartman, 2020; the need to focus on their interaction was argued by Marchet et al. (2014).

Logistics services, the function that organizations outsource most often, has significant environmental impacts, and thus is ripe for inter-organizational sustainability research. In this paper, we focus on the inter-firm relationships of LSPs and their clients in the context of ecologically sustainable freight transportation. We seek to answer a crucial Research Question that must be addressed in the context of environmental sustainability in the logistics service industry:

RQ: How can dyadic shipper-LSP relationships facilitate/deter the adoption of collaborative green initiatives?

Our response to this research question is aligned with recent calls by both Centobelli et al. (2017) and Evangelista et al. (2018). To provide theoretically rigorous explanations of the shipper-LSP interplay, we develop a broad theoretical framework within which we can present our conceptualization of the LSP-shipper interface from an environmental perspective. To do so, we combine findings from literature with dominant organizational theories (i.e. resource dependence theory, agency theory, and transaction cost economics, and stakeholder theory) to identify drivers and barriers of environmental purchasing and collaboration, explaining the rationales behind the parties' environmental decisions. Our proposed theoretical framework will help to identify situations in which closer collaboration between the parties in implementing better environmental practices, and more generally will guide future research into the LSP-shipper interface with respect to adopting such practices.

This study has made three contributions to the supply chain management literature. First, we define the notion of environmental gap between the LSP and the shipper, establishing a conceptual framework within which both sides' motivations can be understood, and important conclusions drawn about how the conflict between them can be resolved. Second, we examine the environmental gap using dominant organizational theories and Stakeholder Theory, showing how different theoretical lenses illuminate different aspects of the LSP-shipper discrepancy. Finally, we present an agenda for future research, including an overview of the critical issues that must be addressed to enable LSPs and shippers to collaborate on environmental issues. Our conceptual framework and its implications will serve as a reference for practitioners and policy-makers as they move toward a less carbon-intensive freight transport industry.

The remainder of this paper is organized as follows. The second section explores the current literature in detail, underscoring the most significant contributions; thus, it positions our study relative to current knowledge. The third section presents the main features of the conceptual model within which we present our propositions. Finally, key findings, implications, conclusions, limitations, and future research directions are all presented in section four.

2.2 Literature Review

GSCM has gained increasing attention within both academia and industry. The conceptualization of sustainability in the context of supply chain management has been considered extensively in the literature. In particular, the study done by Carter and Rogers (2008) can be recognized as a foundation upon which other studies built to further conceptualize the incorporation of sustainability in supply chain decisions. Seuring and Müller (2008b), analyzed the literature in GSCM and developed a conceptual framework for sustainable supply chain management. Sarkis et al. (2011) study the literature on GSCM from an organizational theories perspective to investigate the adoption, diffusion and outcomes of GSCM practices. Numerous theoretical studies have analyzed both general and environmental inter-organizational relationships between shippers and suppliers. Despite this limited number of studies have considered how green initiatives are managed in the context of LSP-shipper inter-organizational interactions.

According to Centobelli et al. (2017), much of the research done with respect to critical role of environmental initiatives adopted by firms involved in the logistics of the product highlights that: 1) environmental issues are becoming increasingly important topic in the logistics industry due to an ever increasing demand for shipment of the goods; 2) environmental sustainability is receiving more attention as it is becoming a critical success factor in cost reduction (e.g. tax relief; eco-efficiency[4] of green practices) and/or increase of sales; and 3) environmental sustainability is becoming an important selection criterion for shippers. In this context, while much of the research done on LSP's green actions and the factors affecting their adoption (e.g. Lieb and Lieb, 2010; Pieters et al., 2012; Perotti et al., 2012;

[4]savings in logistics operations costs as a result of implementing green initiatives and/or technologies

Colicchia et al., 2013), but they provide little insights on shipper's perspective and thus how such environmental practices are included in the dyadic relationships the LSPs have with their customers. In fact, adoption of collaborative green initiatives based on a dyadic customer-LSP relationships is scarcely analyzed and could a be fertile area of investigation.

Limited attention has been given to how shippers and 3PLs can jointly manage environmental issues in research on GSCM (Wolf and Seuring, 2010). A systematic review of literature revealed that the number of studies in the investigation of how the process of negotiating environmental aspects between a focal company and its 3PL can be improved is extremely virginal (See e.g. Centobelli et al., 2017; Evangelista et al., 2018). In the absence of analytical models, we identified the most influential empirical studies of the LSP-shipper interface when it comes to inclusion of environmental practices either as offerings by LSPs and/or requirements by shippers and the factors affecting their adoption. The articles, summarized in Table 1, identified as the most relevant to our study; they mainly focus either on the relative importance of environmental issues in shippers' purchasing of logistics services or the factors influencing the shippers' behavior in requiring green logistics services, and how the LSPs' green offerings are perceived by shippers. By doing so, we also consider the studies that focused on the interactions of the parties and mismatches between 3PLs and shippers in dealing with environmental issues. Thus, these studies look at the process of green logistics purchasing some of which provide shipper, LSP, or dual/dyadic perspective.

Table 2.1: **Environmental Sustainability in the LSP-shipper Interface**

Author	**Title**	**Perspective**
Wolf and Seuring (2010)	Environmental impacts as buying criteria for third party logistical services	Dual
Lieb and Lieb (2010)	Environmental sustainability in the third-party logistics (3PL) industry	LSP
Björklund (2011)	Influence from the business environment on environmental purchasing—Drivers and hinders of purchasing green transportation services	Shipper
Philip and Militaru (2011)	Shippers' ecological buying behaviour towards logistics services in France	Shipper
Martinsen and Björklund (2012)	Matches and gaps in the green logistics market	Dual
Kudla and Klass-Wissing (2012)	Sustainability in shipper-logistics service provider relationships: A tentative taxonomy based on agency theory	Dual
Isaksson and Huge-Brodin (2013)	Understanding efficiencies behind logistics service providers' green offerings	LSP
Björklund and Forslund (2013)	The inclusion of environmental performance in transport contracts	Dual

Continued

Author	**Title**	**Perspective**
Colicchia et al. (2013)	Building environmental sustainability: empirical evidence from Logistics Service Providers	LSP
Martinsen and Huge-Brodin (2014)	Environmental practices as offerings and requirements on the logistics market	Dual
Lammgård and Andersson (2014)	Environmental considerations and trade-offs in purchasing of transportation services	Shipper
Uni Sallnäs (2016)	Coordination to manage dependencies between logistics service providers and shippers	Dual
Jorslfeldt et al (2016)	Implementing environmental sustainability in logistics operations: a case study	Shipper
Bask et al. (2018)	Environmental sustainability in shipper-LSP relationships	LSP
Bahr and Sweeney (2019)	Environmental Sustainability in the Follow-Up and Evaluation Stage of Logistics Services Purchasing: Perspectives from UK Shippers and 3PLs	Dual
Jazairy and Haartman (2020)	Analysing the institutional pressures on shippers and logistics service providers to implement green supply chain management practices	Dual
Jazairy (2020)	Aligning the purchase of green logistics practices between shippers and logistics service providers	Dual

The research carried out by Wolf and Seuring (2010) was recognized as one of the first studies that provides a dyadic perspective into the LSP-shipper interface when the parties coordinate to jointly manage environmental issues. The study discussed the conditions under which ecological impacts are considered by shippers as buying criteria for third party logistical services; strong alliances and collaboration between the LSP and shipper can be realized when synergies between economy and ecology is well understood by both parties. Philipp and Militaru (2011) introduced three main antecedents of shipper's ecological buying behavior namely compatibility between the quality levels of ecological logistics services available and traditional logistics services; the visibility of the shipper's individual ecological actions within the overall supply chain; and the shipper's overall basic ecological strategy anchored at the corporate level. According to the results of this survey, these company-specific antecedents are a more important influence on purchasing behavior than relational aspects and regulatory constraints. Similarly, Björklund (2011) also investigated the factors influencing the shipper's green buying behavior. She analyzed factors such as internal management, brand image, resources of company and the pressures from customers and governmental means of control. Martinsen and Björklund (2012) contributed by analyzing both intra-organizational and inter-organizational gaps between LSP and shipper when they interact with respect to environmental practices. In particular, the authors defined the gaps between LSP's stated offer (perceived demand) and shippers' stated demand (perceived offer) in the green logistics market.

Kudla and Klass-Wissing (2012) analyzed the interface between LSP and shipper using inter-organizational theories and in particular Agency Theory and stimulus-response model, to further characterize the interface from an environmental perspective. They discuss how agency problems such as goal conflicts and difficulties in behavior validation would affect environmental sustainability in the LSP-shipper relationships and how they can be managed using adequate incentive or control mechanisms. Isaksson and Huge-Brodin (2013) explain the LSPs' attitude towards green approach to discuss efficiencies behind their green offerings. while some are working toward a green integration throughout the entire business, others offer green alternatives to the original service offering. Björklund and Forslund (2013) analyzed the inclusion of environmental performance metrics in freight transport contracts. They identified the environmental metrics (e.g. CO_2 emissions and energy consumption) more widely used to control the environmental service level. Martinsen and Huge-Brodin (2014) relates the differences in the way LSPs and shippers offer and require environmental practices to their different types of stakeholders and how environmental initiatives can be included at different stages of LSP-shipper relationships. Lammgård and Andersson (2014) analyzed shippers' preferences when purchasing transportation services. Specifically, they investigated how shippers' perception about the trade-off between environmental considerations and other criteria (i.e. time precision, transport time, and price) has changed over a decade. Sallnäs (2016) explored how dependencies, both general and environmental, between LSPs and shippers in alignment with their environmental ambition can influence the way (i.e. coordination mechanisms) they coordinate environmental practices in their interactions. The studies done by Kudla and Klass-Wissing (2012) and Sallnäs (2016) are similar in that they both characterize the LSP-shipper interface into four specific categories depending on the parties' environmental ambitions (i.e. low versus high) or their levels of stimulus-response to incorporate environmental concerns in their business relations.

Ellarm and Golicic (2015) adopted institutional theory to analyze the partnership between LSPs and shipper on environmental practices. They explored both influencing factors and the effects of the environmental partnership between shippers and carriers and revealed that this cooperation is triggered by coercive, mimetic and normative pressures and encourages the adoption of environmental transport practices. Jørsfeldt et al. (2016) explored how the introduction of an environmentally-sustainability target affects the relationship between buyers and 3PLs. The authors found that clear cross-functional and cross-organizational coordination mechanisms have to be established in order to preserve environmental sustainability target. Bask et al. (2018) did a comprehensive analysis of environmental sustainability in the shipper-LSP relationships. Their results corroborate the previous findings but highlighted the lack of standard methods in measuring environmental impacts of logistics as a barrier against collaboration in environmental initiatives. Bahr and Sweeney (2019) studied the environmental sustainability in the follow-up and evaluation stage of logistics services purchasing. In particular, their findings suggest that there is a need to reorient the focus of the follow-up and evaluation stage from price and service levels toward sustainability through recognising the positive link between cost savings and the development of green initiatives.

Jazairy and Haartman (2020) applies institutional theory to analyze factors that affect the two actors' decisions to adopt green supply chain management practices. They analyze firms' characteristics and external forces (i.e. regulatory, market, competitive) that affect the parties' level of responsiveness to environmental concerns, and could drive shippers toward purchasing green logistics services from LSPs, and LSPs to provide them. Jazairy (2020) explored shippers' and logistics service providers' perceptions of green concerns under diverse contractual settings during the key phases of the logistics purchasing process. In particular, the study derives recommendations that could increase the actors' inter- and intra-organisational alignment on green targets throughout the purchasing process.

2.3 Conceptual Theory Development

There have been numerous calls for new theories of supply chain management (Carter and Rogers, 2008; Carter et al., 2015). The goal of conceptual theory building is to present theory as a system of abstract concepts and the relationships that exist between them (Skilton, 2012); the goal of conceptual theory building is extending an existing theory, developing a new framework, or providing support for an existing framework (Ellram and Golicic, 2015). Despite a growing attention into conceptual theory building as a method in supply chain management (e.g. Carter and Rogers 2008; Kaufmann and Denk 2011; Carter 2011; Ellram and Golicic, 2015), its application is yet to be fully appreciated in research on GSCM and in particular the LSP-shipper interface. Drawing on what was proposed by Meredith (1993), Carter and Rogers (2008) argues that conceptual theory building uses existing theory in conjunction with literature and other sources of data to both inductively and deductively advance the understanding surrounding a particular phenomenon. This might include defining variables, forming relationships among them, and developing predictions through integrating multiple theoretical perspectives (Choi and Wacker, 2011). Theory building will provide deeper insights into the pressures on buyer-supplier relationships, and in particular LSP-shipper relations (Wolf and Seuring, 2010; Kudla and Klass-Wissing, 2012).

This section aims to use organizational theories, including Transaction Cost Economics, Agency Theory, Resource Dependence Theory, and Stakeholder Theory, to develop a broad theoretical framework that can describe the environmental gap within the LSP-shipper interface. We follow the general approach that built upon previous studies (Ellram and Golicic, 2015) with the goal of developing a new framework explaining the environmental goal misalignment between LSPs and shippers. In particular, this section combines findings from the literature examining environmental issues in supply chain management with the organizational frameworks listed above to develop a series of propositions that will help identify drivers and barriers of environmental purchasing and collaboration in the LSP-shipper interface. Each of our theoretical lenses provides valid but incomplete insights into the environmental content of the LSP-shipper interface. The combined approach, we believe, provides a comprehensive conceptual understanding of the interactions of shippers and LSPs in the environmental context.

2.3.1 Resource Dependence Theory

Resource dependence theory posits that, to survive and succeed, an organization must acquire valuable and scarce resources (Pfeffer and Salancik, 2003) at low cost in a stable operating environment (Carter and Rogers, 2008). To acquire resources, a firm must build relationships with organizations that complement it, and consequently creates stable inter-organizational cooperation. Specifically, this theory argues, organizations depend on each other for resources; the resulting patterns of interdependence produce inter-organizational power (Hillman et al., 2009). Malone and Crowston (1994) consider coordination to be a strategy to manage dependencies between entities (Arshinder et al., 2008). Hajmohammad and Vachon (2016) suggest that dependence is the major structure that determines the relationship of buyers with suppliers (Kraljic, 1983; Terpend et al., 2011). Drawing on the insights of Cox et al. (2003), they classify supply chain dependence into four structures, buyer dominance, interdependence, supplier dominance, and independence, and argue that these structures are the source of inter-organizational power (Hillman et al., 2009). Specifically, power-dependence imbalances, such as relationship management strategies adopted to build sustainable supply chains (Touboulic et al., 2014), can substantially affect the buyer–supplier relationship (Cox, 2004; Tangpong et al., 2008).

A recent study of Sallnäs (2016) suggests that the general dependency of LSPs on shippers influences the coordination of their environmental practices. This is aligned with Crum and Allen (1997) who both found a significant difference in the level of dependence between carriers (higher) and shippers compared to other settings in the supply chain. According to Martinsen and Björklund (2012), any gap between LSPs and shippers over environmental issues can be attributed to the dependency of LSPs on shippers. These results align with the findings of Wolf and Seuring (2010), who suggest that LSPs and shippers have a *hierarchical* relationship in which the LSP defers to the shipper on environmental practices. The inclusion of environmental practices in the relationships between LSP and shippers is based on the shippers' requirements of the LSPs, and can constitute a power advantage for the shipper over the LSP (Martinsen and Huge-Brodin, 2014; Selviaridis and Spring, 2007; Marasco, 2008). Moreover, the buyer seems to have a decisive role on environmental practices, as it is generally the buyer who decides on environmental initiatives and in particular the design and adjustment of the LSP's services (Wolf and Seuring, 2010; Lammgård and Andersson, 2014). Thus, to a large extent, LSPs must depend on shippers' decisions about exactly which environmental actions to be included in their relationship; LSPs are eventually constrained by shippers' demands (Jazairy, 2020). The hierarchical nature of LSP-shipper relationship leads to following proposition, which posits how such dependency affects the inclusion of environmental activities in the LSP-shipper interface:

Proposition 2.1. *The general dependency of LSP on shipper is caused by hierarchical nature of their interaction and negatively influences the environmental content in the parties' relationship, in that shipper sets conditions for the coordination of environmental practices.*

The general dependency of LSP's on shipper's decisions on logistics services places LSPs in a "henchman" position (Wolf and Seuring, 2010), binding them to shipper's lack of interest in environmental protection. In short, the LSP is obliged to adapt logistical services to customer demands; moreover, the parties' interactions are transactions-based, and not favorable to partnership and cooperation. Bahr and Sweeney (2019) stress that the common desire for short-term contracts by shippers leads to uncertainty on the side of the 3PLs and impede their engagement in green projects that require up-front investments and thus long contractual period to guarantee the payback (Kacioui-Maurin et al., 2015); due to the increased risks associated with such innovations, LSPs are less proactive in proposing them (Jazairy, 2020).

Consistent with the discussion above, the empirical evidence suggests that LSPs are ahead of their customers on environmental issues[5]; LSPs' green supply exceeds shippers' green demand. (Wolf and Seuring, 2010; Martinsen and Björklund, 2012; Jazairy, 2020). Martinsen and Björklund (2012) define this *gap* as "over-achievement". Analyzing mismatches between LSPs and shippers in dealing with environmental issues, Kudla and Klass-Wissing (2012) indicate that shippers' interest in sustainability is at an early stage, while LSPs' initiatives have a stronger environmental focus. A similar discrepancy was identified by Martinsen and Huge-Brodin (2014): when the shipper's environmental initiatives are weak, the LSP's offerings seem to receive very little attention. Wolf and Seuring (2010) describe the situation in more drastic terms: "There are no real minimum requirements on the side of the customers, who are satisfied if they just fulfill the legal requirements". Generally, LSPs believe that

[5]One reasonable explanation for such observation is that despite barriers against LSPs in adoption of green initiatives (e.g. contingency; technical; regulation; market; blockage; and managerial (Centobelli et al., 2017)), the aggregate impact of drivers (e.g. human; contingency; technical; relational; regulation; market; and benefit (Centobelli et al., 2017)) has pushed LSPs more than shippers towards implementation of environmental practices. See Evangelista et.al. (2018) for more detailed explanation of drivers and barriers affecting the adoption of green initiatives among 3PLs.

shippers are not willing to pay extra for green solutions (Lammgård, 2012; Rossi et al., 2013; Isakkson and Huge-Brodin, 2013; Bask et al., 2018). Perotti et al., 2015 identifies lack of customer interest in green services as a main barrier holding back stronger environmental strategies for 3PLs.

Martinsen and Björklund (2012) show that there is a gap between LSPs' stated green offerings and shippers' perceptions of them; i.e., lack of fit between the two actors' efforts in terms of demanding and offering green logistics practices (Jazairy, 2020). Sallnäs (2016) explains these results and relates shippers' failure to understand the greenness of LSPs to their low environmental ambition (i.e. willingness to include environmental practices in their relationships)[6], and the dependency of LSPs on shippers (see Proposition 1). The service literature relates this gap to differing expectations, reflecting that the parties do not share the same perception of the service (Hakatie, and Ryynanen, 2007). In particular, Evangelista et al. (2014) revealed that, although 3PL companies have investigated the possibility of collaborative environmental actions with clients, but such initiatives are rarely implemented unless LSPs' perceptions of environmental issues and improvement opportunities are aligned with those of their customers. According to Reinhardt (1998), the firm's environmental actions can be valuable, if its customers care for environmentally friendly products and services but they also take notice of these practices. The above discussion leads to following proposition, which explains why an LSP's desire to implement green initiatives is bounded by the shipper's low environmental ambition:

[6]The notion of environmental ambition is closely related to what has been defined as corporate desire to do the right thing (Lieb and Lieb, 2010), in other words, how environmentally aware are the companies involved in freight transport industry. The internal contingency factors (e.g. management, resources, etc.) affecting shippers' purchasing of green transportation services (Björklund, 2011), can be a good benchmark to define factors that shape shipper's environmental ambition.

Proposition 2.2. *The gap in environmental ambition in the LSP-shipper interface stems from the difference between the LSP's green logistics offerings and the shipper's perceived values for them; in particular, the shipper is not motivated to coordinate environmental practices.*

In other words, despite the LSP's environmental ambitions, the shipper has the most influence on environmental practices in the LSP-shipper relationships, as identified in Proposition 1.

In terms of the sustainability criteria, in addition to the CO_2 emissions produced by transportation, other strategic performance objectives were crucial to achieving and sustaining the company's competitive advantage, such as cost and delivery time. Thus, in the trade-off between economic and environmental benefits of green initiatives, non-environmental requirements or operational metrics (i.e. lead time, flexibility, reliability and condition on delivery such as the requirements for short transport times and high frequency in just-in-time operations) might prevent shippers to consider the environmental consequences of their logistics operations (Björklund, 2011; Bask et al. 2018). Philipp and Militaru (2011) refers to such phenomenon as shipper's "perceived compatibility" of ecological logistics services available with their service requirements enabled by traditional logistics services. This is aligned with the findings of Jazairy (2020) who identified the shippers' intra-organizational misalignment for being more efficient or responsive as the source of problem in which case the former can accompany with environmental benefits but not the latter one. Similarly, Jazairy and Haartman (2020) refers to such misalignment as contradicting objectives between the shipper's different organizational units involved in managing logistics functions. This is in line with Jørsfeldt et al. (2016) who identified the importance of cross-functional integration in shipper's company which depends on 3PL's capability on how to achieve sustainability targets while maintaining the strategic performance objectives of cost and delivery times as priorities.

Therefore, any CO_2 emissions-reduction project initiated by the logistics function could only be carried out if it did not compromise the key criteria of costs and operational service levels (Jørsfeldt et al., 2016; Bahr and Sweeney, 2019). Jørsfeldt et al. (2016) suggest that migration from the trade-off approach to adopting a value-seeking approach is key to achieve sustainability targets without compromising the strategic performance objectives of cost and delivery time; the traditional criteria are still the priority, but CO_2 emissions reduction was sought in conjunction with cost reduction. In other words, green benefits are an add-on (Bahr and Sweeney, 2019). Our discussion above leads to:

Proposition 2.3. *The shipper's low perceived value for LSP's green logistics offerings is due to lack of integration of environmental sustainability with operational and economic indicators; higher perceived compatibility between non-environmental and environmental requirements will result in higher levels of ecological behavior.*

Thus, the shipper is prepared to incorporate green services once environmental sustainability is integrated with operational and economic indicators and a direct relationship is clearly elucidated by LSP. This necessitates the development of key performance indicators (KPIs) indicators that work best in enhancing both environmentally and operationally efficient transports (Bask et al., 2018; Jazairy, 2020). Consistent with the above discussion, Isaksson and Huge-Brodin (2013) address the integration of green thinking into general service offerings (as opposed to offering green choices) as a complement to a more basic offering during negotiation/selection process, to help promoting environmental practices during post-contractual agreement. LSPs can stimulate customers' interest in these offerings and thus influence shippers with low environmental ambition. Martinsen and Huge-Brodin (2014) categorize such environmental practices as belonging to the more general logistics marketplace and "fairly standard" in nature, which have been refer to as so-called: "quick win" activities (Kudla and Klass-Wissing, 2012); and operational "quick fixes" (Nilsson et al., 2017), and are mainly focused on eco-efficient solutions. Drawing on discussion above we put forward the following proposition:

Proposition 2.4. *The shipper's environmental ambition can be stimulated if the LSP integrates basic environmental practices into general service offerings; this strategy may change the shipper's mindset about the potential value of green logistics.*

Martinsen and Björklund (2012) further explain the environmental gap (Propositions 1-2), and relate it to LSP's failure in communication of its environmental offers in the green logistics market and point out the urgent need for improved exchange of information and collaboration between the actors. Environmental communication helps the parties to reach a mutual understanding on green offers and demands and effectively cooperating to attain green targets. Gilley et al. (2000) point out that potential reputational impacts of firms' environmental actions tend to be lower when such practices are not communicated to customers. Therefore, since business outcomes from environmental actions are contingent on customers' awareness of these practices, firms should apply environmental communication to increase the visibility of their environmental efforts (Du et al., 2010) and their corresponding value to customers. Maas et al. (2014) highlight the positive impact of "environmental communication" on promoting LSP's "pollution prevention" capability and its competitive advantage from shipper's perspective. Pieters et al. (2012) provide empirical evidence on 3PLs that promote collaboration with customers through "awareness programs" to inform customers about the CO_2 footprint of their shipments. Abbasi and Nilsson (2016) showed the impact of increase awareness among customers on their behavior and outlooks when it comes to purchasing sustainable logistical services. In line with this argument, we put forward the following proposition:

Proposition 2.5. *The gap between LSP's stated offer and shipper's perception of this offer can be decreased by environmental communication aimed at increasing the shipper's awareness about the potential ecological impacts of its product logistics.*

In fact, recent studies indicate that shippers' demand for environmentally responsible transportation is rising (de Haas and Kronborg Jensen, 2010; Facanha and Horvath, 2005; Wolf and Seuring, 2010). Nonetheless, the evidence that environmental issues dominate buying criteria for LSP services is limited. The empirical evidence indicates that the triggering effect of cost savings (i.e. financial benefits) resulting from green logistics and deterring impact of high investment costs and/or lack of financial resources underlie the adoption of environmental actions in the LSP-shipper interface (Rossi et al., 2013; Bloemhof et al., 2015; Perotti et al., 2015). There may be a trade-off between environmental problems and economic performance, but the economic dimension has been identified as the primary factor in subsequent decision making (Wolf and Seuring, 2010). Oglethorpe and Heron (2010) highlight that the coordination of environmental practices can be realized if they are promoted by the LSP as a source of financial benefits. Sallnäs (2016) emphasizes the importance of linking environmental practices to financial benefits to encourage shipper to select green options. Maas et al. (2014) also point out that both sides might not be willing to contribute to the required investments since it is difficult for the parties to distribute the costs and potential benefits (i.e. cost savings) associated with environmental actions. Jazairy and Haartman (2020) relate shipper's reluctance to pay extra for green logistics solutions to lack of a direct relationship between cost savings (financial benefits) and environmental performance, though warns that LSPs often lag in this area.

Arshinder et al. (2008) underscore the relevance of supply chain contracts to the management of dependencies in supply chains. Contracts have been studied as mechanisms of coordination in supply chains (e.g. Cachon, 2003; Cachon and Lariviere, 2005). De Giovanni (2014) investigates how coordination through contracts can affect the benefits of collaborating for environmental purposes. Den Hartog et al. (2010) relate the failure of new service ideas, such as green logistics offerings, to the lack of an appropriate distribution model, as is commonly observable in interactions between users and providers of logistics services (Lukassen and Wallenburg, 2010). In particular, LSPs must balance the price and the value they offer customers in the context of environmental logistics (Anderson et al., 2000). In the end, it is shipper who make the final choice based on perceived customer value in comparison to price (Lammgård and Andersson, 2014).

Green initiatives carried out by 3PL can mitigate the unit carbon emission of the logistics service and consequently the environmental impact of the product while increasing revenue for both sides simultaneously. "Emissions offset programs"[7] are among the very few revenue models and pricing schemes most often mentioned in the literature. Thus, it is far from certain how environmental thinking can best be integrated into logistics service offerings to reap both economic and environmental benefits. Indeed, the lack of collaboration of

[7] The customer has the option to choose a lower price for the LSP's green service offering(s) but is required to invest in CO_2-reduction programs offered by the LSP.

LSPs and their customers has more to do with this different understandings of the financial benefits of environmental cooperation; if both parties spend time learning and improving their efforts to be green, they can at the same time improve their financial performance (Lai et al., 2011; Perotti et al., 2012; Lun et al., 2014). The following proposition posits a precondition required to stimulate a shipper's willingness to improve the green efficiency of logistics:

Proposition 2.6. *A shipper's environmental ambition can be increased by the LSP if it promotes its services by offering financial benefits such as new revenue models or pricing schemes, encouraging collaboration of the parties to realize those benefits.*

In line with Proposition 3, Bask et al. (2018) emphasize integrating environmental sustainability with operational performance and cost indicators in order to boost competitive advantage for LSPs. According to Evangelista et al. (2018), much of the research done on green logistics provides a qualitative and indirect measure of the impact of green initiatives on the environmental, economic and operational aspects of logistics operations. Specifically, the authors call for development of standard metrics to be used to measure 3PLs environmental performance at both an organizational level and across the supply chain: Knowledge is limited, not only about how logistics performance should be measured in terms of environmental criteria (i.e. CO_2 emissions), but more importantly about how it should be linked to economic and operational performance (Bask et al., 2018). Perotti et al. (2012), Colicchia et al. (2013), Oberhofer and Dieplinger (2014), Evangelista et al. (2014), and Bask et al. (2018) all suggest that the lack of a standard and/or widely accepted methodology to measure environmental performance/impacts of different logistics solutions, including indicators and shared metrics, is a key barrier making it difficult for the parties to share the costs and benefits of developing environmentally friendly solutions and leverage such initiatives as marketing arguments. According to Arvidsson et al. (2013), inertia on environmental issues in the freight transport industry is primarily due to the ambiguity of transportation efficiency measures, as well as uncertainties about costs and benefits on both sides. Bahr and Sweeney (2019) relate deficient follow-up green efforts by shippers to the lack of environmentally specific service level agreements or KPIs. This necessitates the development of KPIs indicators that work best in enhancing both environmentally and operationally efficient transports (Bask et al., 2018; Jazairy, 2020). Our discussion above leads to the following proposition:

Proposition 2.7. *Development of widely accepted methods for measuring environmental performance of logistics is pre-requisite to adoption of appropriate revenue models/pricing schemes and an effective environmental communication that enable the parties to share the costs and benefits of environmental initiatives and use them as marketing levers.*

Although the literature seems to indicate that LSPs are more dependent on the shipper than vice versa, there are likely to be situations where the opposite dependency exists (Sallnäs, 2016). Pfeffer and Salancik, (1976 and 1978) argue that resource dependence is positively associated with establishment of supply chain linkages and vertical coordination. The result of their study is aligned with a more recent research by Arminas (2004) who argues that reliance of firms on critical (scarce and valued) resources will drive them to increase their coordination with other members of supply chain. This dependency will lead to more coordination through strategic partnerships with suppliers and help firms to acquire access to supplier knowledge, technologies, and expertise.

Within the LSP-shipper interface, LSPs could play a crucial role for shippers who aim to lessen their environmental impact from logistics. Shippers who have outsourced their logistics operations are, at least to some extent, in the hands of LSPs, whose logistics expertise is essential to success with environmental practices (Sallnäs, 2016). In this context, Martinsen and Huge-Brodin refer to LSPs' expertise as "environmental competence" and suggest that the level of "logistics intensity" in the shippers' industries could impact their level of involvement with LSPs' in implementation of green initiatives. Carter and Carter (1998) suggest that increased vertical coordination between suppliers and buyers (e.g. the number and complexity of transactions in a spot market) impacts environmental purchasing and collaboration. Philipp and Militaru (2011) discuss that a better perceived quality of relationship between the shipper and the LSP results in more alignment between the shipper's and LSP's ecological strategies. But dependency could also be the other way around, in that LSPs need shippers' involvement in order to succeed with their actions to reduce environmental impact. Thus, LSPs and shippers are mutually dependent when they decide to work jointly on environmental practices (see, e.g. Lun et al., 2015). This dependency could be mutual (in other words, interdependency), resulting from greater vertical coordination between LSPs and shippers and thus a higher level of environmental purchasing. This tendency to outsource leads to the following proposition, which posits that resource dependency is a driving factor for coordination in the supply chain:

Proposition 2.8. *The more critical logistics to the firm's business success, the more the shipper depends on the LSP's key resources to manage traditional logistics services, and the more likely it is to increase its vertical coordination with LSP in dealing with environmental issues.*

This implies that industries where logistics plays a central role in shippers' operations would exhibit closer collaboration between the parties involved in mobility of goods along the supply chain in which the more the parties are interdependent and the more they are expected coordinate environmental practices in their relationships.

Consistent with the insight brought by Proposition 6, Lun et al. (2015) showed that customer involvement is key to development of green capability that enables the parties to achieve environmental performance and economic gains simultaneously. Laari et al., 2016 found a similar relationship between external environmental collaboration and financial benefits achieved as a result of greening operations. The proposition is also aligned with suggestions that environmentally adapted supply chains can only be realized by cooperation between environmentally aware supplier and a focal company (Seuring and Müller, 2008b). Martinsen and Huge-Brodin (2014) and Sallnäs (2016) both suggest that, the more complex the green initiatives, the greater interdependency of the parties and the more commitment required by the shipper for success.

Achrol et al. (1983) proposed that as environmental uncertainty increases, vertical co-ordination will increase. Moreover, the relationship between resource dependence and co-ordination becomes more important under conditions of uncertainty (Pfeffer and Salancik, 1978). According to Thompson (1967), seeking rationality under uncertainty, the uncertainty of how evolving green concerns will affect logistics sector and market, means to adapt to such environmental changes by both shipper and logistics service providers as quickly as possible (Isaksson and Huge-Brodin, 2013). Among other market-related factors, such as pressures from customers, governments and other stakeholders, environmental uncertainty has been highlighted as a main driver that may trigger, or hinder, green actions (Lin and Ho, 2011;

Ho and Lin, 2012; Rossi et al., 2013). Hence, seeking rationality under uncertainty necessitates cooperative relationships with other organizations that can provide complementary resources. Our discussion leads to the following proposition[8]:

Proposition 2.9. *There is a positive relationship between the degree of coordination and the interaction of uncertainty and interdependency in LSP-shipper interface.*

This implies that the uncertainty about how emerging green concerns will shape the market in the near future necessitates seeking rationality to adapt to such environmental changes. Thus, looking at the increasing environmental impact of transportation, the parties are expected to cooperate formally and work proactively as quickly as possible, before environmental measures become a liability and turn into costs. This includes the need for the parties to prepare for green demands both by consumer and government and the competitive pressures resulting from green logistics market development (Martinsen and Björklund, 2012) which necessitate having a first-mover advantage (Martinsen and Huge-Brodin (2013).

2.3.2 Stakeholder Theory

The Sustainable Supply Chain Management (SSCM) framework proposed by Carter and Rogers (2008) underscores the importance of inter-organizational collaboration among companies along the supply chain while targeting sustainability goals derived from customer and stakeholder requirements. Stakeholder engagement in SSCM generally stems from the need for corporate practices to be visible and transparent. Sarkis et al. (2004) argue, and Martinsen and Huge-Brodin (2014) highlight, that in the context of GSCM, stakeholder analysis is

[8] Our discussion under Stakeholder Theory aims to further justify why LSPs and shippers is facing with an unclear picture of how activities will be under more scrutiny in near future.

useful because environmental actions are not only a way to achieve competitive advantage, but also a perceived necessity for stakeholder requirements. Zhu and Sarkis (2007) also list market and regulatory pressures as influential toward better environmental performance.

Martinsen and Huge-Brodin (2014) relate the environmental goal misalignment between LSPs and shippers to the power structure (see Propositions 1 and 2) and whether the parties consider each other to be primary or secondary stakeholders[9]. Thus, it can be assumed that shippers' primary stakeholders are likely to be more concerned about shippers' core activities (e.g. manufacturing the final product, using raw material and components provided by suppliers) rather than the more peripheral activities (i.e. non-value added activities) carried out by LSPs. Similarly, Jazairy and Haartman (2020) linked the lack of shippers' engagement in green logistics purchasing to the dominant emphasis within regulatory, market and competitive pressures on shippers' internal, industry-related activities—thus diverting their attention away from external, green logistics purchasing ones. Thus, LSPs are a secondary point of consideration from the perspective of shippers' stakeholders, often because the environmental impacts of logistics are less visible to the public.

Increasing awareness of the environmental impacts of products has resulted in stricter environmental regulations and changes in consumer behavior, both of which increase pressures on companies to become more environmentally friendly (Isaksson and Huge-Brodin, 2013). In the transport sector specifically, issues of environmental performance are pressing both shippers and LSPs to reduce the externality of their operations, putting them under greater scrutiny by both primary and secondary stakeholders (Wolf and Seuring, 2010; McKinnon and Piecyk, 2010). However, when studies focus on shipper-LSP interface, the role of

[9] According to Kirchoff et al, 2011, end consumers and regulatory authorities are categorized under primary and secondary stakeholders, respectively.

stakeholders such as regulators and customers tend to be overlooked (Jazairy and Haartman, 2020).

With an increase in customers' environmental awareness, consumers are increasingly concerned about the ecological footprint of products. Kirchoff et al. (2011) argue that "green consumers" are a growing stakeholder in which the way they perceive firms' environmental initiatives influences the degree to which a firm's demand and supply functions are integrated reflects those perceptions. In particular, the results of the Green Trends Survey by DHL in 2010 confirm that, by 2020, environmental issues will become a key buying criterion: 51 percent of end consumers will prefer "a company with green transport/shipping solutions over a cheaper provider". Also, 56 percent of business customers that their end consumers will favor a company with green transport and shipping. Consequently, 59 percent of business customers estimated that green logistics will be a crucial factor in winning customers in future. Carter and Carter (1998) identify consumers as having a direct impact on firms' environmental purchasing. LSPs must find environmentally friendly ways to deliver products and services in order to improve their green offerings (Murphy and Poist, 2003). A LSP's green logistics services would play a vital role in by enabling its customers to deliver even "greener" products and services to end-customers (Wu and Dunn, 1995). In this sense, logistics can be the missing link in the greening of the supply chain. This discussion leads to the following proposition:

Proposition 2.10. *To the extent that end consumers become more environmentally conscious, shippers become more dependent on LSPs for inclusion of green aspects into logistics operations, and therefore increasingly coordinate environmental practices with LSPs.*

Björklund (2011) points out the hindrance impact of customers/consumers' non-environmental demands (e.g. lead time or on-time delivery) on shippers' environmental purchasing; transport purchasing companies ought to find ways to communicate to their customers/consumers in order to increase their awareness about how hindering their non-environmental demands can be for the environmental performance. Jazairy and Haartman (2020) highlights how the requirements of shippers' customers such as cost and speed of delivery might play a key role in demotivating LSP for the adoption of green logistics in the supply chain. In other words, customers' non-environmental requirements along the supply chain might force the supplier (i.e. shipper) to use less environmentally friendly logistics of the product.

Rivera-Camino (2007) argues that the extent to which firms response to stakeholder needs is associated with how close they are to final consumers. This is in line with Hoejmose et al. (2012) who relate lack of effort on the part of shippers involved in B2B to the distance form customers and lack of visibility; firms operating in highly visible markets (i.e. B2C) engage in environmentally practices more intensively and proactively than those in B2B sectors (González-Benito and González-Benito 2006). Empirical evidence from logistics service industry supports the above argument that firms operating in B2C segments and closer to end consumers place higher priority on green aspects (Isaksson and Huge-Brodin, 2013). The results of Kudla and Klass-Wissing (2012) also confirm that shippers operating in end-consumer-oriented industries or B2C (e.g. fast-moving consumer goods) and reputation-sensitive sectors are more interested in the LSPs' sustainability programs. In their study, Bahr and Sweeney (2019) showed that there is a divergence of practice between retailers and manufacturers and in which retailers had stronger requirements for environmental practices in both purchasing process and later during follow-up and evaluation phase. In a similar fashion, Jazairy and Haartman (2020) discuss that while B2C actors are exposed to more pressure than B2B ones, the B2B actors' level of involvement in green practices is commensurate with their varying proximities to end users, in which the closer the business to end-consumer, the more it involves in green initiatives. Our discussion leads to:

Proposition 2.11. *The closer shippers to end consumers, the more concrete their requirements for inclusion of green aspects into logistics operations; shippers involved in B2C markets are more dependent on LSPs' green capability than those ones in B2B business, and thus have stronger incentive to purchase green logistics.*

Wolf and Seuring (2010) argue that, in line with increasing consumer pressures, regulation and legislation might still be the strongest levers for changing business practices. Nonetheless, transportation activities are not currently subject to strict environmental regulations on GHGs emissions (Fahimnia et al., 2015)[10]. The possibility of so-called carbon accounting, which in response to climate change might become mandatory in the transport industry, gives the parties in a supply chain an economic incentive to reduce pollution to an acceptable level and encourages both 3PL services and their customers to implement real changes in their environmental actions. This is especially true when setting carbon tax, carbon offset, clean development, and cap and trade are possible options in order to control the total amount of carbon emissions in the near future (Aronsson and Huge-Brodin 2006; Piecyk and McKinnon 2007). In particular, part of the motivation for making carbon accounting a legal requirement is to force "polluters" to pay the marginal external cost of their activities (EEA, 2006; IEA, 2009; Piecyk and McKinnon, 2010; Piecyk et al., 2015).

[10]Governmental and legislative practices in countries where LSPs operate might impose certain penalties and/or taxes on 3PLs' operations to enhance the use of alternative fuels, but there are no laws and regulations concerning the environmental impacts of logistics with respect to CO_2 emissions. Most of the measures currently implemented in the freight transport industry are not sufficient enough, so that they can set incentives for 3PL or transport buying companies to change their processes (Wolf and Seuring, 2010).

Government intervention in the form of regulatory measures has been discussed as a motive for 3PL's adoption of green practices, but at present the regulatory framework is unclear, and has had no significant influence on the adoption of green initiatives in the freight transport industry (Pålsson and Kovács, 2014; Pålsson and Johansson, 2016). In general, it was found that uncertainties make the LSPs more reactive and less willing to act proactively by taking initiatives (Jazairy and Haartman, 2020); without clear and long-term directions from regulators, the willingness in the LSP industry to take risks is low (Abbasi and Nilsson, 2016). Rossi et al. (2013) and Evangelista (2014) indicate that regulatory measures sometimes act as a barrier to the adoption of more sustainable actions in logistics. In fact, it is unclear which demands, or pressures, are, or should be on the LSP; Typically, shippers face no minimum legal requirements on environmental impacts of their outsourced logistics but their industry-specific functions (Jazairy and Haartman, 2020).

There is currently an on-going debate about whether shippers or LSPs should ultimately pay for the emissions costs of logistics, especially in the event of non-compliance. Drawing on insights from Propositions 1-2 and 9-10, we suggest that environmental regulations should be imposed on shippers and LSPs in a way that reflects their power structure with respect to environmental practices. Our argument above leads to the following proposition:

Proposition 2.12. *The greater the extent to which LSPs depend on shippers for inclusion of environmental practices in the supply chain, the more stringent are the regulations imposed on shippers. The interdependence structure may change as a result.*

The Proposition justifies a Penalty Distribution scenario, under which the shipper (i.e. receiver of logistics services) should pay at least a proportion of the costs of pollution resulting from shipment of goods. This implies that the stringency of regulatory measures imposed on the shipper should be commensurate with the proportion of environmentally minded consumers in a market; the less consumers are aware of the environmental impacts of logistics of a shipper's product, the more responsibility should be imposed on the shipper.

The findings suggest that environmental demands for lower carbon products trigger CO_2 reductions throughout the supply chain (Jørsfeldt et al., 2016). In line with this, Stanny (2013) argues that mandatory environmental reporting standards could help to increase market transparency. Maas et al. (2014) point out that environmental reporting system increase the transparency regarding the environmental friendliness of logistics service. 3PL providers that would like to compete on environmentally based business strategies and claims would find it easier to make these claims more visible in comparison to their competitors and their respective service offerings. Based on such standards, the customers of 3PL providers will also find it easier to integrate environmental sustainability as a selection criterion into their logistics service procurement process. Gilley et al. (2000) point out that potential reputational impacts of firms' environmental actions tend to be lower when such practices are less visible to customers. Philipp and Militaru (2011) suggest that more visible individual ecological actions of shippers within the overall supply chain result in a higher level of ecological buying behavior toward logistics services. In a similar fashion, Jazairy and Haartman, (2020) discuss that shippers operating in industries with high tangible environmental impacts in production processes or end products tend to react to pressures on their environmental impacts and find ways to compensate such impact through green logistics purchasing. Drawing on the point raised by Carter and Rogers (2008), transparency can play an important role in the development of sustainable supply chains; when carbon labelling is required, it will affect the secondary role of the LSP from the shipper's perspective. Moreover, transparency necessitates a closer vertical collaboration between the parties across a supply chain. Our discussion leads to:

Proposition 2.13. *Once carbon footprint becomes a standard characteristic of products, transparency increases and shippers become more dependent on LSPs to improve environmental performance, thereby motivating shippers and LSPs to collaborate more closely.*

Therefore, 3PL providers need to monitor future developments concerning environmental reporting practices, so that they can respond to requirements of the market and help shippers increasing their business transparency.

2.3.3 Agency Theory and Transaction Cost Economics

Agency theory (Eisenhardt, 1989; Ouchi, 1979) provides a framework for understanding a buyer's response to supply chain risks (Ketchen and Hult, 2007; Zsidisin and Ellram, 2003). In this framework, the buying party (i.e. principal) delegates work to the contractor (agent), that is, the supplier, and tries to control the agent's opportunistic behaviors (Lassar and Kerr, 1996; Jiang, 2009; Moore, 2001). The study on core issues in SSCM by Seuring and Müller (2008a) highlights "Supplier Management" and in particular "auditing and monitoring" of suppliers as one of the issues at the supplier-buyer interface that usually becomes necessity after supplier selection based on environmental and social criteria. In the scope of SSCM, Sustainable Supplier Development (SSD) initiatives include both monitoring (control)-based and collaboration-based risk mitigation strategies (Vachon and Klassen, 2008; Klassen and Vereecke, 2012; Vachon and Klassen, 2006; Parmigiani et al., 2011) and are defined as the buyer's plans and strategies to integrate ecological and social issues into the supply management processes to improve suppliers' performance (Bai and Sarkis, 2010; Krause et al., 2007).

In this setting, environmental monitoring encompasses practices initiated by the purchaser to monitor or control the supplier, while environmental collaboration refers to the buyer and supplier jointly working toward environmental solutions (Vachon and Klassen, 2006). According to agency theory, principals might choose among three distinct control mechanisms (i.e. output; behavior; and input control) to minimize the agents' hidden actions (Eisenhardt, 1989; Ouchi, 1979). Hajmohammad and Vachon (2016) categorize the combination of output and behavior control mechanisms as monitoring-based, and input control mechanism as a collaboration-based risk mitigation strategy, respectively[11].

Like many other inter-organizational relationships, the LSP-shipper interface is also affected by so-called agency problems when shipper and LSP act as principal and agent, respectively. Two aspects of the agency problem are mentioned in literature: moral hazard and adverse selection. Moral hazard refers to a situation in which lack of effort by the agent affects the achievement of the principal's goals and objectives. Adverse selection refers to the misrepresentation of the agent's real abilities and skills in meeting principal's goals in a dyadic relationship. In other words, adverse selection involves hidden information, whereas moral hazard involves hidden action (Pavlou et al. 2007). Problems of agency can arise mainly for two reasons: (1) the principal and the agent have diverging goals, and (2) the principal cannot verify directly whether the agent has behaved appropriately. The inclusion of sustainability into the LSP-shipper interface is also subject to agency problems resulting

[11]See Hajmohammad and Vachon (2016) for detailed explanation of monitoring and collaborative risk mitigation strategies and how they relate to three control mechanisms introduced by Agency Theory. Based on Hajmohammad and Vachon (2016), monitoring-based risk mitigation strategy corresponds to output and behavior control mechanisms and consists of verifying supplier performance and its compliance against a pre-determined criteria through relying on supplier reports or direct audits of supplier's activities (i.e. output and behavior control) and collaboration-based risk mitigation strategy which consists of verifying supplier performance by partnership/sponsorship, joint development of solutions/technologies, and sharing information (i.e. input control).

from information asymmetries, including hidden actions and information. Adverse selection and moral hazard can be resolved using an adequate evaluation of partner's capabilities prior to the contract, or using incentives, information and control mechanisms after the contract (see e.g. Alparslan, 2006; Roiger, 2007), to reduce goal conflicts and validate behavior.

A comprehensive overview of the agency problems of sustainability practices in dyadic shipper–LSP relationships (Kudla and Klass-Wissing, 2012) emphasizes that increased demand for sustainable behavior is associated with agency problems of adverse selection and moral hazard. Seuring and Müller (2008a) mention "certification of suppliers" according to environmental criteria as common in the supplier selection process. In particular, the role of ISO 14001 has been discussed in relation to selecting suppliers to green the supply chain. An Environmental Management System (EMS) that includes ISO 14001 accreditation and the Dow Jones Sustainability Index (DJSI) has also been discussed in the green logistics literature (Martinsen and Huge-Brodin, 2010; Martinsen and Björklund, 2012; Pazirandeh and Jafari, 2013; Lammgård and Andesson, 2014). According to Martinsen and Huge-Brodin (2014), EMS is now being considered as shipper's minimum requirements prior to the choice of partner, or as a pre-condition guide (Seuring and Müller, 2008a; Wolf and Seuring, 2010; Bask et al., 2018). The LSP-shipper interface is susceptible to adverse selection if a dyadic relationship is categorized by high ambition of shippers for sustainable activities and low sustainability performance of LSPs. The empirical evidence confirms that the LSP-shipper interface is rarely categorized as a low-high interface, and if so it occurs when the LSP is not certified to environmental standards (Kudla and Klass-Wissing, 2012; Martinsen and Huge-Brodin, 2014; Sallnäs, 2016). Sarkis (2003) also suggests that environmental risk with certified companies should be lower risks than when not certified. This leads to the next proposition:

Proposition 2.14. *Adverse selection and partner switching in the LSP-shipper interface is less likely if the shipper verifies the adequacy of the partner according to environmental criteria before any contractual agreement.*

This implies that lower environmental ambition from LSP's side can lead to a risk of shippers moving to LSPs with higher environmental ambition prior or during the contract.

Recognizing that LSPs are generally dependent on shippers, Sallnäs (2016) highlights that "direct supervision"[12] is an indispensable part of the LSP-shipper interface whenever the relationship requires or offers an environmental practice, regardless of the shipper's level of environmental ambition. Direct supervision of an LSP by a shipper with low environmental ambition generally reflects financial rather than environmental motives. Moreover, Kudla and Klass-Wissing (2012) link moral hazard to information asymmetry (e.g. hidden characteristics, hidden actions, and hidden information) and suggest that it can be resolved by implementing incentive, information and control mechanisms to reduce goal conflicts and difficulties in behavior validation. In particular, they suggest that if a dyadic relationship is categorized by a high desire of shippers for sustainability activities, adequate information, control and incentive mechanisms must be implemented by shippers to balance goal conflicts, prevent hidden actions and result in appropriate sustainability activities.

Hajmohammad and Vachon (2016) suggest that when the supplier's dependence on the buyer is relatively high (i.e., in situations of buyer dominance or interdependence), the buyer is more likely to mitigate supplier sustainability risk through monitoring-based or

[12] In direct supervision, the responsibility of coordination lies with someone who does not actually perform the task, but instead gives directives to those who do (Mintzberg 1989). Sallnäs (2016) names CO_2 emissions and environmental reports as a means of direct supervision.

collaboration-based strategies, in that perceived risk pushes the parties toward collaboration-based strategies; more interdependence generally means more collaboration regardless of the perceived level of risk. The buyer's perceived risk is very sensitive to the consequences of supplier misconduct, and can be attributed to visibility in the marketplace (Bowen, 2002) as well as stakeholder salience (Parmigiani et al., 2011). Despite the increasing societal focus on environmental issues and the influence of transportation on CO_2 emissions, the empirical evidence shows that environmental efficiency has remained low in importance for many years in the purchase of transport services (Lammgård and Andersson, 2014). In fact, shippers see little connection between the environmental efficiency of their logistics and business-related risks such as regulatory and reputational risks, among those mentioned by Lash and Wellington (2007). This implies that, given the low level of transparency of the logistical environmental impacts of shippers' products along the supply chain and the low pressure from stakeholders, it is unlikely that their supplier's misconducts will do serious damage to the buyer's image and reputation. Thus, drawing on the insights from by Propositions 1-2, the following proposition relates to the monitoring of an LSP's environmental performance within the LSP-shipper interface:

Proposition 2.15. *Because of the LSP's dependency on the shipper and the low perceived risk that non-green logistics activities of the LSP will influence stakeholders' perceptions, the shipper will control of LSP's environmental performance by monitoring (i.e. direct supervision) rather than by collaboration-based risk mitigation strategy.*

This implies that increasing transparency in logistics industry is key to changing shipper's perceived risk of using non-green logistics and thereby changing the interdependence structure, pushing the parties toward collaborative-based risk mitigation strategy. Such transition put the necessity of quantitative measuring of environmental impacts resulting from logistics of product along the shipper's supply chain. There have been studies on development of systematic metrics or scales (such as green framework criteria) for measuring the LSP's environmental performance (see e.g. Kim and Han, 2011; Lam and Dai, 2015); nonetheless, CO_2 emissions and energy efficiency are the metrics most widely used in practice (Björklund and Forslund, 2013; Martinsen and Huge-Brodin, 2014; Sallnäs, 2016; Centobelli et al., 2017). Björklund and Forslund (2013) suggest that environmental performance improvement depends positively on the inclusion of environmental metrics and incentives or penalties to encourage compliance in the transport contracts between LSPs and shippers. However, despite the progress in the development of systematic metrics or scales/indexes (such as CO_2 emissions and energy efficiency) for quantitatively measuring the LSP's environmental performance, many LSPs fail to measure their environmental performance, and do not have an environmental management system implementing emission auditing and reporting. In fact, in logistics there is limited knowledge of how the quantitative impact of green initiatives on environmental performance should be measured, even in terms of its most evident environmental impact, CO_2 emissions (Evangelista et al., 2018)[13]. Content analysis of related literature finds no systematic approach, nor any set of indexes integrating energy efficiency and environmental impact.

In alignment with resource dependence theory that emphasizes on the acquisition of valued resources in a low-cost manner, one of the main pillars of transaction cost economics is that firms attempt to acquire resources in a low-cost way (Williamson, 1975). Within a supply chain context, the threat of opportunistic behavior by other members of the supply chain

[13]Oberhofer and Dieplinger (2014) provided a quantitative measure for the environmental performance of green actions in terms of GHG emissions; this appears to be the only estimate in the literature of the emissions savings following from implementation of green actions.

necessitates costly auditing activities (Stump and Heide, 1996) that create transaction costs in terms of investment monitoring and reporting requirements (Carter and Rogers, 2008). Thus, the principal efforts for partner selection, evaluation prior contractual agreement and control during an existing contract, are linked to agency costs for reducing the possibility of divergence by an agent from the principal's goals (Kudla and Klass-Wissing, 2012). "Direct supervision and external auditing" is the most common coordination mechanism adopted by shippers when they jointly manage environmental issues with LSPs (Sallnäs, 2016).

Despite this, De Giovanni and Vinzi (2014) find that monitoring suppliers does not lead to efficiencies in environmental collaboration. The underlying reason, they suggest, might be that information sharing and trust in the supply chain gives all actors the incentive to act cooperatively, diminishing the need for monitoring. Drawing on empirical evidence, Hajomohammad and Vachon (2006) emphasize the substantial resources that must be invested to minimize the impacts on a buyer from its supplier's opportunistic sustainability misconducts; the more efficiently these behaviors are controlled, the lower the level of supplier sustainability risk a buyer will face. Carter and Rogers (2008) underscore how transparency and vertical coordination along the supply chain can help supplier sustainability while reducing transaction costs for both supplier and buyer. Indeed, transparency through sharing of monitoring information will promote greater collaboration and improve environmental performance. Shippers are typically looking for a way to ensure that their carriers followed environmentally sustainable transportation practices, without necessitating the monitoring of individual carrier behavior (Ellram and Golicic, 2015). The underlying reason might be that information sharing and trust in the supply chain gives all actors the incentive to act cooperatively, diminishing the need for monitoring. Our above discussion leads to the following proposition:

Proposition 2.16. *The more transparent the LSP's green logistics activities, the less sustainability risk (i.e. risk of opportunistic behaviour) faced by the shipper and the lower its monitoring costs; the consequence is increased collaboration and better economic and environmental performance.*

Indeed, transparency through sharing of monitoring information will promote greater collaboration and improve environmental performance while reducing transaction costs for both supplier and buyer. Consistent with the insight brought by Proposition 16, the LSP's capability in measuring the environmental impacts of shipper's logistics is a giant step toward increasing transparency which in turn reduce the shipper's need to invest in monitoring LSP's environmental performance and consequently result in lower transactions costs. This in fact underscores the important role that Information and Communications Technology (ICT) such as RFID, Internet of Things (IoT) and Blockchain play in lowering monitoring costs, increasing transparency, lowering transaction costs and therefore yielding to higher economic and environmental performance.

2.4 Concluding Remarks

Recent studies on the purchasing of green logistics services suggest a tension—and some associated misalignment—between shippers and 3PLs on this topic (Bahr and Sweeney, 2019). Our study helps to explain why shippers and LSPs are reluctant to invest in environmental improvements and why both parties may be inactive.

Our study relates shipper-LSP environmental goal misalignment to the general dependency of LSPs on shippers. That dependency, which has been noted in previous works (e.g., Wolf and Seuring, 2010; Lammgård and Andersson, 2014), reflects the hierarchical relationships in which the shipper is the party who decides the environmental performance of product logistics . Buyer dominance, or the power advantage of shipper over LSP (i.e. power-dependence imbalance) (Touboulic et al., 2014) obliges LSPs to adapt logistical services to customer demands and requirements. The environmental gap between the parties stems from lack of fit (i.e. alignment) between the LSP's ecological logistics offerings and the shipper's perceived value of those offers. In particular, the empirical evidence suggests that the shipper's perception of green logistics services is driven by the extent to which environmental sustainability criteria are compatible with traditional (non-environmental) requirements, namely economic and operational metrics/indicators (Philipp and Militaru, 2011; Bask et al., 2018; Jazairy, 2020). Critical elements in changing the shipper's mindset and reducing the environmental goal misalignment include: 1) integration of basic environmental practices (i.e. quick fixes (Nilsson et al., 2017); quick win activities (Kudla and Klass-Wissing, 2012)) into general logistics offerings (Isaksson and Huge-Brodin, 2013); and 2) environmental communication to increase the visibility of environmental efforts/impacts (Du et al., 2010; Pieters et al., 2012).

Despite the importance of contracts in managing the parties' dependencies in the supply chain (Arshinder et al., 2008), the design of LSP-shipper contracts –through appropriate revenue/pricing models that link environmental practices to financial outcomes– is still at an early stage. To illuminate the benefit of LSP-Shipper collaboration and coordination on environmental action, such models must, at a minimum, focus on (a) rationally distributing the cost and benefits of environmental action between shippers and LSPs; (b) linking standard environmental metrics (KPIs) to the shipper's operational and economic performance objectives.

It is argued that resource dependence is positively associated with vertical coordination with other members of supply chain (Arminas, 2004), and that increased vertical coordination between buyers and suppliers impacts environmental purchasing and collaboration (Carter and Carter, 1998). The more dependent the shipper on successful management of logistics, the more interdependent the parties will be in managing traditional logistics services, and the more likely they coordinate their environmental practices (Philipp and Militaru, 2011).

Increasing awareness of the environmental impacts of product logistics has resulted in stricter environmental regulations and changes in consumer behavior, both of which increase pressures on shippers and LSPs to become more environmentally friendly (Isaksson and Huge-Brodin, 2013). Despite this, many scholars relate the lack of shippers' engagement in green logistics purchasing to the dominant regulatory, market and competitive pressures on shippers' internal, industry-related activities as opposed to green logistics (e.g Jazairy and Haartman, 2020). The more environmentally conscious the end-consumers become, the more shippers will depend on LSPs' expertise to deliver greener products, and therefore the more they will coordinate environmental practices with LSPs. Shippers involved in highly visible and reputation-sensitive B2C markets and closer to end-consumers are more likely to engage in green logistics practices than those involved in B2B markets (Hoejmose et al., 2012; Kudla and Klass-Wissing 2012; Isaksson and Huge-Brodin, 2013; Bahr and Sweeney, 2019; Jazairy and Haartman, 2020). Part of the motivation for making carbon accounting a legal requirement is to encourage both 3PL services and their customers to implement real changes at the environmental level. Our study suggests that environmental regulations should be shared across shippers and LSPs (i.e. penalty distribution) in a way that reflects their power structure with respect to environmental practices.

Transparency has an important role in the development of sustainable supply chains through a closer vertical collaboration between the parties (Carter and Rogers, 2008). Mandatory environmental reporting standards could help to increase transparency regarding environmental impacts of logistics services (Stanny, 2013; Maas et al., 2014). Philipp and Militaru (2011) suggest that more visible individual ecological actions of shippers within the overall supply chain result in greater reputational impacts of firms' environmental actions, and the more impact it may have on the shipper's ecological buying behavior toward logistics services. In particular, carbon labelling can increase the shipper's dependency on the LSP's green solutions, thus encouraging environmental purchasing and collaboration.

Like many other inter-organizational relationships, the LSP-shipper interface is also affected by so-called agency problems (i.e. moral hazard). The shipper (i.e. principal) might adopt either monitoring/auditing-based or collaboration-based control mechanisms to minimize LSP's (agent's) hidden actions. The shipper's (buyer's) choice of control mechanism is driven by the dependency structure between buyer and supplier (LSP), and the buyer's perception of the risk of supplier's non-compliance (Hajmohammad and Vachon, 2016). Given the general dependency of LSPs on shippers and the shipper's low perceived reputational impacts for non-green logistics, the shipper tends to control the LSP's environmental performance by monitoring (i.e. direct supervision and external auditing) rather than by any collaboration-based risk mitigation strategy. Environmental performance improvement may well depend on the inclusion of environmental metrics to encourage compliance in the transport contracts between LSPs and shippers (Björklund and Forslund, 2013). In general, increasing transparency in the logistics industry is key to changing the shipper's perceived risk of non-green logistics, thereby changing the interdependence structure and pushing the parties toward a collaborative risk mitigation strategy.

The threat of opportunistic behavior necessitates costly auditing activities (Stump and Heide, 1996) that create transaction costs in terms of investment monitoring and reporting (Carter and Rogers, 2008). The shipper's efforts to control the LSP's actions are linked to agency costs aimed at reducing the risk that the agent diverges from the principal's goals (Kudla and Klass-Wissing, 2012). Thus, transparency through sharing of monitoring information builds trust in the supply chain and will promote greater collaboration and improve environmental performance while reducing transaction costs for both supplier and buyer (Carter and Rogers, 2008).

Our study sheds light on the reasons underlying environmental goal misalignment between the LSP and the shipper. Of course, further investigation is required to understand the moderating impacts of market pressures and the mediating impacts of agency problems and transaction costs on the parties' environmental collaboration. Moreover, our conceptual framework suggests what has to be done by both practitioners and policy makers in order to achieve green logistics in supply chains.

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Chapter 3

Environmental Goal Misalignment between Logistics Service Providers and Shippers: A Game-Theoretic Analysis

3.1 Introduction

With recent calls for more strict regulations on environmental impacts and the emergence of environmentally conscious consumers, supply chain members must account for the associated emission costs of their activities that are borne by the community and ecosystem.

Consumers' awareness of the ecological footprint of products is rising throughout the world (Klassen and McLaughlin, 1996; Chen, 2001; Mahenc, 2008; Young et al., 2010; Altmann, 2015) and they are more persistant in demanding environmentally friendly products. In future, carbon footprint indicators will become a global standard for both services and products; package labels will report CO_2 emissions of each product (DHL, 2009; Benjaafar et al., 2013). More recent studies confirm that consumers pay attention to eco-labels and are willing to pay more for demonstrably green products and services (DHL, 2009; Echeverria et al., 2014; Chen et al., 2015). As a result, the market will be the main decelerator of climate change as the demand becomes more sensitive to carbon emission levels (Letmathe and Balakrishnan, 2005; DHL, 2009; Tang and Zhou 2012; Krass et al. 2013).

Supply chain members must respond to environmental concerns by taking initiatives to green the supply chain and reduce carbon footprints while maintaining market share. Even supply chain members not directly associated with the consumer market are being pushed to incorporate green initiatives into their agendas. As a company's environmental performance is affected by the activities of other firms along its value chain (Caro et al., 2013; Touboulic et al., 2014; Plambeck and Taylor, 2016), all firms must account for the environmental performance of their upstream suppliers (Jira and Toffel, 2013).

The logistics operation is the link of the supply chain that is the highest priority for change to 81 percent of companies who have established a Green Supply Chain (Insight, 2008). The results from the *Green Trends Survey* carried out by DHL in 2010 [1] confirm that sustainability will become a key buying criterion; 51 percent of end consumers would prefer products from a company with green logistics/transport solutions over a cheaper provider. Also, 59 percent of business customers (i.e. shippers) estimated that the green logistics of their products would be a crucial factor in winning end-consumers.

Logistics Service Providers (LSPs) and shippers (i.e. the users of the logistics service)

[1] See `https://delivering-tomorrow.de/wp-content/uploads/2015/08/delphi-studie_english-1.pdf` for an in-detail discussion over: (1) the expected impact of green shipping/logistics solutions on end consumers' perception of a product; (2) how shippers perceive the impact of adopting green transport/logistics on end consumers' preferences.

are currently under pressure to reduce the environmental externalities resulting from their operations (McKinnon and Piecyk, 2012). The critical role of green logistics in providing low carbon products presents a considerable opportunity for LSPs to diminish carbon footprints in their supply chain and deliver greener products to end-consumers (Wu and Dunn, 1995). Moreover, so-called carbon accounting obliges polluting LSPs to account for the emission costs of their activities[2] (EEA, 2006; IEA, 2009; Piecyk and McKinnon, 2010). On the other hand, the demand for logistics services depends on the sales volumes of shipping industries, underlining the importance for shippers to integrate logistics into their inter-organizational sustainability management (Kudla and Klass-Wissing, 2012).

Notwithstanding the ambitious targets announced by leading LSPs to mitigate the carbon intensity of their operations (Lieb and Lieb, 2010; McKinnon and Piecyk, 2012), most LSPs still hesitate to invest in sustainable actions. A recent survey of LSPs also indicates that most shippers are currently reluctant to spend more for sustainable logistics services offerings (Colicchia et al., 2013). The debate on who will ultimately be responsible to pay for green initiatives suggests that there is *friction* between logistics companies and their clients over responsibility for managing environmental issues. The empirical evidence indicates that the shipper (buyer) is the party who sets the *conditions* for inclusion of environmental practices in its relationship with the LSP (supplier) (see e.g. Wolf and Seuring, 2010 or Sallnäs, 2016). The general dependency of LSPs on shippers identified in the empirical data implies an environmental goal *misalignment* (i.e. gap) between LSPs and shippers where a decision made by the shipper is not necessarily in line with what the LSP's target. In other words, the parties lack alignment on green targets (Jazairy, 2020).

[2]To live up with the expectations of the Paris agreement, the government of Canada has enacted Carbon Pricing (e.g. Carbon Tax) on trucking industry since April 1, 2019.

Our focus in this study is to introduce and define precisely the notion of *environmental gap* between supply chain parties' environmental decisions. To this end, we first develop profit-maximization models of the LSP (service supplier) and shipper (buyer of logistics services) in a two-echelon supply chain to analyze the environmental decisions of these parties in a decentralized setting. In our analysis, we examine the impacts of consumers' environmental preferences, regulatory measures, and the shipper's share of green investment on the environmental decisions of *product logistics*[3], when each party holds the channel power over target emission level. Using economic analysis, we describe how the parties' emission targets depend on their negotiation power over the joint environmental decision. By considering the parties' emissions target decisions in a decentralized setting as a possible disagreement point, we explicate the matches and gaps between their environmental targets. To explain these gaps, we discuss the implications for the parties' emissions target decisions of change in shipper's level of involvement in green investment. We characterize each party's optimal level of contribution to green logistics investment in a negotiation in which one party or the other decides the joint target emission level. We further discuss the implications on the parties' emissions target decisions of a possible distribution of carbon tax across the two parties.

Our analysis adds a new perspective to the study of supplier-buyer environmental practices, emphasizing the need for conflict resolution in the parties' accountability for environmental issues in the supply chain. The contributions of this study are threefold: (1) We build a methodological foundation for quantitative analysis of the gap between an LSP and

[3]Product logistics can be described as the management of the flow of things between the point of origin and the point of consumption in order to meet the product requirements of customers.

a shipper in management of environmental issues. Unlike previous two-echelon supplier-buyer models in green supply chain management research, we simultaneously consider the *strategic* decisions of the shipper and the LSP regarding the environmental performance of logistics; (2) We contribute to gap analysis in the service literature by both (a) finding gaps (i.e., misalignment) between the shipper's and the LSP's desired environmental performance levels and (b) explaining those gaps, providing a rigorous explanation of some empirical observations about the LSP-shipper interface; and (3) We shed light on ways to improve environmental outcomes in freight delivery operations. Our analysis indicates whose responsibility it should be to pay for green investment and logistics regulatory measures (Carbon Tax) in the presence of the parties' conflict over the joint target environmental performance and their negotiation/bargaining on how to share aforementioned costs.

The remainder of this paper is organized as follows. Section two explores the current body of literature to justify the importance of this study. Section three presents the main features, assumptions, and formulation of mathematical model and its development. Section four analyzes the economic model and discusses the insights it provides. Finally, key findings, conclusions, limitations and future research directions are presented in section five.

3.2 Literature Review

3.2.1 Green Logistics and LSP-shipper Interface

Given the critical role of logistics operations in increasing LSPs' (and their clients') competitiveness, and the further push for internalization of its external costs (Himanen et al. 2005; Piecyk and McKinnon 2007), management of logistics operations must become a foundation for the healthy development of business activity in the long term.

The general message emerging from a large body of surveys is that companies want the management of their logistics stream to provide them with green credentials. However, none of these surveys makes explicit reference to any need to protect the environment; companies assign higher values to corporate image, competitive advantage, cost saving, and compliance with government regulation (Eyefortransport, 2007; Aberdeen Group, 2008; and Insight, 2008). Research by Selviaridis and Spring, (2007), Marasco, (2008) and Wolf and Seuring (2010) confirms the dominance of traditional performance objectives, such as price, quality requirements, service performance, and timely delivery, as buying criteria for third-party logistics (3PL) services.

Martinsen and Bjorklund (2012) define this gap as "over-achievement" when LSPs seem to be ahead of their clients in response to future environmental concerns and legislation. Nevertheless, drawing on inter-organizational theories, Kudla and Klass-Wissing (2012) suggest that LSPs may not respond to inquiries from shippers and may sometimes be unable to achieve green standards. Thus, there appears a mismatch between the parties' environmental ambitions (low versus high) to incorporate environmental concerns in their business relations (Martinsen and Bjorklund, 2012; Wolf and Seuring, 2010; Isaksson and Huge-Brodin, 2013). The service literature confirms that the gap: the potential for synergies between economy and ecology is not well understood by either LSPs or shippers (Wolf and Seuring, 2010); the parties may not even share the same perception of what services should be provided (Hakatie and Ryynanen, 2007).

The trend towards global outsourcing underscores the critical role of stronger relationships between LSPs and other parties in supply chains (Seth et al., 2006). However, organizational strategies to approach sustainability in a supply chain are based on a short-term perspective, and it is difficult for companies to find a strategy that is optimal from both the environmental and economic point of view. Likewise, having recognized customers to be a major driver for being environmentally responsible, 3PLs have considered strategic partnerships with their customers based on common strategic directions (Colicchia, 2013). Sallnäs (2016) studied how dependencies between LSP and shipper can influence the way they coordinate environmental practices. Another study showed how strong alliances and collaboration between LSPs and shippers may contribute to raising awareness of the economic benefits of improving environmental performance (Wolf and Seuring, 2010).

Even though recent reviews of green supplier accreditation underscore the importance of a supplier's environmental performance as a purchasing criterion for buying firms (see, e.g., Genovese et al., 2013; Govindan et al., 2015; Zimmer et al., 2016), scant attention has been paid to the role of LSPs in research on green supply chain management (Martinsen and Björklund, 2012). There are two possible explanations. First, most global shippers focus their attention on the environmental practices of raw material suppliers, not on service suppliers such as logistics service providers (Wolf and Seuring, 2010). Second, LSPs are recognized to be the least integrated link in supply chains (Lemoine and Skjoett-Larsen, 2004); they merely support other members of the supply chain (Spens and Bask, 2002).

3.2.2 Green Supply Chain Management

Explicit environmental considerations have been integrated into supply chain management problems by including environmental regulations, emissions costs associated with operations, concurrent inclusion of sustainability and economic goals, green innovation/investment decisions, consumer sensitivity to environmental impacts, and emissions targeting decisions. Analysis of single echelon models has focused on green/sustainable supply chain problems, where a single player's decision process included environmental sustainability. As suggested by Konur (2017), even though some of these studies take into account the other players' environmental performance (particularly different mode carriers/suppliers of transportation and logistics), they are not explicitly included in the decision-making process (see, e.g., Konur, 2014; Konur and Schaefer, 2014; Absi et al., 2016; Chen and Wang, 2016).

For the most part, two-echelon supply chain models are vendor-buyer models in a Stackelberg game with a leader and a follower at either the upper or lower echelon, depending on the nature of the supply chain channel. The common approach in the study of such supply chain channels is to analyze and compare decentralized and centralized supply chain channels, and to develop cooperative mechanisms such as revenue sharing or cost sharing contracts (see, e.g., Swami and Shah, 2013; Ghosh and Shah, 2015). In this line, a limited number of studies have analyzed the interactions of supply chain members on the efforts invested in environmental performance (Yenipazarli, 2017). Moreover, in such setting, the leader (i.e. supplier) is the agent who usually holds the power to determine joint environmental performance and/or sharing the green investment costs, a decision that will not necessarily benefit the follower (i.e. buyer) (Konur, 2017). Consistent with much of the current literature, environmental practice in an LSP-shipper interface can be a good representative of such *disagreement.*

Our game-theoretic analysis borrows some elements from the standard models mentioned above including their common assumptions, but is distinctive in that it:

(1) takes into account both parties' powers to determine the joint environmental decision of product logistics and their conflict over accountability for greening operations. We believe that our study is the first to introduce a *two-dimensional* channel power with respect to environmental decisions, emphasizing the buyer's (i.e. follower in a two-echelon supply chain setting) power to select the environmental performance of the supplier's product or service (i.e. leader);

(2) focuses on green investment to reduce the environmental impact of product logistics, using environmental performance improvement to increase end-consumer demand in an environmentally conscious market. Our study is among the few studies measuring environmental performance improvement based on both current and target carbon *emission* levels, assuming a negative relationship between product demand and environmental impact; and

(3) includes government intervention to control the environmental impacts of product logistics by imposing a carbon tax, either on the LSP or on both parties. Our study is the first to consider a penalty on the buyer (of a service or product) as opposed to only the supplier in a two-echelon supply chain setting, and to introduce a *Carbon Tax Distribution* scenario.

3.3 Model Setup

We develop a two-echelon supply chain model comprising an upstream supplier (i.e. LSP) whose demand for logistics service derives from a downstream buyer (i.e. shipper) who sells its product at the final market. We construct our economic model on the basis of both parties' power to make the joint environmental performance decision and by assuming:

(1) that consumers' environmental consciousness is a component of demand that reflects the environmental emissions due to logistics[4]: while sensitive to product retail price, customers also prefer products that are demonstrably green in their logistics operations;

(2) that green investment to mitigate a product's carbon emissions is the responsibility of the LSP, allowing the shipper to co-invest in the green initiatives. Therefore, we consider the implications of the shipper accepting a proportion of green investment depending on preexisting relations between the parties (i.e. cost-sharing parameter is exogenous). Note that the demand-enhancing benefit of logistics emission reduction accrues to both parties, encouraging their contributions to green investment. In section 3.4.3, we characterize the shipper's (each party's) optimal proportion of contribution to green investment and discuss how bargaining forms the division of parties' respective contributions to greening investment (i.e. cost-sharing parameter is endogenous);

(3) that the Polluter-Pays principle applies and that the LSP is responsible for *Carbon Tax* on logistics operations. In an extension to our analysis (in section 3.4.4), we examine the implications on parties' emissions target decisions if a portion of carbon tax is transferred to the shipper (i.e. Carbon Tax distribution). In both scenarios, we consider Carbon Tax as an exogenous parameter that is determined by government. We further study the parties' negotiation on responsibility to pay Carbon Tax and the role bargaining can play in

[4]Recall that we consider only emissions resulting from product logistics; emissions due to manufacturing are not included in our model. In other words, we assume that the product already exists, and the only issue is getting it to market. Thus, without loss of generality, the shipper is assumed to be a non-manufacturer that procures the product from an upstream supply chain partner; we can incorporate the production emissions of product in its current emission level E_0, but it complicates the presentation of our results.

sharing responsibility for Carbon Tax, where carbon tax-sharing parameter is endogenously determined by both parties.

Our model does not consider the operational aspects of greening logistics, allowing us to adopt the stylized supplier-buyer game-theoretic approach to analyze the incentives of the LSP (supplier) and the shipper (buyer) over green investment in the face of carbon tax and consumer environmental pressures. In particular, we assume without loss of generality that the logistics operation is optimally *eco-efficient* for any given level of green investment. That is, operational-level initiatives such as optimized transport networks, load to truck capacity ratio, and despeeding are implemented. Thus, in our model the green investment reflects the parties' decisions after agreeing to adopt *Green Vehicle Technologies* that achieve the highest potential abatement and maximally reduce the carbon intensity of logistics operations.

The parameters of our economic analysis are presented in Table 1. To distinguish among parameters of LSP and shipper, we use subscripts l and s, respectively. Moreover, L(S) stands for LSP(shipper)-oriented model.

3.3.1 Consumer Pressures and Product Demand Function

Drawing on the insights brought by "Green Trends Survey" (DHL, 2010) and in alignment with Klassen and McLaughlin (1996) and Kassinis and Soterious (2003), we assume a negative linear correlation between the environmental impact of the shipper's logistics and consumer demand. Demand for a product increases as logistics emissions decrease. Environmental performance improvement can enhance end-consumer demand because it promotes the product position in the market with environmentally-minded consumers. Of course, customers are sensitive to price as well as emissions: demand for a product decreases as retail

Table 3.1: **Table 1: Notation**

Parameters	Definition
$D(P_s,\ E)$	Demand for product/logistics service
A	Potential market size
λ	Sensitivity of demand to price of product
γ	Sensitivity of demand to greenness of product
P_s	Price charged by shipper (per unit of product)
P_l	Price charged by LSP (per unit of product)
C_s	Procurement cost (per unit of product)
C_l	Logistics cost (per unit of product)
C_T	Carbon Tax (per unit of product carbon emission)
α	Proportion of green investment paid by shipper
β	Proportion of carbon tax paid by shipper
C_e	Cost coefficient of logistics emission reduction
E_0	Emission level of logistics before green investment (per unit of product)
E	Emission level of logistics after green investment (per unit of product)
$\pi^*_{l_I}$	LSP's profit in decentralized supply chain $I \in \{L, S\}$
$\pi^*_{s_I}$	Shipper's profit in decentralized supply chain $I \in \{L, S\}$

Decision Variables	Definition
E_i	Target emission level from each party's perspective $i \in \{l, s\}$
P_s	Optimal retail price
P_l	Optimal logistics service price

price increases. Thus, our additive linear demand function is [5]:

$$D\left(P_s,\ E\right) = A - \lambda P_s - \gamma E \tag{3.1}$$

where P_s is the product price and E is the level of emissions per unit of delivered product resulting from logistics activities. Also, the parameters λ and γ describe the consumer market, representing the sensitivities of demand to price and to carbon emissions from logistics activities. This type of demand function is widely used in game-theoretic supply chain models dealing with interfirm interactions (see footnote 5). The supply chain structure of our model implies that demand for logistics services is equivalent to the aggregate demand for product at the final market. Because of the derivative character of logistics services, the requirements for logistics service are equivalent to the demand for the product. In other words, we measure product demand using logistics service demand metric (e.g., number of truckload trips over a given distance).

3.3.2 Green Investment and Parties' Emissions Targets

In our study we use a green investment function to express the additional cost to reduce a product's logistics carbon emissions from current level E_0 to a target level E, satisfying $0 < E < E_0$, as follows:

$$C\left(E\right) = C_e\left(E_0 - E\right)^2 \tag{3.2}$$

[5]The demand function and green investment function we later introduce in 3.2 were first proposed by Yalabik and Fairchild (2011) and have been adopted later by other studies (see e.g. Chen et al. (2017)).

where C_e is a coefficient of greening product logistics and represents the fixed cost of environmental improvement. According to (2), the green investment is assumed to be convex with respect to target environmental level E [6]. The cost for further reduction in emissions increases as additional reductions are achieved: marginal improvement in the ecological impacts of logistics requires increasing amount of investment. Note that this type of cost structure to reflect the diminishing improvements of the green investment is consistent with the current literature (see footnote 5). We focus on a single product value chain in which each shipment is the same quantity (as agreed) carried by the same transportation mode (e.g. road transport by truck) over the same distance (minimum distance possible achievable). This means a minimum constant average emission per unit shipped per unit of travel distance (km or mile) at its current level E_0, suggesting an eco-efficient operations already in place. Thus, in our model, we do not incorporate an explicit savings in logistics costs due to investment in green vehicle technologies.

Investment in green initiatives mitigates logistics carbon emissions, while possibly increasing revenue for both sides through an increase in demand for product. In our model, the target emissions level E can be decided either by the LSP or the shipper, reflecting their negotiating power in making the joint environmental decision. For each party, a trade-off between costs and benefits determines the optimal strategy. For the shipper, paying a premium price for a green logistics offering by the LSP results in increased revenue from demand expansion in the carbon sensitive market. For the LSP, investment in sustainable logistics operations benefits the LSP by reducing carbon tax and increasing demand in an environmentally conscious market.

[6] Our green investment function allows the possibility of reaching $E = 0$, but we argue that in practice, the associated costs for approaching zero-emissions logistics operations will exceed what they can achieve.

3.3.3 LSP's and Shipper's Profit-Maximization Problems

Considering (1) and (2), the LSP's profit-maximization problem is:

$$maximize\ \pi_l\left(P_l, E\right) = D\left(P_s, E\right)\left(P_l - C_l - C_T E\right) - \left(1-\alpha\right) C_e \left(E_0\ - E\right)^2 \tag{3.3}$$

$$s.t.\ 0 < E < E_0$$

Note that P_l is the logistics service price, C_l is the LSP's unit cost to carry out the service, and C_T is the penalty (tax) per unit of carbon emission per unit of product. This implies that the total penalty borne by the LSP is directly dependent on the total quantity of product shipped, the logistics emission level per unit of product, and the carbon tax C_T per unit of logistics carbon emission. Also note that $(1-\alpha)$ is the proportion of green investment to be borne by the LSP and measures the shipper's level of willingness to invest in improving the carbon intensity of its operations.

Similarly, based on (1)-(3), the shipper's profit maximization problem is:

$$maximize\ \pi_s\left(P_s, E\right) = D\left(P_s, E\right)\left(P_s - C_s - P_l\right) - \alpha\ C_e \left(E_0\ - E\right)^2 \tag{3.4}$$

$$s.t.\ 0 < E < E_0$$

Note that C_s represents the unit cost incurred by shipper to procure the product. Also note that $\alpha \geq 0$ is the shipper's proportion of green investment charged to improve carbon intensity of logistics operations.

3.3.4 Information Structure and Decision Sequences

The target environmental level E in (3) and (4) is decided by the party who holds the channel power with respect to target environmental level. We denote the desired target emission level E from LSP's and shipper's perspective by E_l and E_s, respectively. In the *LSP-oriented model*, the LSP maximizes its profit by deciding the optimal logistics service price P_l^* and optimal target emission level E_l^*, to which the shipper responds by setting the retail price P_s to maximize its profit. In the *shipper-oriented model*, the shipper maximizes its profit by deciding the optimal product retail price P_s^* and optimal target emission level, E_s^*, in response to the logistics service price, P_l, set by the LSP. Figures 1 and 2 illustrate the decision framework (i.e. order of decisions) we analyze the problem under both models.

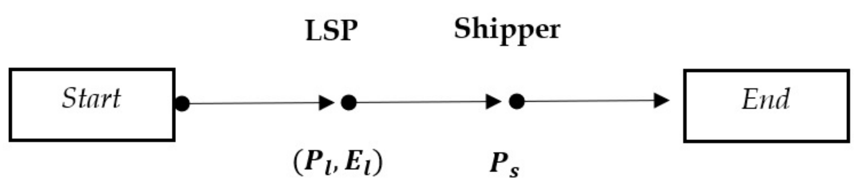

Figure 3.1: **LSP-Oriented Model (L)**

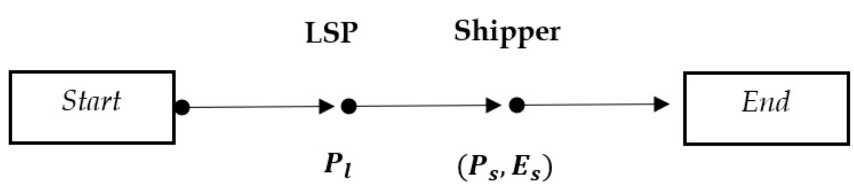

Figure 3.2: **Shipper-Oriented Model (S)**

Thus, in the games we analyze, the LSP's decision always precedes the shipper's decision. The LSP always sets its price P_l in the first stage and the shipper always sets its price, P_s, in the second stage. In addition, each player sets the environmental target, E_i, in its stage where $i \in \{l, s\}$. In the LSP-oriented model, the LSP sets the target level E, E_l, in stage 1. In the shipper-oriented model, the shipper sets the target level E, E_s, in stage 2. Thus, strategy profiles in the in the LSP-oriented and shipper-oriented games can be written (P_l, E_l; P_s) and (P_l; P_s, E_s), respectively.

Note that, in assessing the cost-sharing between the parties (parameter α), we consider two scenarios under each model: 1) the cost-sharing parameter is exogenous, so that pre-existing relations or channel power forms the basis of cost-sharing. In particular, in Figures 1 and 2 the value of α is fixed, in advance. 2) the cost-sharing parameter is endogenous: the LSP, shipper, or negotiation through a Nash Bargaining determines the parties' respective share in green investment costs. Such agreement on how to share the greening costs is assumed to be in place prior to parties' respective sequence of decisions under each model (Figures 1 and 2).

Table 2 illustrates a two-dimensional channel power with respect to: 1) Target Environmental Level E; and 2) Cost-Sharing Parameter α. Note that $\alpha^*_{i_I}$ represents the shipper's share of green investment under each scenario where $I \in \{L, S\}$ and $i \in \{l, s, n\}$ represents channel power with respect to target environmental performance and cost-sharing parameters, respectively.

Table 3.2: **Notation for Shipper's Share of Green Investment Costs**

<table>
<tr><td colspan="2"></td><td colspan="3">Who determines α?</td></tr>
<tr><td colspan="2"></td><td>LSP (l)</td><td>Shipper (s)</td><td>Negotiation (n)</td></tr>
<tr><td rowspan="2">Who determines E?</td><td>LSP (L)</td><td>$\alpha^*_{l_L}$</td><td>$\alpha^*_{s_L}$</td><td>$\alpha^*_{n_L}$</td></tr>
<tr><td>Shipper (S)</td><td>$\alpha^*_{l_S}$</td><td>$\alpha^*_{s_S}$</td><td>$\alpha^*_{n_S}$</td></tr>
</table>

3.4 Analysis and Results

In this section, we describe the analysis of the interface between LSP and shipper from an environmental perspective in a decentralized supply chain channel in which LSP is the leader and shipper is the follower. In this two-stage Stackelberg setting, we first characterize each party's profit-maximization level of carbon emissions when each party has power over the environmental level of product logistics. Second, by comparing the consequences of parties' negotiation power, we illustrate how they might differ in their decisions on the target emissions level and explicate any discrepancy (i.e. gap). Third, we characterize the parties' optimal level of contribution to green investment when each party can hold power with respect to target emission level and/or share of green investment. We finalize our analysis by discussing the implications of sharing the carbon tax burden on parties' emission target levels.

3.4.1 Parties' Optimal Emissions Target Decisions

3.4.1.1 LSP-Oriented Model (L)

In the LSP-oriented model (Figure 1), the LSP has the power to decide the target emissions level E. We analyze the two-stage sequential game backwards to derive the sub-game perfect equilibrium (P_l, E_l; P_s), the parties' profits ($\pi^*_{l_L}$, $\pi^*_{s_L}$), and characterize the LSP's optimal emission level, E^*_l.

- **LSP's Optimal Emission Level and Firm-Level Profits**

Lemma 3.1. *If* $(\gamma + \lambda C_T)^2 - 8\lambda C_e(1-\alpha) < 0$ *and* $E_0 < \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$*, then the LSP's profit-maximizing level of carbon emission is :*

- *if* $E_0 > \frac{(\gamma+\lambda C_T)(A-\lambda(C_l+C_s))}{8\lambda C_e(1-\alpha)}$ *then*

$$E^*_l = \frac{8\lambda C_e(1-\alpha)E_0 - (\gamma + \lambda C_T)(A - \lambda(C_l + C_s))}{8\lambda C_e(1-\alpha) - (\gamma + \lambda C_T)^2} \tag{3.5}$$

- *the firms' resulting profits in equilibrium are*

$$\left\{\pi^*_{l_L}, \pi^*_{s_L}\right\} = \left\{ \frac{C_e(1-\alpha)((\gamma+\lambda C_T)E_0 - (A-\lambda(C_l+C_s)))^2}{8\lambda C_e(1-\alpha) - (\gamma+\lambda C_T)^2}, \right. \left. \frac{C_e(4\lambda C_e(1+\alpha^2) - \alpha(8\lambda C_e + (\gamma+\lambda C_T)^2))((\gamma+\lambda C_T)E_0 - (A-\lambda(C_l+C_s)))^2}{(8\lambda C_e(1-\alpha) - (\gamma+\lambda C_T)^2)^2} \right\} \tag{3.6}$$

Note that if $E_0 \geq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$, then the LSP cannot make any profit at any level of E_l.

Proof: See Appendix A. □

The condition $(\gamma + \lambda C_T)^2 - 8\lambda C_e(1-\alpha) < 0$, or $C_T < \frac{2\sqrt{2\lambda C_e(1-\alpha)} - \gamma}{\lambda}$, ensures that the LSP's profit function is concave. Thus, the maximum regulatory pressure under which an LSP can operate profitably reflects the shipper's contribution $(1-\alpha)$ and consumer sensitivity with respect to retail price λ and carbon emission level γ. In addition (see Lemma 1 in Appendix), the requirement that the shipper has positive profit also constrains the LSP.

3.4.1.2 Shipper-Oriented Model (S)

In the shipper-oriented model, the shipper can decide the target emission level E. We analyze a two-stage sequential game backwards to derive the sub-game perfect equilibrium (P_l; P_s, E_s), the parties' profits ($\pi^*_{s_S}$, $\pi^*_{s_S}$), and characterize the shipper's optimal emission level E^*_s.

- **Shipper's Optimal Emission Level and Firm-Level Profits**

Lemma 3.2. *If* $\gamma^2 - 4\lambda C_e\alpha < 0$ *and* $E_0 < \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$, *then the shipper's profit-maximizing level of carbon emission is:*

- *if* $E_0 > \frac{\gamma\alpha(A-\lambda(C_l+C_s))}{8\lambda C_e\alpha^2+\gamma^2(1-2\alpha)-\lambda\gamma\alpha C_T}$ *then*

$$E_s^* = \frac{(8\lambda C_e\alpha^2 + \gamma^2\,(1-2\alpha) - \lambda\gamma\alpha C_T)E_0 - \gamma\alpha(A-\lambda(C_l + C_s))}{8\lambda C_e\alpha^2 + \ \gamma^2\,(1-3\alpha) - 2\alpha\lambda\gamma C_T} \tag{3.7}$$

- *the firms' resulting profits in equilibrium are*

$$\begin{aligned}\left\{\pi^*_{l_S}, \pi^*_{s_S}\right\} =& \Bigg\{ \frac{C_e\alpha^2((\gamma+\lambda C_T)E_0 - (A-\lambda(C_l + C_s)))^2}{8\lambda C_e\alpha^2 + \ \gamma^2\,(1-3\alpha) - 2\alpha\lambda\gamma C_T}, \\ & \frac{C_e\alpha^3(4\lambda C_e\alpha - \gamma^2)((\gamma+\lambda C_T)E_0 - (A-\lambda(C_l + C_s)))^2}{(8\lambda C_e\alpha^2 + \ \gamma^2\,(1-3\alpha) - 2\alpha\lambda\gamma C_T)^2} \Bigg\}\end{aligned} \tag{3.8}$$

Note that if $E_0 \geq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$, then the shipper cannot make any profit at any level of E_s.

Proof: See Appendix B. □

The condition $\gamma^2 - 4\lambda C_e\alpha < 0$, or $\alpha > \frac{\gamma^2}{4\lambda C_e}$, ensures that the shipper's profit function is concave. Thus, in the absence of consumer environmental pressure ($\gamma = 0$), the minimum required green investment by the shipper approaches zero, and the shipper has no economic incentive to invest in green logistics operations.

3.4.2 Matches and Gaps in the Parties' Emissions Target Decisions

By referring to the conditions we found for the parties' desired emission target decisions (Lemmas 1 and 2), we concentrate our analysis on conditions where optimal emission levels, E_l^* and E_s^*, are derived from (5) and (6) and both parties operate profitably: $\frac{\gamma^2}{4\lambda C_e} < \alpha < 1 - \frac{\gamma\left(\sqrt{\gamma^2+16\lambda C_e}-\gamma\right)}{8\lambda C_e}$ and $C_T < \min\{\frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha},\ \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}\}$.

In Figure 3, the "triangle" defines the boundary conditions[7] under which (5) and (6) apply and our analysis is feasible (i.e. Feasible Region). This triangle reappears in figures 5 and 6. Also note that, we search for situations where environmentally-friendly action is compatible with profit-seeking. In particular, we consider a range of initial carbon intensities, E_0, under which both parties have incentives to reduce pollution to an acceptable level (see Lemmas 1 and 2); We assume that consumer and regulatory pressures limit decisions to a range that allows companies to consider improving their environmental performance without risking their supply chain.

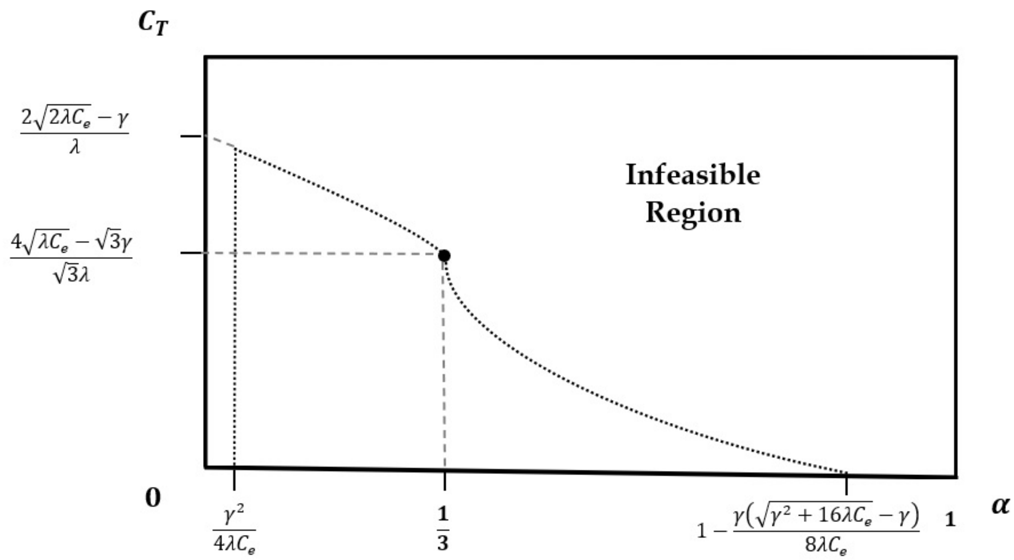

Figure 3.3: **Feasible Area**

By considering the impact of parties' power in emissions targeting decisions, we explicate the matches and gaps in the parties' desired environmental performance. In this way, we

[7]Concavity and positivity of profit functions are realized under both L and S models. Also note that $\gamma < \frac{2\sqrt{\lambda C_e}}{\sqrt{3}}$ is an implicit assumption for the feasible area to hold (see Appendix for more detail). Thus, the extent to which the consumer environmental consciousness increases, the more Feasible area tends to shrink with an increase in γ.

characterize the conditions that make $\Delta E = |E_s^* - E_l^*|$ either zero (matches) or positive (gaps).

3.4.2.1 Matches in the Parties' Emissions Target Decisions

Proposition 3.1. *Depending on shipper's level of green investment and consumer pressures, and independent of initial carbon intensity of logistics operations, the unique value of carbon tax that makes the environmental gap zero,* $\Delta E = |E_s^* - E_l^*| = 0$, *is given by*

$$\mathrm{C}_T(\alpha) = \begin{cases} C_{T_1} = \frac{8\lambda C_e \alpha - \gamma^2}{\lambda\gamma} & \text{if } \frac{\gamma^2}{4\lambda C_e} \leq \alpha \leq \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} \\ \\ C_{T_2} = \frac{\gamma(1-2\alpha)}{\lambda\alpha} & \text{if } \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} \leq \alpha \leq \frac{1}{2} \end{cases}$$

Proof: See Appendix C. $\square$

The proof considers the boundary conditions under which Lemmas 1 and 2 hold, and shows that

- For any value of C_T satisfying $\frac{\gamma}{\lambda} \leq C_T < \min\{\frac{\sqrt{\gamma^2+32\lambda C_e}-3\gamma}{2\lambda}, \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}\}$, there are two critical points for α, $\alpha_1 = \frac{\gamma^2+\lambda\gamma C_T}{8\lambda C_e}$ and $\alpha_2 = \frac{\gamma}{\lambda C_T + 2\gamma}$, at which the gap between the parties' desired environmental performance levels is zero. Note that $\frac{\gamma^2}{4\lambda C_e} < \alpha_1 \leq \alpha_2 \leq \frac{1}{3}$. Moreover, if $\alpha = \hat{\alpha} = \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$ then $\alpha_1 = \alpha_2$, $C_T = \frac{2\sqrt{2\lambda C_e(1-\hat{\alpha})}-\gamma}{\lambda} = \frac{\sqrt{\gamma^2+32\lambda C_e}-3\gamma}{2\lambda}$, and $E_l^* = E_s^*$.

- For any value of C_T satisfying $0 < C_T < \frac{\gamma}{\lambda}$, $\alpha_2 = \frac{\gamma}{\lambda C_T + 2\gamma}$ is the only feasible value for α that makes the environmental gap zero. Note that $\frac{1}{3} < \alpha_2 < \frac{1}{2}$.

- When $C_T = 0$, there is a unique value of the parties' respective green investment ($\alpha = 1 - \alpha = \frac{1}{2}$) at which their emission reduction targets match each other and the environmental gap is zero [8].

Figure 4 is a representation of Proposition 1, showing when the matches between the parties' desired environmental performance levels occur. The two heavy solid lines represent the points $(\alpha, C_T(\alpha))$ at which $E_s^* = E_l^*$ and the environmental gap is zero.

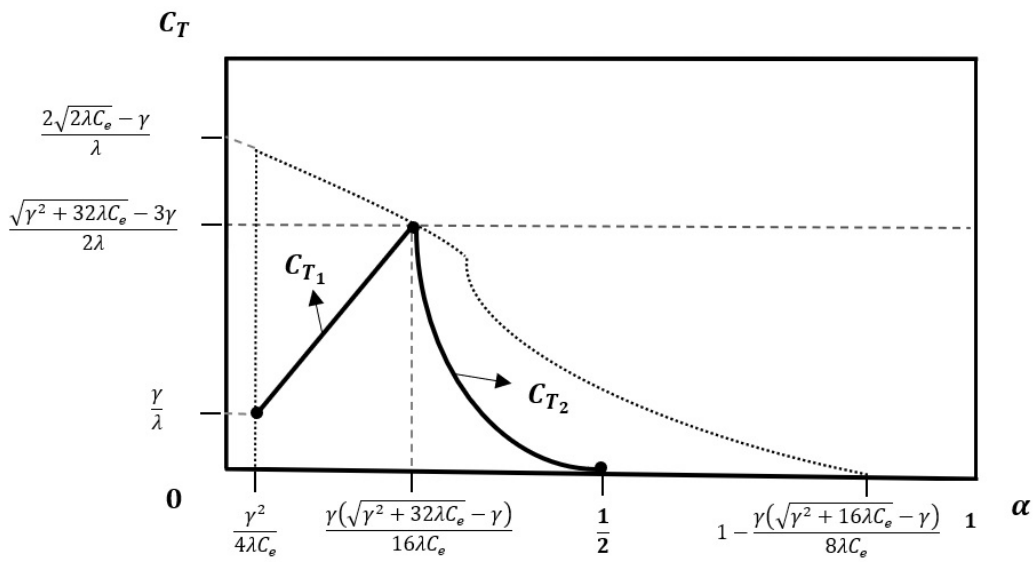

Figure 3.4: **Matches in parties' environmental performance levels**

Proposition 1 indicates that necessary conditions for the parties' optimal emission levels to match are $\alpha \leq \frac{1}{2}$ and $C_T \leq \min\{\frac{\sqrt{\gamma^2+32\lambda C_e}-3\gamma}{2\lambda}, \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}\}$. These conditions characterize the situations in which there is a balance between regulatory measures, consumer pressures, and the parties' relative share of green investment.

[8]The parties' emissions target levels match if and only if they share the green investment equally. This implies that a change in the consumer environmental consciousness does not affect (decrease or increase) the environmental gap as consumer pressure affects the parties' desired environmental performance equally.

Note that, when $\gamma \geq \frac{2\sqrt{\lambda C_e}}{\sqrt{3}}$ (i.e. consumer environmental pressure is sufficiently large), then matches points only occur at $C_{T_2} = \frac{\gamma(1-2\alpha)}{\lambda\alpha}$ where $\frac{1}{3} \leq \alpha \leq \frac{1}{2}$.

3.4.2.2 Gaps in the Parties' Emissions Target Decisions

Proposition 3.2. *The two parties' emission target levels are different, so the environmental gap within LSP-shipper interface is positive,* $\Delta E = |E_s^* - E_l^*| > 0$*,*

- when $\frac{\gamma^2}{4\lambda C_e} \leq \alpha < \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$,

$$\begin{cases} \text{If } C_T < \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma} & \text{, then } E_s^* < E_l^*. \\ \\ \text{If } \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma} < C_T < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} & \text{, then } E_s^* > E_l^* \end{cases}$$

- when $\frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} < \alpha \leq \frac{1}{3}$,

$$\begin{cases} \text{If } C_T < \frac{\gamma(1-2\alpha)}{\lambda\alpha} & \text{, then } E_s^* < E_l^*. \\ \\ \text{If } \frac{\gamma(1-2\alpha)}{\lambda\alpha} < C_T < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} & \text{, then } E_s^* > E_l^*. \end{cases}$$

- when $\frac{1}{3} \leq \alpha \leq 1 - \frac{\gamma\sqrt{\gamma^2+16\lambda C_e}-\gamma^2}{8\lambda C_e}$,

$$\begin{cases} \text{If } C_T < \frac{\gamma(1-2\alpha)}{\lambda\alpha} & \text{, then } E_s^* < E_l^*. \\ \\ \text{If } \frac{\gamma(1-2\alpha)}{\lambda\alpha} < C_T < \frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha} & \text{, then } E_s^* > E_l^*. \end{cases}$$

Proof: See Appendix D. □

Figure 5 is a representation of Proposition 2. For any point in the Feasible Region (Figure 3), it elucidates the gaps between the parties' desired environmental performance levels when leading the supply chain channel ($E_s^* \neq E_l^*$). Note that, when $\gamma \geq \frac{2\sqrt{\lambda C_e}}{\sqrt{3}}$, then the results hold where $\frac{1}{3} \leq \alpha \leq 1 - \frac{\gamma\sqrt{\gamma^2+16\lambda C_e}-\gamma^2}{8\lambda C_e}$.

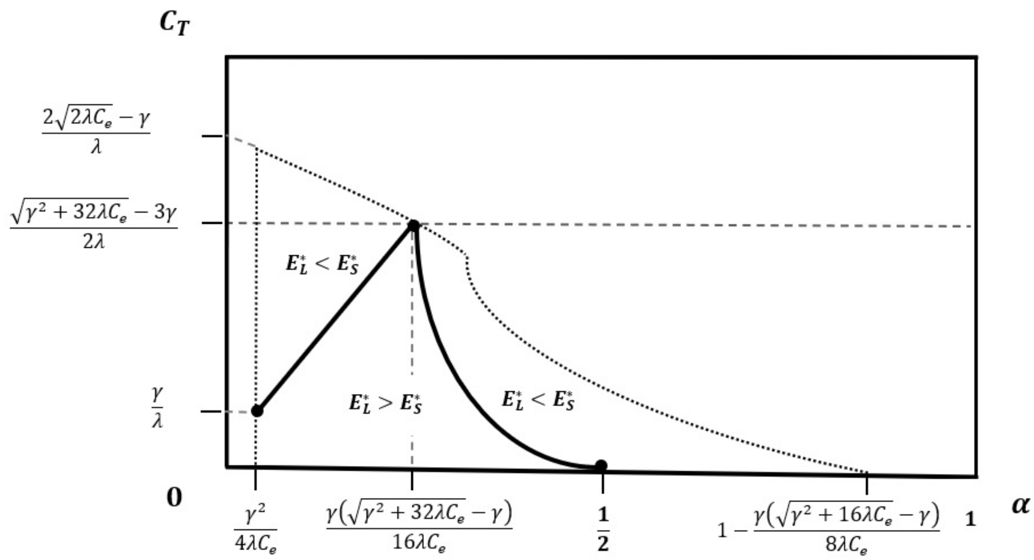

Figure 3.5: **Gaps in parties' environmental performance levels**

The areas defined by the heavy lines, the points at which the parties' desired environmental performance is matched ($E_s^* = E_l^*$), within the "triangle" (Feasible Region) represent the conditions under which the parties' desired environmental performances are different. The area bounded by heavy lines is where the ratio of carbon tax to shipper's share of green investment, $\frac{C_T}{\alpha}$, is moderate, and the shipper desires a lower emissions level than LSP when it is increasing its contribution to green investment. Otherwise, the interaction of above conditions will lead to one-way environmental ambition by either shipper or LSP, making it very unlikely that the parties will achieve a consensus regarding their emissions target levels in the supply chain [9].

Proposition 3.3. *The parties' optimal environmental targets change with respect to shipper's share of green investment as follows:*

1. *If (α, C_T) lies in the Feasible Region, then the LSP's desired environmental performance E_l^* is decreasing in shipper's proportion of green investment α.*

2. *There is a unique value of α, $\alpha = \frac{\gamma}{\sqrt{8\lambda C_e}} = \alpha'$, at which the shipper's desired environmental performance E_s^* is a minimum.*

Proof: See Appendix E. □

Proposition 3 (Part 1) illustrates that the higher the environmental ambition of the shipper for greening the logistics operation, the lower the LSP's target emission. In fact, the shipper's higher proportion of green investment attenuates the LSP's financial burden[10] for decreasing the emission level of the product. This result suggests a "hierarchical" relationship between LSPs and shippers (Wolf and Seuring, 2010) with the LSP's dependency being on the shipper's collaboration to reduce the ecological impacts of logistics (Sallnäs, 2016).

As Figure 5 demonstrates, and consistent with the insight brought by Proposition 3 (Part 1), when shipper's relative contribution for investment in green logistics is sufficiently high

[9] It is worth to mention that in the presence of governmental intervention ($C_T > 0$), the more sensitive the consumer to carbon emissions of product logistics (i.e. higher γ), the area where shipper is more environmentally ambitious than LSP (i.e. $E_s^* < E_l^*$) tends to increase in relative in size as γ increases: First, the shipper's minimum required investment to remain profitable is increasing in γ; Second, a part of the LSP's profit is spent on the penalty levied by government, reducing its ability to respond to consumer pressure, and thus the area under which the LPS operates profitably, shrinks with an increase in γ (See feasibility conditions provided in Figure 3).

[10] The financial burden of green logistics in the presence of consumer pressures is defined as the cost of additional investments incurred to green the operations, plus any penalty levied by regulatory agencies for not improving environmental performance.

(in the *right*-hand area of the "triangle", where $\alpha > \alpha_2$), the LSP always seeks a lower emissions level than the shipper for any value of carbon tax. This is reasonable in the sense that the major proportion of green investment is on shipper's side, and thus the LSP will better off if it asks for a lower target emission level and pays less penalty, and thus achieving a higher revenue. However, this is achievable if and only if the LSP is capable of conducting environmentally friendly practices and has no incentive for opportunistic behavior in lowering the carbon intensity of logistics operations. Nonetheless, the literature suggests that, in the real world, one-way environmental ambition of the shipper might risk the shipper switching LSP (Sallnäs, 2016), unless switching costs are very high.

On the other hand, when the shipper's relative portion of green investment is low enough ($\alpha < \hat{\alpha}$), there is a threshold level of carbon tax, $C_T > C_{T_1}$, at which the LSP starts to target lower emissions level in response to higher regulatory measures (the upper *left* area of the "triangle"), regardless of the shipper's share of green investment. Thus, any gap resulting from an LSP's over-achievement may be a proactive response to, or in anticipation of, more stringent environmental regulatory measures (Martinsen and Bjorklund, 2012). The result is also consistent with the suggestion of McKinnon and Piecyk (2012) that regardless of their customers' environmental ambition, many of world's top LSPs have announced ambitious targets to mitigate the carbon intensity of their operations.

Proposition 3 (Part 2) shows that the higher the proportion of shipper's contribution to sustainability of the logistics operation, the lower the emission target it seeks in the supply chain channel it leads. However, there is a threshold for α, α', at which the shipper's optimal emission level is a minimum; any higher proportion of green investment beyond that threshold will reduce the target environmental performance (i.e. raise the optimal emission level).

The minimum emissions target at $\alpha = \frac{\gamma}{\sqrt{8\lambda C_e}}$ reflects the interaction of consumer sensitivity to carbon emission and product price. Thus, even at the maximum possible level of consumer environmental pressure at the final market, the shipper's benefit from investing more in green logistics beyond the threshold α' does not compensate for the increase in green investment cost. The shipper's behavior is truly reflected in Figure 5, where the shipper targets a lower emission level - in the *middle* area of the "triangle" bounded by heavy lines. Our result can explain when lack of effort on the part of an agent (the LSP) affects the principal's (shipper's) goals and objectives (i.e. target emission level).

3.4.3 Parties' Contribution to Green Logistics Investment

In section 3.4.2 we discussed how the parties' power with respect to target environmental level E can affect the joint environmental decision, assuming cost-sharing parameter α is exogenous, and that preexisting relationships or channel power form the basis of cost-sharing between the firms (i.e. LSP or shipper-oriented model). In this section we aim to demonstrate that how the parties differ in their preferences about sharing the costs of green initiatives under each model. In particular, we characterize the optimal proportion of the green logistics operations under each model, when either the LSP, the shipper, or negotiation between them determine how to share green investment costs.

3.4.3.1 LSP's Optimal Contribution to Green Logistics Investment

We first characterize the LSP's optimal level of contribution to green investment when either LSP or shipper decides the joint target emission level.

Proposition 3.4. *The LSP's optimal level of contribution to green logistics operations is as follows:*

1. *When the LSP makes the joint environmental decision, its profit is strictly increasing in α, so its optimal proportion of contribution to green investment costs is zero (i.e. $\alpha^*_{l_L} = 1$).*
2. *When the shipper makes the joint environmental decision, the LSP's optimal share of green investment cost is $1 - \frac{2\gamma}{3\gamma+2\lambda C_T} = 1 - \alpha^*_{l_S}$.*

Proof: See Appendix F. □

The results from Proposition 4 (Part 1) are in line with Proposition 3 (Part 1) and implies that the LSP benefits from shipper's contribution to green investment when the LSP has power over joint environmental decision. In other words, the greater the shipper's contribution to green investment, the lower the LSP's target emission level, the lower the carbon tax, and the higher the profit for the LSP. Thus the LSP's profit is maximized at $\alpha^*_{l_L} = 1$ and the LSP has no incentive to bear any fraction of green investment costs. Also, the results from Proposition 4 (Part 2) are aligned with Proposition 3 (Part 2). When the shipper has the power to make the joint environmental decision, the LSP benefits from shipper's contribution only up $\alpha^*_{l_S} = \frac{2\gamma}{3\gamma+2\lambda C_T}$, increasing its portion of green investment cause the shipper to target a higher emission level. The threshold defined in Part 2 is decreasing in regulatory measures but increasing in consumer pressures implying that the LSP must take greater responsibility for greening logistics in the presence of more stringent regulatory forces forces, incentivizing the shipper to target a better environmental performance. Thus, in the presence of stronger consumer pressures, the LSP is less motivated to contribute in green investment and tends to shift a greater proportion of investment costs to shipper.

3.4.3.2 Shipper's Optimal Contribution to Green Logistics Investment

We now analyze the shipper's optimal level of contribution to a green logistics operation when either LSP or shipper decides about the joint target emission level.

Proposition 3.5. *The shipper's optimal level of contribution to green logistics operations is as follows:*

1. *When the LSP makes the joint environmental decision, the shipper's optimal fraction of green investment is* $\alpha = \frac{(\gamma+\lambda C_T)^2}{16\lambda C_e} = \alpha^*_{s_L} \leq \frac{1}{3}$.

2. *When the shipper makes the joint environmental decision, there is a unique optimal value of* $\alpha = \alpha^*_{s_S}$. *Then it follows that* $\alpha^*_{s_L} = \alpha^*_{s_S}$ *if and only if* $C_e = \frac{(\gamma+\lambda C_T)^2(2\gamma+\lambda C_T)\left((\lambda C_T)^2+\lambda\gamma C_T-\gamma^2\right)}{16\lambda\gamma\left((\lambda C_T)^2+2(\lambda\gamma C_T-\gamma^2)\right)} = \widehat{C_e}$, *and* $\alpha^*_{s_S} > \alpha^*_{s_L}$ *if and only if* $C_e > \widehat{C_e}$.

Proof: See Appendix G. □

The results from Proposition 5 (Part 1) imply that when the LSP holds the channel power with respect to target emission level (i.e. LSP-oriented model), co-investment in green logistics benefits the shipper by providing an incentive to the LSP to reduce the product logistics emission (see Proposition 3, Part 1). This in turn results in less carbon tax for the LSP and higher revenue from market expansion for the supply chain. Thus, the marginal benefit of collaboration in green logistics investment increases in the values of carbon tax, C_T, and consumer sensitivity to environmental impacts of product logistics, γ, but decreases in the logistics emissions reduction cost, C_e. Nevertheless, the shipper's optimal value of green investment is at most $\frac{1}{3}$ ($\alpha^*_{s_L} \leq \frac{1}{3}$); any share of investment beyond that will make the shipper worse off.

On the other hand (Part 2), when the shipper holds the channel power with respect to target emission level (i.e. shipper-oriented model), the shipper is motivated to co-finance the LSP in logistics emission reduction and ask for a greener logistics operation with lower emission level (see Proposition 3, Part 2) because, by sharing a portion of the green investment, the shipper can reduce the LSP's financial burden to conform to the shipper's target emission level. This in turn results in lower shipping cost and higher revenue from increased demand in the market. In particular, when the shipper sets the environmental target (i.e. shipper-oriented model), the shipper's contribution to green investment is greater ($\alpha^*_{s_S} > \alpha^*_{s_L}$) provided the investment coefficient is sufficiently large ($C_e > \widehat{C_e}$). In other words, when the logistics emission reduction cost C_e is large enough, the shipper is more willing to bear a larger share of green investment than when the LSP makes the joint environmental decision. This suggests that the more control the shipper has over the environmental performance of logistics, the more incentive it has to invest in green logistics initiatives.

Propositions 4 and 5 support the conclusions of previous empirical studies that even though the LSP is the party responsible for the green initiative, a shipper with a high level of environmental ambition must rely on the LSP's contribution; environmentally adapted supply chains require cooperation (in the distribution of green investment) between an environmentally aware supplier (LSP) and a focal company (shipper) (Seuring and Müller (2008);

Lun et al., 2015; Sallnäs, 2016). We look at the negotiation of the parties in distribution of green investment in the presence of parties' conflict over target emission level:

3.4.3.3 Bargaining of Parties over Distribution of Green Logistics Investment

Proposition 3.6. *The solution of the parties' Nash Bargaining problem over distribution of green investment costs is* [11]*:*

1. *When the LSP makes the joint environmental decision, the shipper's optimal fraction of green investment in the parties' Nash Bargaining solution is* $\alpha^*_{n_L}$ *where* $\alpha^*_{s_L} < \alpha^*_{n_L} < \alpha^*_{l_L} = 1$ *if* $C_e > \frac{3(\gamma+\lambda C_T)^2}{16\lambda} = \acute{C}_e$*, and* $\alpha^*_{n_L} < \alpha^*_{s_L} < \alpha^*_{l_L} = 1$ *if* $C_e < \acute{C}_e$*.*

2. *When the shipper makes the joint environmental decision, the shipper's optimal fraction of green investment in the parties' Nash Bargaining solution is* $\alpha^*_{n_S}$ *where* $\alpha^*_{l_S} < \alpha^*_{n_S} < \alpha^*_{s_S}$ *if* $C_e > \frac{(3\gamma+2\lambda C_T)^2}{32\lambda} = \grave{C}_e$*, and* $\alpha^*_{s_S} < \alpha^*_{n_S} < \alpha^*_{l_S}$ *if* $C_e < \grave{C}_e$*.*

Proof: See Appendix H. □

Table 3 summarizes the results of Propositions 4–6. It shows the shipper's share of green investment when the LSP, the shipper, or negotiation between the two determines the parties' contribution to green investment, under both LSP- and shipper-oriented models. In particular, the table illustrates how the share of green investment under Nash Bargaining (Proposition 6) is positioned relative to the shares resulting when the LSP or shipper determines the share of green logistics investment (Propositions 4 and 5).

[11] In order to ensure the existence, uniqueness, and stability of the equilibrium decisions on how the parties should share the green investment cost, it is assumed that $\gamma < \lambda C_T$. This is realized when we assume that the consumer is less sensitive to environmental impacts of product than its retail price (i.e. $\gamma < \lambda$) and carbon tax is large enough ($C_T \geq 1$).

Table 3.3: **Shipper's Share of Green Investment Cost** (α)

		Who determines α?		
		LSP (l)	**Shipper (s)**	**Negotiation (n)**
Who determines E?	**LSP (L)**	$\alpha^*_{l_L} = 1$	$\alpha^*_{s_L} = \frac{(\gamma+\lambda C_T)^2}{16\lambda C_e}$	When $C_e > \acute{C}_e$: $\alpha^*_{s_L} < \alpha^*_{n_L} < \alpha^*_{l_L}$ When $C_e < \acute{C}_e$: $\alpha^*_{n_L} < \alpha^*_{s_L} < \alpha^*_{l_L}$
	Shipper (S)	$\alpha^*_{l_S} = \frac{2\gamma}{3\gamma+2\lambda C_T}$	When $C_e > \widehat{C_e}$: $\alpha^*_{s_S} > \alpha^*_{s_L}$ When $C_e < \widehat{C_e}$: $\alpha^*_{s_S} < \alpha^*_{s_L}$	When $C_e > \grave{C}_e$: $\alpha^*_{l_S} < \alpha^*_{n_S} < \alpha^*_{s_S}$ When $C_e < \grave{C}_e$: $\alpha^*_{s_S} < \alpha^*_{n_S} < \alpha^*_{l_S}$

Note. Table 3 is a reproduction of Table 2 in Section 3.3.4.

The results of Proposition 6 concern the Nash Bargaining predictions of results of negotiation over the parties' contributions to green investment costs. In particular (Part 1), when the LSP makes the joint environmental decision and the green investment cost is large ($C_e > \acute{C}_e$), the shipper is less motivated to co-finance logistics emission reduction (see Proposition 5, Part 1). Thus the parties end up at a level between their optimal contributions to green investment, representing a balance between their low incentives to improve the environmental impact of logistics in the absence of bargaining. However, when green investment cost is relatively low ($C_e < \acute{C}_e$), the shipper has more incentive to co-invest in green logistics (see Proposition 5, Part 1) beyond what the parties may agree on through bargaining, making bargaining a less attractive option from the LSP's perspective.

The results of Proposition 6 (Part 2) indicate that when the shipper makes the joint environmental decision, Nash Bargaining allows the parties to reach a consensus on sharing green investment that lies between what the shipper itself and the LSP desires him/her to contribute to green investment. In particular, when green investment cost is sufficiently large ($C_e > \grave{C}_e$), the LSP imposes less responsibility on the shipper's side, allowing the party to target a lower emission level (see Proposition 4, Part 2). On the other hand, when green investment cost is relatively low ($C_e < \grave{C}_e$), the shipper contributes less to green investment than what the LSP wants. In other words, as green investment cost increases, the shipper tends to increase its contribution relative to what the LSP wants.

Note that both thresholds defined for green investment cost in Proposition 6 (Part 1; $\acute{C}_e$ and 2; $\grave{C}_e$) increases in level of carbon tax, C_T, and in consumer sensitivity with respect to environmental impacts of product logistics, γ, but decrease in consumer sensitivity to product retail price, λ. This suggests that when the LSP makes the joint environmental decision (Part 1), and the consumer sensitivity with respect to environmental impacts or stringency of regulations increases, it is less probable that bargaining creates a balance between the parties' low incentives to improve the environmental impacts of logistics. Shipper has more incentive to invest in green logistics, incentivizing the LSP to target better environmental performance and thus realize more benefits for both sides at the final market (Proposition 5, Part 1). However, when the shipper makes the joint environmental decision, the more environmentally conscious the consumers, or the greater the penalty on environmental impacts of product logistics, the more probable it is that the shipper will contribute less, making bargaining a more attractive option from the LSP's perspective.

3.4.4 Carbon Tax Distribution and Parties' Emissions Targeting Decisions

The general dependency of LSPs on shippers that we identified in Proposition 3 appears to negatively influence environmental performance in the LSP-shipper interface, in that the shipper is the party who initiates the request for the green logistics service and sets the conditions for the inclusion of environmental practices. In our model we specify that the LSP is the party responsible for penalty, but assigning a portion of carbon tax to shipper might be an effective way to increase the dependency of shipper on the LSP in the management of environmental issues. Here we examine how the parties' desired environmental performance might change with the distribution of a proportion β is to paid by the shipper. In particular, we examine the conditions that this structure might increase shipper's commitment to more sustainable logistics operations.

Proposition 3.7. *When a proportion of carbon tax β is imposed on the shipper:*

1. *The LSP's desired environmental performance $E_l'^*$ remains unchanged: $E_l'^* = E_l^*$.*

2. *The shipper's desired environmental performance $E_s'^*$ changes as follows:*

- *if $\frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} < \alpha \leq \frac{1}{3}$, $E_s'^*$ is minimized at $\beta = \beta' = \frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)}$.*
- *if $\frac{1}{3} < \alpha \leq \frac{1}{2}$, then the minimum value of $E_s'^*$ occurs at $\beta = \bar{\beta} = \frac{2\sqrt{\lambda C_e \alpha}-\gamma}{\lambda C_T}$.*

Proof: See Appendix I. □

Note that $\beta < \bar{\beta}$ ensures the concavity of shipper's profit function under the carbon tax distribution scenario. Also note that $\beta' < \bar{\beta}$ if and only if $\alpha < \frac{1}{3}$.

Proposition 7 (Part 1) indicates that transferring a proportion of carbon tax from the LSP to the shipper does not affect the LSP's target environmental performance. We can explain the LSP's behavior by analyzing the implication of reducing the LSP's financial burden from the carbon tax by referring to the setting explained in (4.1.1). First, the shipper's reaction (i.e. best response) to a carbon tax is to increase the product price by $\frac{\beta C_T E}{2}$ where the target emission level E is determined by LSP. The shipper's decision is then followed by the LSP's decision to reduce the logistics service price by $\beta C_T E$. These decisions create two balancing effects: (1) the LSP's revenue increases because the carbon tax is now shared; and (2) the LSP's revenue decreases because the increased product retail price reduces demand. In equilibrium, the optimal product retail price and demand, and the LSP's revenue remain constant, as the shipper's initial reaction to increase the product price will be offset by the lower logistics service price offered by the LSP, so the LSP's optimal emission level remains unchanged. As a result, the LSP's optimal emission target level will fall to exactly the level we found in Lemma 1.

Proposition 7 (Part 2) shows that under certain conditions, shifting a proportion of the carbon tax from the LSP to the shipper will result in higher level of shipper's investment in green logistics operations, and thus a lower target emission level. However, there is a threshold for β at which the shipper achieves the minimum possible emission level; imposing a higher proportion of carbon tax will increase the level of emissions in the supply chain. Indeed, when the proportion of carbon tax surpasses a specific threshold, $\beta > \beta'$, the shipper's profit will decrease, so that it has less to invest in decreasing the emission level. The result is an increase in the optimal value for target emission level.

Proposition 7 has several important implications. First, it shows that when shipper's proportion of green investment is relatively low ($\alpha \leq \frac{1}{3}$), shifting a proportion of carbon tax, β', to the shipper will result in the maximum possible emission reduction in the supply chain. However, when shipper 's involvement in green investment is sufficiently high ($\frac{1}{3} < \alpha \leq \frac{1}{2}$), the maximum possible reduction in emissions level is achieved with a lower proportion of carbon tax, $\bar{\beta}$, imposed on the shipper. This is particularly important as shippers are generally recognized to be the party that makes the joint environmental decision, positioning the LSP as "henchman"; as suggested by Wolf and Seuring (2010). Second, given the conditions we derived in Proposition 2, when $\alpha < \hat{\alpha}$ and $\frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma} < C_T < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}$ (this area corresponds to the top *left* of "triangle" in Figure 5, where $E_l^* < E_s^*$), and the results of Proposition 7, show that when a portion of the carbon tax is imposed on the shipper, the environmental gap is reduced and the carbon intensity of product logistics is lower. In other words, imposing a portion of carbon tax ($\beta < \beta'$) on the shipper causes the shipper to invest more and reduce its target emission level. As a result, the environmental gap is reduced and the parties are better aligned for managing environmental issues.

3.5 Concluding Remarks

Given the carbon intensity of logistics operations, LSPs and shippers are currently under more scrutiny, both from the consumer and government side, to reduce the externalities of their operations. Nevertheless, the debate about who will ultimately be responsible to pay for green initiatives leads to controversy between logistics companies and their customers. This is consistent with the argument that, in a decentralized supply chain setting, the leader, the agent who holds the power to determine joint environmental performance, will not necessarily make decisions that benefit the follower.

Notwithstanding the importance of a supplier's environmental performance to customers, little attention has been paid to inclusion of suppliers of transportation and logistics into the supply chain decision-making process with respect to environmental performance. Our economic analysis is an early attempt to analyze quantitatively the interface between a LSP and a shipper from an environmental perspective. We first demonstrate how the parties' actions in support of a target level of environmental performance might differ, depending on who holds the power over joint environmental decision of the product logistics in the supply chain. By considering the parties' emissions target decisions in a decentralized setting as a possible disagreement point, We explicitly identify the matches and gaps between the parties' desired environmental performance levels.

We characterize the conditions at which the parties agree on a common target emission level which makes the environmental gap zero. These match points represent conditions under which consumers' environmental pressure, policy measures, and the parties' relative levels of investment in greening product logistics are in equilibrium. We show that, in the absence of regulatory measures, a change in the consumer environmental pressure would not diminish the gap, so that the parties can reach consensus with respect to target emission level when they share green investment equitably. In the presence of a carbon tax, the more environmentally conscious the consumers, the more probable it is that the shipper aims for better environmental performance. Indeed, increasing consumer environmental pressure will push both parties to reduce their target emission levels equivalently. In this case, however, part of the LSP's profit is spent on paying the carbon tax, so that the LSP's response to consumer pressures is weaker than the shipper's. When policy measures are sufficiently strong, the LSP always seek a lower emission level regardless of the shipper's level of investment in green logistics. On the other hand, when regulatory measures are moderate, the shipper starts to target a lower emission level as it increases its level of contribution to green investment. However, if the shipper's share of investment is relatively high, the LSP will benefit, in a way that targets a lower emission level than shipper.

We also evaluate the parties' emissions targets when the shipper's involvement in green logistics increases. We illustrate that the higher the willingness of the shipper for investment in green logistics, the lower the target emission of the LSP. These findings support the view that LSPs depend on shippers for inclusion of green elements into logistics operations. The shipper with a higher level of responsibility for green investment seeks better environmental performance, but only up to the point where the shipper's benefit from market expansion compensates it for the increasing cost of greener logistics operations; the additional cost is offset by the benefit achieved at the final market. This implies that an environmentally adapted supply chain can be realized only if the two parties' contributions are shared fairly.

We characterize each party's optimal contribution to green investment, which maybe determined by either party, or by negotiation. When the LSP makes the joint environmental decision and the green investment cost is sufficiently large, the shipper is less motivated to co-finance logistics emission reduction. Thus, the parties end up at an equilibrium between their optimal contribution to green investment, representing a balance between the parties' low incentives to improve the environmental impact of logistics in the absence of bargaining. However, when green investment cost is relatively low, the shipper has more incentive to co-invest in green logistics beyond what the parties can agree on through bargaining, so making bargaining less attractive option from the LSP's perspective. On the other hand, when the shipper makes the joint environmental decision, negotiation through Nash Bargaining allows the parties to reach a consensus, with respect to share of green investment, that lies between what the shipper and the LSP desires him/her to contribute to green investment. When green investment cost is sufficiently large, the LSP imposes less responsibility on the shipper's side, allowing the party to target a lower emission level. However, when green investment cost is relatively low, the shipper contributes less to green investment than what the LSP wants.

Finally, we examine the implications on emission target decisions of sharing carbon tax across the two parties. We show that when a portion of carbon tax is imposed on the shipper, the LSP's desired emission target remains unchanged. We argue that the the shipper's desire to increase the product price is offset by the LSP's decision to reduce logistic price in the presence of a carbon tax distribution. Under this condition, the shipper increases its green investment to reach a lower target emission level. This implies that distribution of carbon tax between the two parties can cause the environmental gap to decrease.

As observed frequently in the current literature, environmental practice in an LSP-shipper interface often gives rise to disagreement, when the shipper is the party who holds power over environmental performance of the logistics service. In future research, our main focus will be to characterize the conditions under which the parties' emissions target decisions in a decentralized setting approach the environmental goals, that would ideally be achieved in a centralized setting. In particular, by considering the parties' emissions target decisions in a decentralized setting as a possible *disagreement point*, we are working to develop a collaborative *gain-sharing* or cost-sharing mechanism to allow parties to reduce the environmental gap in the LSP-shipper interface, showing when and how the parties can achieve their joint environmental targets while improving their financial performance.

3.6 Appendix

3.6.1 Appendix A. Proof of Lemma 1

We analyze the two-stage sequential game backwards to derive the sub-game perfect equilibrium. In the second stage, the shipper (follower) decides the optimal product price P_s^* to maximize its profit. Consider the shipper's payoff function in (4), $\pi_s(P_s, E) = D(P_s, E)(P_s - C_s - P_l) - \alpha C_e(E_0 - E)^2$, and take the first derivative with respect to price, and solve for P_s, We obtain P_s^*: $\frac{\partial \pi_S(P_s,E)}{\partial P} = 0 \Leftrightarrow P_s^*(P_l, E) = \frac{A-\gamma E}{2\lambda} + \frac{1}{2}(C_s + P_l)$. The second derivative is $-2b < 0$ and therefore the optimal price is a maximum. Consider the LSP's payoff function defined in (3), $\pi_l(P_l, E) = D(P_s, E)(P_l - C_l - C_T E) - (1-\alpha)C_e(E_0 - E)^2$. Anticipating the shipper's best response for product retail price, in the first stage the LSP (leader) sets the logistics service price P_l^* and the desired emission reduction target E_l^* to maximize its profit. Taking the first derivative of the LSP profit with respect to logistics service price and solving for P_l, we obtain $P_l{}^*$:$\frac{\partial \pi_l(P,E)}{\partial P} = 0 \Leftrightarrow P_l^*(E) = \frac{A-\gamma E}{2\lambda} + \frac{1}{2}(C_l - C_s + C_T E)$. The second derivative is $-2b < 0$ and therefore the optimal price is a maximum. By substituting $P_l{}^*$ into the LSP's payoff function for P_l and simplifying we can rewrite $\pi_l(P_l, E)$ as $\pi_l(E) = \frac{1}{8\lambda}(A - (\gamma E + \lambda(C_l + C_s C_T E)))^2 - (1-\alpha)C_e(E_0 - E)^2$ where the demand function is $D(E) = \frac{1}{4}(A - (\gamma\ E + \lambda(C_l + C_s + C_T E)))$. Taking the first derivative of $\pi_l(E)$ with respect to emission level and solving for E, we obtain E_l^*: $\frac{\partial \pi_l(E)}{\partial E} = 0 \Leftrightarrow E_l^* = \frac{8\lambda C_e\left(1-\alpha\right)E_0 - (\gamma + \lambda C_T)(A - \lambda(C_l + C_s))}{8\lambda C_e(1-\alpha) - (\gamma + \lambda C_T)^2}$. Taking the second derivative, we have $\frac{\partial^2 \pi_l(E)}{\partial E^2} = \frac{1}{4\lambda}((\gamma + \lambda C_T)^2 - 8\lambda\, C_e(1-\alpha))$. In case $(\gamma + \lambda C_T)^2 - 8\lambda\, C_e(1-\alpha) < 0$ (second derivative negative) $E_l{}^*$ is a maximum. Solving for inequality we get our boundary condition for C_T: $C_T < \frac{2\sqrt{2\lambda C_e(1-\alpha)} - \gamma}{\lambda}$. By taking the boundary condition $0 < E_l{}^* \leq E_0$ into account, the inequality $\frac{(\gamma+\lambda C_T\ \ )(A-\lambda(C_l+C_s))}{8\lambda C_e(1-\alpha)} <\ E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ must be true, and we obtain the lower and upper boundaries for ${E_l}^*$. Also note that $(\gamma+\lambda C_T\ \ )^2 - 8\lambda\ C_e\,(1-\alpha) < 0 \Leftrightarrow \frac{(\gamma+\lambda C_T\ \ )(A-\lambda(C_l+C_s))}{8\lambda C_e(1-\alpha)} < \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$. Thus, ${E_l}^* = 0\ \Leftrightarrow\ E_0 \leq \frac{(\gamma+\lambda C_T\ \ )(A-\lambda(C_l+C_s))}{8\lambda C_e(1-\alpha)}$. Also, for the case $E_0 > \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$, the maximum profit for the LSP is achieved when $E = E_0$. However, when $E = E_0$, $\pi_l\ \geq 0 \Leftrightarrow\ E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$; otherwise demand and thus profit would be negative. In particular, When $E = E_0$, $D = \frac{1}{4}(A - (\gamma\ E + \lambda\,(C_l + C_s + C_T E_0))) \geq 0$, implying $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$. Therefore, when $E_0 \geq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ then $\pi_l \leq 0$. We thus obtain the optimality conditions for ${E_l}^*$ as stated in Lemma 1. Moreover, the parties' profits in equilibrium are defined as follows: $\pi^*_{l_L} = \frac{C_e(1-\alpha)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{8\lambda C_e(1-\alpha)-(\gamma+\lambda C_T)^2}$ and $\pi^*_{s_L} = \frac{C_e\left(4\lambda C_e\left(1+\alpha^2\right)-\alpha(8\lambda C_e+(\gamma+\lambda C_T)^2)\right)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{\left(8\lambda C_e(1-\alpha)-(\gamma+\lambda C_T)^2\right)^2}$. Note that the LSP's profit is always positive given the condition defined for concavity of the LSP's profit function. The shipper's profit is always positive when $4\lambda C_e\,(1+\alpha^2) - \alpha(8\lambda C_e + (\gamma+\lambda C_T)^2) > 0$. Solving for inequality we get our boundary condition for C_T: $C_T < \frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha}$ ■.

3.6.2 Appendix B. Proof of Lemma 2

We analyze a two-stage sequential game to derive the sub-game perfect equilibrium. In the second stage, the shipper (follower) decides retail price P^*_s and desired emission reduction target E^*_s to maximize its profit for any logistics service price P_l offered by LSP. Consider the shipper's profit in (4), $\pi_s\,(P_s, E) = D\,(P_s - C_s - P_l) - \alpha C_e\,(E_0\ - E)^2$. Take the first derivative of the profit with respect to price and solve for P_s; we obtain P^*_s: $\frac{\partial \pi_s(P_s,E)}{\partial P} = 0 \Leftrightarrow\ P^*_s\,(P_l, E) = \frac{A-\gamma E}{2\lambda} + \frac{1}{2}\,(C_s + P_l)$. The second derivative is $-2b < 0$ and therefore the optimal price is a maximum. By substituting P^*_s into the shipper's payoff function for P_s and simplifying we can rewrite $\pi_s\,(E)$ as $\pi_s\,(E) = \frac{1}{4\lambda}\,(A - (\gamma E + \lambda(C_s + P_l)))^2 -$

$\alpha\, C_e\,(E_0 - E)^2$ where the demand function is $D\left(P_l\,, E\right) = \frac{1}{2}(A - (\gamma\; E + \lambda\,(C_s + P_l)))$. Take the first derivative of $\pi_s\,(E)$ with respect to emission level and solve for E, obtaining $E_s{}^*$:$\frac{\partial \pi_s(E)}{\partial E} = 0 \Leftrightarrow E_s{}^*\,(P_l) = \frac{4\lambda C_e \alpha E_0 - \gamma(A-\ \lambda(C_s+P_l))}{4\lambda C_e\alpha - \gamma^2}$. Taking the second derivative, we have $\frac{\partial^2 \pi_s(E)}{\partial E^2} = \frac{1}{2\lambda}(\gamma^2 - 4\lambda\; C_e\alpha)$. In case $\gamma^2 - 4\lambda\; C_e\alpha < 0$ (second derivative negative) $E_s{}^*$ is a maximum. Solving for inequality we get our boundary condition for α: $\alpha > \frac{\gamma^2}{4\lambda C_e}$. In the second stage, the LSP (leader) sets the logistics service price P_l^* to maximize its profit. The shipper's optimal emission level, $E_s^*(P_l)$, is dependent on the LSP's optimal price that is calculated based on shipper's decision on its' price and emission level. Thus, $P_l^* = \frac{\partial \pi_l(P_s^*, E_s{}^*)}{\partial P_l} = \frac{\left(\gamma^2(\gamma(1-2\alpha)-\lambda\alpha C_T)-4\lambda C_e\alpha^2(\lambda C_T-\gamma)\right)E_0+\left(2\lambda\left(\gamma\alpha C_T-2C_e\alpha^2\right)-\gamma^2(1-2\alpha)\right)(A-\lambda C_s)+C_l\left(\lambda\alpha\gamma^2-4\lambda^2C_e\alpha^2\right)}{\lambda(2\alpha\lambda\gamma C_T-8\lambda C_e\alpha^2-\gamma^2(1-3\alpha))}$. The second derivative $\frac{-2\lambda^2 C_e(8\lambda\; C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma\; C_T)}{(\gamma^2-4\lambda C_e\alpha)^2}$, is negative when $8\lambda C_e\alpha^2 +\ \gamma^2\,(1-3\alpha) - 2\alpha\lambda\gamma C_T$ is positive or $C_T < \frac{8\lambda C_e\alpha^2+\gamma^2(1-3\alpha)}{2\lambda\gamma\alpha}$. In order for P_l^* to be valid, we must have $C_T < \frac{8\lambda C_e\alpha^2+\gamma^2(1-3\alpha)}{2\lambda\gamma\alpha}$ and $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ which result in positive demand, positive revenue per unit of demand, and positive profit for the LSP[12]. Also note that the positive revenue per unit of demand implies the positivity of P_l^* as well. Substituting the LSP's optimal price into the shipper's optimal emission level defined in the first stage, we have $E_s^* = \frac{(8\lambda C_e\alpha^2+\gamma^2(1-2\alpha)-\lambda\gamma\alpha C_T)E_0-\gamma\alpha(A-\lambda(C_l+C_s))}{8\lambda C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma C_T}$. Now consider the boundary condition for concavity of LSP's profit function, $C_T\ \ < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}$. Because $\frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} \leq \frac{8\lambda C_e\alpha^2+\gamma^2(1-3\alpha)}{2\lambda\gamma\alpha}$ always holds when $0 \leq \alpha \leq 1$; it follow that, within the boundary defined for carbon tax, $8\lambda C_e\alpha^2 +\ \gamma^2\,(1-3\alpha) - 2\alpha\lambda\gamma C_T$ is always positive. By taking the boundary condition $0 < E_s{}^* \leq\ E_0$ into account, the inequality $\frac{\gamma\alpha(A-\lambda(C_l+C_s))}{8\lambda C_e\alpha^2+\gamma^2(1-2\alpha)-\lambda\gamma\alpha C_T} <\ E_0 \leq \frac{A-\ \lambda(C_l+C_s)}{\gamma+\lambda C_T}$

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[12] By considering the boundary conditions under which our analysis in Lemma 2 holds we have: $D = \frac{2\lambda C_e\alpha^2((\gamma+\lambda C_T)E_0-\left(A-\lambda(C_l+C_s)\right))}{(2\alpha\lambda\gamma C_T-8\lambda C_e\alpha^2-\gamma^2(1-3\alpha))}$, $(P_l - C_l - C_T E) = -\frac{(\alpha\lambda\gamma C_T-4\lambda C_e\alpha^2-\gamma^2(1-2\alpha))((\gamma+\lambda C_T)E_0-\left(A-\lambda(C_l+C_s)\right))}{(2\alpha\lambda\gamma C_T-8\lambda C_e\alpha^2-\gamma^2(1-3\alpha))}$, and $\pi_l = \frac{C_e\alpha^2((\gamma+\lambda C_T)E_0-\left(A-\lambda(C_l+C_s)\right))^2}{(2\alpha\lambda\gamma C_T-8\lambda C_e\alpha^2-\gamma^2(1-3\alpha))^2}$ where $P_l = P_l^*$ and $E = E_s^*$. It is straightforward to illustrate that the demand and revenue per unit of demand are positive when $C_T < \frac{8\lambda C_e\alpha^2+\gamma^2(1-3\alpha)}{2\lambda\gamma\alpha}$ and $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$. The profit is always positive.

must be true, and we obtain the lower and upper boundaries for ${E_s}^*$. Also note that $8\lambda\ C_e\alpha^2 +\ \gamma^2\,(1-3\alpha) - 2\alpha\lambda\gamma\ C_T > 0 \Leftrightarrow \frac{\gamma\alpha(A-\lambda(C_l+C_s))}{8\lambda C_e\alpha^2+\gamma^2(1-2\alpha)-\lambda\gamma\alpha C_T} < \frac{A-\ \lambda(C_l+C_s)}{\gamma+\lambda C_T}$. Thus ${E_s}^* = 0 \Leftrightarrow E_0 \leq \frac{\gamma\alpha(A-\lambda(C_l+C_s))}{8\lambda C_e\alpha^2+\gamma^2(1-2\alpha)-\lambda\gamma\alpha C_T}$. For the case $E_0 > \frac{A-\ \lambda(C_l+C_s)}{\gamma+\lambda C_T}$, the maximum profit for the shipper is achieved when $E = E_0$. However, when $E = E_0$, $\pi_s \geq 0 \Leftrightarrow E_0 \leq \frac{A-\ \lambda(C_l+C_s)}{\gamma+\lambda C_T}$, otherwise the demand and thus profit would be negative. Note that if $E = E_0$, then $D = \frac{-\alpha(\gamma^2-4\lambda C_e\alpha)((\gamma+\lambda C_T)E_0-\left(A-\lambda(C_l+C_s)\right))}{2(2\alpha\lambda\gamma C_T-8\lambda C_e\alpha^2-\gamma^2(1-3\alpha))} \geq 0$ results in $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ when $C_T < \frac{8\lambda C_e\alpha^2+\gamma^2(1-3\alpha)}{2\lambda\gamma\alpha}$. Therefore, if $E_0 \geq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ then $\pi_s \leq 0$. We thus obtain the optimality conditions for ${E_s}^*$ as stated in Lemma 2. The parties' profits in equilibrium are: $\pi^*_{l_S} = \frac{C_e\alpha^2((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{8\lambda C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma C_T}$ and $\pi^*_{s_S} = \frac{C_e\alpha^3(4\lambda C_e\alpha-\gamma^2)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{(8\lambda C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma C_T)^2}$. Note that the LSP's and shipper's profits are always positive given the conditions defined for concavity of their profit functions $\blacksquare$.

3.6.3 Appendix C. Proof of Proposition 1

Referring to the optimality conditions defined for both parties' desired environmental performance (Lemmas 1 and 2), we focus our analysis on the intersection between optimal emission level E_l^* and E_s^*. We always consider the conditions that ensure the concavity and positivity of profit functions, which are $\frac{\gamma^2}{4\lambda C_e} < \alpha < 1$ and $C_T < \min\{\frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha},\ \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}\}$. Note that $\frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha} > \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}$ if and only if $\alpha < \frac{1}{3}$; when $\alpha = \frac{1}{3}$ then $C_T = \frac{4\sqrt{\lambda C_e}-\sqrt{3}\gamma}{\sqrt{3}\lambda}$. Moreover, we assume throughout our analysis that the initial carbon intensity of logistics operations E_0 is positioned within the boundaries derived for both E_l^* (Lemma 1) and E_s^* (Lemma 2). In particular, $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ ensures that both parties operate profitably when they improve their desired environmental performance. We now characterize the matches and gaps that exist in the parties' desired environmental performances in the supply chain. In particular, we characterize the conditions that make $\Delta E = |E_s^* - E_l^*|$ either zero or positive. $\Delta E = |E_s^* - E_l^*| = \left|\frac{(\gamma(\gamma+\lambda C_T)-8\lambda C_e\alpha)(\lambda\alpha C_T-\gamma(1-2\alpha))((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))}{\left(-8\lambda C_e+(\gamma+\lambda C_T)^2+8\lambda C_e\alpha\right)(-8\lambda C_e\alpha^2-\gamma^2(1-3\alpha)+2\alpha\lambda\gamma C_T)}\right|$. Now we analyze the critical points at which $E_s^* = E_l^*$. By considering the $E_s^* - E_l^*$ expression stated above, it is straightforward to see that there are three critical points at which $E_s^* = E_l^*$: $C_{T_1}(\alpha) = \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\alpha}$, $C_{T_2}(\alpha) = \frac{\gamma(1-2\alpha)}{\lambda\alpha}$, and $C_{T_3} = \frac{A-\lambda(C_l+C_s)-\gamma E_0}{\lambda E_0}$. The third possible value for regulatory measures , $C_{T_3} = \frac{A-\lambda(C_l+C_s)-\gamma E_0}{\lambda E_0}$, is excluded from our analysis since it corresponds to the maximum level of initial emissions under which both parties can operate profitably when decreasing the environmental impact of their operations (see Lemmas 1 and 2). In other words, the marginal profit achieved by the both parties tends to decrease and move towards zero when the value of carbon tax approaches C_{T_3}. By taking the feasibility conditions for positivity of C_{T_1}, and C_{T_2} we have: $C_{T_1} = \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma} > 0 \;\Leftrightarrow \alpha > \frac{\gamma^2}{8\lambda C_e}$ and $C_{T_2} = \frac{\gamma(1-2\alpha)}{\lambda\alpha} > 0 \;\Leftrightarrow \alpha < \frac{1}{2}$. Also, the boundary condition for concavity and positivity of the parties' profits, $C_T < \min\{\frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha}, \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}\}$, implies conditions under which the two possible values for carbon tax, (C_{T_1} and C_{T_2}), will make the environmental gap zero: $C_{T_1} = \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\alpha} < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} \iff 8\lambda C_e\alpha^2 + \gamma^2\alpha - \gamma^2 < 0$ and $C_{T_2} = \frac{\gamma(1-2\alpha)}{\lambda\alpha} < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} \iff 8\lambda C_e\alpha^2 + \gamma^2\alpha - \gamma^2 > 0$. Solving for $8\lambda C_e\alpha^2 + \gamma^2\alpha - \gamma^2 = 0$, we derive the following feasibility conditions for the values of points at which the environmental gap is zero: If $\alpha < \frac{1}{3}$ then $C_{T_1} = \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma}$ when $\frac{\gamma^2}{8\lambda C_e} \leq \alpha < \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$ and $C_{T_2} = \frac{\gamma(1-2\alpha)}{\lambda\alpha}$ when $\frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} < \alpha \leq \frac{1}{3}$. We revise the former boundary to $\frac{\gamma^2}{4\lambda C_e} \leq \alpha < \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$ by considering the condition for concavity of the shipper's profit function. Solving for $\alpha = \frac{\gamma^2}{4\lambda C_e} < \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$ we reach $\frac{\gamma^2}{4\lambda C_e} < \frac{1}{3}$. To ensure our results are feasible, we assume that consumer sensitivity with respect to carbon emissions is much lower than product of consumer sensitivity with respect to price and the cost coefficient of green investment ($\gamma \ll \lambda C_e$). This enables to avoid us limiting the feasibility conditions of our analysis in Proposition 2 when either of parties targets a lower/higher emission reduction target. First, note that $C_{T_1} = C_{T_2}$ when $\alpha = \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$. Also, $C_{T_1}(\alpha = \frac{\gamma^2}{4\lambda C_e}) = C_{T_2}(\alpha = \frac{1}{3}) = \frac{\gamma}{\lambda}$. Thus, our results imply that if $\frac{1}{3} < \alpha \leq \frac{1}{2}$ then because $C_{T_2} = \frac{\gamma(1-2\alpha)}{\lambda\alpha} < \frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha}$, C_{T_2} is the only feasible solution which makes the environmental gap zero. This also necessitates that $\alpha = \frac{1}{2} < 1 - \frac{\gamma\left(\sqrt{\gamma^2+16\lambda C_e}-\gamma\right)}{8\lambda C_e}$ and is true when $\frac{\gamma^2}{4\lambda C_e} < 1$ (which must always hold). Note that when $\frac{\gamma^2}{4\lambda C_e} = \frac{1}{3}$ then $\frac{\gamma^2}{4\lambda C_e} = \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$; when $\frac{\gamma^2}{4\lambda C_e} \geq \frac{1}{3}$ the matches occur at C_{T_2} where $\frac{1}{3} \leq \alpha \leq \frac{1}{2}$.

Given the results we derived, it is straightforward to show the following properties. First, referring to the expression we defined for $\Delta E = |E_s^* - E_l^*|$ in Proposition 1, there are two critical points for α at which $E_l^* = E_s^*$: $\alpha_1 = \frac{\gamma^2+\lambda\gamma C_T}{8\lambda C_e}$ and $\alpha_2 = \frac{\gamma}{\lambda C_T+2\gamma}$. These values correspond to C_{T_1} and C_{T_2} and thus are feasible when $\frac{\gamma^2}{4\lambda C_e} \leq \alpha < \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$ and $\frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} < \alpha \leq \frac{1}{2}$ respectively. This implies that $\alpha_1 < \alpha_2$ when $C_T < \frac{\sqrt{\gamma^2+32\lambda C_e}-3\gamma}{2\lambda}$ not vice versa. Also, α_1 and α_2 are positive in which $\alpha_2 < 1$. We further conclude that both α_1 and α_2 lie between 0 and 1, and thus they are feasible. As well, $E_l^* = E_s^*$ at $\alpha = \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$, when $C_T = \frac{\sqrt{\gamma^2+32\lambda C_e}-3\gamma}{2\lambda} = \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda}$ and $\alpha_1 = \alpha_2 = \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} = \hat{\alpha}$. Thus, when $C_T > \frac{\sqrt{\gamma^2+32\lambda C_e}-3\gamma}{2\lambda}$, we can show that there is no feasible point for α at which $E_s^* = E_l^*$ and $E_s^* > E_l^*$. Second, it is straightforward to show that when $C_T = 0$, then $\alpha_2 = \frac{1}{2}$.

We thus obtain the conditions under which the environmental gap is zero $\Delta E = |E_s^* - E_l^*| = 0$, as stated in the Proposition 1 ■.

3.6.4 Appendix D. Proof of Proposition 2

Referring to the expression we defined for $\Delta E = |E_s^* - E_l^*|$ in Proposition 1, in order to derive the conditions under which $E_s^* > E_l^*$ or $E_s^* < E_l^*$, we carry out the following steps. First, in order to meet the boundary condition $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ in Lemmas 1 and 2, the term $(\gamma + \lambda\ C_T)E_0 - (A - \lambda(C_l + C_s))$ must be always negative. Second, when $0 \leq \alpha \leq 1$, $\frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} = \frac{8\lambda C_e\alpha^2+\gamma^2(1-3\alpha)}{2\lambda\gamma\alpha}$ if and only if $\alpha = \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$. This implies that $\frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} \leq \frac{8\lambda C_e\alpha^2+\gamma^2(1-3\alpha)}{2\lambda\gamma\alpha}$ always holds when $0 \leq \alpha \leq 1$. Third, $\frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} < \frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha}$ if and only if $\alpha < \frac{1}{3}$. Fourth, when $C_T < \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma}$, the term $(\gamma(\gamma + \lambda\ C_T) - 8\lambda\ C_e\alpha)$ is negative; otherwise this term is positive. By similar reasoning, when $C_T < \frac{\gamma(1-2\alpha)}{\lambda\alpha}$, the term $(\lambda\alpha\ C_T - \gamma(1 - 2\alpha))$ is negative; otherwise this term is positive. Fifth, we can show that the following relationships are always true: 1) when $0 \leq \alpha < \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$ then $\frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma} < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} < \frac{\gamma(1-2\alpha)}{\lambda\alpha}$; 2) when $\frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} < \alpha \leq \frac{1}{3}$ then $\frac{\gamma(1-2\alpha)}{\lambda\alpha} < \frac{2\sqrt{2\lambda C_e(1-\alpha)}-\gamma}{\lambda} < \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma}$; and 3) when $\frac{1}{3} < \alpha < 1$ then $\frac{\gamma(1-2\alpha)}{\lambda\alpha} < \frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha} < \frac{8\lambda C_e\alpha-\gamma^2}{\lambda\gamma}$. Note that, in consistent with Proposition 1, and for feasibility of our results, we assume that $\frac{\gamma^2}{4\lambda C_e} < \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$ when $\frac{\gamma^2}{4\lambda C_e} < \frac{1}{3}$. Also, solving for $C_T = \frac{2\sqrt{\alpha\lambda C_e}(1-\alpha)-\gamma\alpha}{\lambda\alpha} = 0$ we have $\alpha = 1 - \frac{\gamma\sqrt{\gamma^2+16\lambda C_e}-\gamma^2}{8\lambda C_e}$. It follows that, the boundary conditions on α are $\frac{\gamma^2}{4\lambda C_e} \leq \alpha \leq 1 - \frac{\gamma\sqrt{\gamma^2+16\lambda C_e}-\gamma^2}{8\lambda C_e}$, and we obtain the conditions under which $|E_s^* - E_l^*| \neq 0$ as stated in Proposition 2 ■.

3.6.5 Appendix E. Proof of Proposition 3

Taking the first derivative of the LSP's optimal environmental performance level, E_l^* in Lemma 1, with respect to shipper's proportion of green investment, α, we obtain: $\frac{\partial E_l^*}{\partial \alpha} = \frac{8\lambda C_e(\gamma+\lambda C_T)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))}{\left(8\lambda C_e(1-\alpha)-(\gamma+\lambda C_T\ )^2\right)^2}$. To meet the boundary condition $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ in Lemmas 1 and 2, the term $(\gamma + \lambda\ C_T)E_0 - (A - \lambda(C_l + C_s))$ must always be negative. Thus, the LSP's desired environmental performance is strictly decreasing in α: $\frac{\partial E_l^*}{\partial \alpha} < 0$. Moreover, it is straightforward to demonstrate that the second derivative of the LSP's optimal emission level, with respect to change in shipper's proportion of green investment, is negative which implies the concavity of E_l^*.

Taking the first derivative of the shipper's optimal environmental performance level, E_s^* in Lemma 2, with respect to shipper's proportion of green investment, α, we obtain: $\frac{\partial E_s^*}{\partial \alpha} = \frac{\gamma(\gamma^2-8\lambda C_e\alpha^2)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))}{(8\lambda C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma C_T)^2}$ To meet the boundary condition $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ in Lemmas 1 and 2, the term $(\gamma + \lambda\ C_T)E_0 - (A - \lambda(C_l + C_s))$ must be negative. Thus, we see that when $0 < \alpha < \frac{\gamma}{\sqrt{8\lambda C_e}}$ the quantity $\gamma^2 - 8\lambda\ C_e\alpha^2$ is positive and therefore $\frac{\partial E_s^*}{\partial \alpha} < 0$. Also when $\alpha > \frac{\gamma}{\sqrt{8\lambda C_e}}$, the quantity $(\gamma^2 - 8\lambda\ C_e\alpha^2)$ is negative and, therefore $\frac{\partial E_s^*}{\partial \alpha} > 0$. We conclude that E_s^* is convex in α and therefore will have a unique minimum at $\alpha = \frac{\gamma}{\sqrt{8\lambda C_e}} = \alpha'$ ■.

3.6.6 Appendix F. Proof of Proposition 4

Taking the first derivative of the LSP's profit we derived in Lemma 1 (i.e LSP-oriented model), with respect to shipper's proportion of green investment, α, we obtain: $\frac{\partial \pi_{lL}^*}{\partial \alpha} = \frac{C_e(\gamma+\lambda C_T)^2((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{(8\lambda C_e(1-\alpha)-(\gamma+\lambda C_T)^2)^2} > 0$, which is strictly positive. This implies that the LSP's optimal proportion of contribution to green investment costs is zero.

Taking the first derivative of the LSP's profit we derived in Lemma 2 (i.e shipper-oriented model), with respect to shipper's proportion of green investment, α, we obtain: $\frac{\partial \pi_{lS}^*}{\partial \alpha} = -\frac{\gamma C_e\alpha(2\lambda C_T\alpha+\gamma(3\alpha-2))((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{(8\lambda C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma C_T)^2} = \alpha_{l_S}^*$. Solving for α we get: $\alpha^* = \frac{2\gamma}{3\gamma+2\lambda C_T}$. It is straightforward to show that the LSP's profit function in Lemma 2 is concave at $\alpha_{l_S}^* = \frac{2\gamma}{3\gamma+2\lambda C_T}$ and thus is a maximum ■.

3.6.7 Appendix G. Proof of Proposition 5

Taking the first derivative of the shipper's profit we derived in Lemma 1 (i.e LSP-oriented model), with respect to his/her proportion of green investment, α, we obtain: $\frac{\partial \pi_{sL}^*}{\partial \alpha} = \frac{C_e(\gamma+\lambda C_T)^2(16\lambda C_e\alpha-(\gamma+\lambda C_T)^2)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{(8\lambda C_e(1-\alpha)-(\gamma+\lambda C_T)^2)^3}$. Solving for α we get: $\alpha^* = \frac{(\gamma+\lambda C_T)^2}{16\lambda C_e} = \alpha^*_{s_L}$. To meet the boundary condition of Lemma 1, the term $8\lambda\, C_e\,(1-\alpha)-(\gamma+\lambda C_T)^2$ must be positive. Thus, when $0 < \alpha < \frac{(\gamma+\lambda C_T)^2}{16\lambda C_e}$, $(16\lambda\, C_e\alpha-(\gamma+\lambda C_T)^2)$ is positive and therefore $\frac{\partial \pi_{sL}^*}{\partial \alpha} > 0$. Also when $\alpha > \frac{(\gamma+\lambda C_T)^2}{16\lambda C_e}$, $(16\lambda\, C_e\alpha-(\gamma+\lambda C_T)^2)$ is negative and therefore $\frac{\partial \pi_{sL}^*}{\partial \alpha} < 0$. This implies that π_{sL}^* is a maximum at $\alpha^*_{s_L} = \frac{(\gamma+\lambda C_T)^2}{16\lambda C_e}$. Taking the second derivative we obtain: $\frac{\partial^2 \pi_{sL}^*}{\partial \alpha^2} = \frac{8\lambda {C_e}^2(\gamma+\lambda C_T)^2\left(5(\gamma+\lambda C_T)^2-16\lambda C_e-32\lambda C_e\alpha\right)\left((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s))\right)^2}{\left(8\lambda C_e(1-\alpha)-(\gamma+\lambda C_T)^2\right)^4}$ ensures the concavity of shipper's profit function. Thus, the inequality $\alpha^*_{s_L} = \frac{(\gamma+\lambda C_T)^2}{16\lambda C_e} > \frac{5(\gamma+\lambda C_T)^2-16\lambda C_e}{32\lambda C_e}$ must hold. Solving this inequality we get $\alpha^*_{s(L)} < \frac{1}{3}$.

Taking the first derivative of the shipper's profit we derived in Lemma 2 (i.e shipper-oriented model), with respect to his/her proportion of green investment, α, we obtain: $\frac{\partial \pi_{sS}^*}{\partial \alpha} = \frac{\gamma C_e\alpha^2(-16\lambda C_e(\gamma+\lambda C_T)\alpha^2+\gamma(3\gamma^2+16\lambda C_e+2\lambda\gamma C_T)\alpha-3\gamma^3)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^2}{(8\lambda C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma C_T)^3}$. Solving for α we get: $\alpha^* = \frac{\gamma(3\gamma^2+16\lambda C_e+2\lambda\gamma C_T \pm\sqrt{(3\gamma^2-16\lambda C_e)^2+4\lambda\gamma C_T(3\gamma^2-32\lambda C_e)+4(\lambda\gamma C_T)^2\ })}{32\lambda C_e(\gamma+\lambda C_T)}$. Recall that, the term $8\lambda C_e\alpha^2+\ \gamma^2\,(1-3\alpha)-2\alpha\lambda\gamma C_T$ is positive when feasibility conditions are to be met. Thus, $(-16\lambda\ C_e\,(\gamma+\lambda C_T)\,\alpha^2+\gamma(3\gamma^2+16\lambda\ C_e+2\lambda\gamma\ C_T)\alpha-3\gamma^3)$ is positive when α is between the two roots and is negative otherwise. This implies that $\pi^*_{s_S}$ is a maximum at $\alpha^*_{s_S} = \frac{\gamma(3\gamma^2+16\lambda C_e+2\lambda\gamma C_T+\sqrt{(3\gamma^2-16\lambda C_e)^2+4\lambda\gamma C_T(3\gamma^2-32\lambda C_e)+4(\lambda\gamma C_T)^2})}{32\lambda C_e(\gamma+\lambda C_T)}$ and the shipper's profit function is concave (second derivative expression not provided for brevity).

By comparing the shipper's optimal contribution to green logistics investment: $\alpha^*_{s_S} - \alpha^*_{s_L} = \frac{\gamma(3\gamma^2+16\lambda C_e+2\lambda\gamma C_T+\sqrt{(3\gamma^2-16\lambda C_e)^2+4\lambda\gamma C_T(3\gamma^2-32\lambda C_e)+4(\lambda\gamma C_T)^2\ })-2(\gamma+\lambda C_T)^3}{32\lambda C_e(\gamma+\lambda C_T)}$, we can show that the there is a unique threshold for C_e at which $\alpha^*_{s_L} = \alpha^*_{s_S}$: $C_e = \frac{(\gamma+\lambda C_T)^2(2\gamma+\lambda C_T)\left((\lambda C_T)^2+\lambda\gamma C_T-\gamma^2\right)}{16\lambda\gamma\left((\lambda C_T)^2+2(\lambda\gamma C_T-\gamma^2)\right)} =$

$\widehat{C_e}$. Then it follows that $\alpha^*_{s_S} > \alpha^*_{s_L}$ if and only if $C_e > \widehat{C_e}$. Note that $C_e > \widehat{C_e}$ is always positive if $\gamma < \lambda C_T$.

3.6.8 Appendix H. Proof of Proposition 6

The equilibrium $\alpha^*_{n_I}$ would be the solution to the problem *maximize* $\pi^*_{n_I} = \pi^*_{l_I}.\pi^*_{s_I}$ where $\pi^*_{l_I}$ and $\pi^*_{s_I}$ are the profits of the LSP and shipper as provided in Lemmas 1 and 2 and $I \in \{L, S\}$ represents the LSP and shipper oriented models.

Taking the first derivative of the Nash product of the parties' profits we derived in Lemma 1, with respect to shipper's proportion of green investment, in other words α, we obtain: $\frac{\partial \pi^*_{nL}}{\partial \alpha} = \frac{{C_e}^2(\gamma+\lambda C_T)^2\left(20\lambda C_e\alpha^2-2(12\lambda C_e+(\gamma+\lambda C_T)^2\right)\alpha+4\lambda C_e+(\gamma+\lambda C_T)^2)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^4}{\left(8\lambda C_e(1-\alpha)-(\gamma+\lambda C_T)^2\right)^4}$. Solving for α we get: $\alpha^* = \frac{2\gamma^2+24\lambda C_e+4\lambda\gamma C_T+2(\lambda C_T)^2 \pm \sqrt{4\left(12\lambda C_e+(\gamma+\lambda C_T)^2\right)^2-80\lambda C_e(4\lambda C_e+(\gamma+\lambda C_T)^2}}{40\lambda C_e}$. Thus, $\left(20\lambda C_e\alpha^2 - 2(12\lambda C_e + (\gamma+\lambda C_T)^2\right)\alpha + 4\lambda\ C_e + (\gamma+\lambda C_T)^2)$ is negative when α is between the two roots and is positive otherwise. This implies that $\pi^*_{n_I}$ is a maximum at $\alpha^*_{n_L} = \frac{2\gamma^2+24\lambda C_e+4\lambda\gamma C_T+2(\lambda C_T)^2-\sqrt{4\left(12\lambda C_e+(\gamma+\lambda C_T)^2\right)^2-80\lambda C_e(4\lambda C_e+(\gamma+\lambda C_T)^2}}{40\lambda C_e}$ and the Nash product of the parties' profits is concave (second derivative expression not provided for brevity).

Taking the first derivative of the Nash product of the parties' profits we derived in Lemma 2 (i.e shipper-oriented model), with respect to shipper's proportion of green investment, $\frac{\partial \pi^*_{nS}}{\partial \alpha} = \frac{-\gamma {C_e}^2\alpha^4\left((24\lambda C_eC_T+28\lambda\gamma C_e)\alpha^2-(6\gamma^3+4\lambda\gamma^2C_T\right)\alpha+5\gamma^3-24\lambda\gamma C_e)((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))^4}{(8\lambda C_e\alpha^2+\ \gamma^2(1-3\alpha)-2\alpha\lambda\gamma C_T)^4}$. Solving for α we get: $\alpha^* = \frac{6\gamma^3+24\lambda\gamma C_e+4\lambda\gamma^2C_T \pm \sqrt{\left(6\gamma^3+24\lambda\gamma C_e+4\lambda\gamma^2C_T\right)^2-80\lambda\gamma^3C_e(7\gamma+6\lambda C_T)}}{8\lambda C_e(7\gamma+6\lambda C_T)}$. Thus, we show that $\left((24\lambda C_eC_T + 28\lambda\gamma C_e)\alpha^2 - (6\gamma^3 + 4\lambda\gamma^2C_T\right)\alpha + 5\gamma^3 - 24\lambda\gamma\ C_e)$ is positive when α is between the two roots and is negative otherwise. This implies that $\pi^*_{n_S}$ is a maximum at $\alpha^*_{n_S} = \frac{6\gamma^3+24\lambda\gamma C_e+4\lambda\gamma^2C_T+\sqrt{\left(6\gamma^3+24\lambda\gamma C_e+4\lambda\gamma^2C_T\right)^2-80\lambda\gamma^3C_e(7\gamma+6\lambda C_T)}}{8\lambda C_e(7\gamma+6\lambda C_T)}$ and the Nash product of the parties' profits is concave (second derivative expression not provided for brevity).

Next, we compare the shipper's optimal contribution to green logistics investment in the LSP-oriented model and when either the LSP, the shipper, or negotiation between them determine how to share green investment costs. First, by comparing the shipper's optimal contribution to green investment when either the shipper, or negotiation between the parties determine how to share the green investment costs and solving for green investment cost , C_e, we have: $\alpha^*_{s_L} - \alpha^*_{n_L} = 0$ then $C_{e_1} = \frac{-(\gamma+\lambda C_T)^2}{16\lambda}$ and $C_{e_2} = \frac{3(\gamma+\lambda C_T)^2}{16\lambda}$. We can show that $\alpha^*_{n_L} > \alpha^*_{s_L}$ if and only if $C_e > C_{e_2}$. That is said we get the results as provided in Proposition 6 (Part 1).

Finally, we compare the shipper's optimal contribution to green logistics investment in the shipper-oriented model and when either the LSP, the shipper, or negotiation between them determine how to share green investment costs. First, by comparing the shipper's optimal contribution to green investment when either the shipper, or negotiation between the parties determine how to share the green investment costs and solving for green investment cost , C_e, we have: $\alpha^*_{s_S} - \alpha^*_{n_S} = 0$ then $C_{e_1} = \frac{\gamma(\gamma+2\lambda C_T)}{4\lambda}$ and $C_{e_2} = \frac{(3\gamma+2\lambda C_T)^2}{32\lambda}$. We can show that $\alpha^*_{n_S} < \alpha^*_{s_S}$ if and only if $C_e > C_{e_2}$. Also, by comparing the shipper's optimal contribution to green investment when either the LSP, or negotiation between the parties determine how to share the green investment costs and solving for green investment cost , C_e, we have: $\alpha^*_{l_S} - \alpha^*_{n_S} = 0$ then and $C_{e_2} = \frac{(3\gamma+2\lambda C_T)^2}{32\lambda}$. We can show that $\alpha^*_{n_S} > \alpha^*_{l_S}$ if and only if $C_e > C_{e_2}$. The results also imply that $\alpha^*_{s_S} > \alpha^*_{l_S}$ if and only if $C_e > C_{e_2}$. Note that the uniquness of our results is realized when $\gamma < \lambda C_T$. That is said we get the results as provided in Proposition 6 (Part 2).

3.6.9 Appendix I. Proof of Proposition 7

First, we re-define the LSP's profit function in (3) under the carbon tax distribution scenario as: $\pi_l\,(P_l, E) = D\,(P_s,\ E)\,(P_l - C_l - \beta C_T E) - (1-\alpha)\,C_e\,(E - E_0\ )^2$. Here, E is the target emission level under the carbon tax distribution scenario and is determined by the LSP. Following the steps of Lemma 1, it is straightforward to show that, when a proportion of carbon tax, β, is imposed on the shipper, the LSP's desired environmental performance remains exactly as in Lemma 1. In particular, compared Lemma 1, we the shipper's best response to the LSP's decision on logistics service price and emission level is defined as $P_s^*\,(P_l, E) = \frac{A-\gamma E\ +\lambda E\beta C_T}{2\lambda} + \frac{1}{2}\,(C_s + P_l)$. Thus, there is an increase of $\frac{\beta C_T E}{\mathbf{2}}$ in product price, compared to Lemma 1. Consequently, the LSP's optimal decision for logistics price is $P_l{}^* = \frac{A-\gamma E}{2\lambda} + \frac{1}{2}\,(C_l - C_s + C_T E(1-2\beta))$, which shows a decrease of $\beta C_T E$ compared to Lemma 1. It is straightforward to show the LSP's revenue remains unchanged as the decrease in logistics price is exactly offset by the increase in the LSP's revenue reflecting the portion of carbon tax imposed on the shipper. Moreover, demand is $D\,(E) = \frac{1}{4}(A - (\gamma E + \lambda\,(C_l + C_s + C_T E)))$, which is identical to Lemma 1. Thus, the product price, product demand, and the LSP's revenue per unit of demand remain unchanged, as does the LSP's optimal target emission level, $E_l'^*$, under carbon tax distribution scenario. In particular, $E_l'^* = E_l^*$ (The parties' optimal profits and optimal price expressions not provided for brevity).

Second, we re-define the shipper's profit function in (4) under carbon tax distribution scenario as: $\pi_s\,(P_s, E) = D\,(P_s,\ E)\,(P_s - C_s - P_l - (1-\beta)C_T E) - \alpha\ C_e\,(E - E_0\ )^2$. Here, E is the target emission level under carbon tax scenario and is determined by the shipper. Following the steps of Lemma 2, we find that, when a proportion of carbon tax is imposed on the shipper, the shipper's desired environmental performance, $E_s'^*$, is defined as: $E_s'^* = \frac{\left(8\lambda C_e\alpha^2+\gamma^2(1-2\alpha)-\lambda\gamma C_T(\alpha+\beta(3\alpha-2))\right)E_0-\alpha\left((\gamma+\lambda\beta C_T)(A-\lambda(C_l+C_s))+\lambda^2\beta C_T\right)}{8\lambda C_e\alpha^2+(\gamma+\lambda\beta C_T)(\gamma(1-3\alpha)-\lambda C_T(2\alpha-\beta(1-\alpha)))}$ (The parties' optimal profits and optimal price expressions not provided for brevity). Taking the second derivative we have: $\frac{\partial^2\pi_s(E)}{\partial E^2} = \frac{1}{2\lambda}((\gamma+\lambda\beta C_T\ )^2 - 4\lambda\ C_e\alpha)$ where $\beta < \frac{2\sqrt{\lambda C_e\alpha}-\gamma}{\lambda C_T}$ ensures the concavity of shipper's profit function. Note that, in consistent with Lemma 2, $E_s'^* \leq\ E_0$ if and only if $\alpha(\gamma+\lambda\beta C_T)((\gamma+\lambda\ C_T)E_0-(A-\lambda(C_l+C_s))) < 0$, which is true exactly when $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$. Taking the first derivative of the shipper's optimal environmental performance, $E_s'^*$ with respect to shipper's proportion of carbon tax, β , we get: $\frac{\partial E_s'^*}{\partial\beta} = \frac{\lambda\alpha C_T(8\lambda C_e\alpha^2+(\gamma+\lambda\beta C_T)^2(\alpha-1))((\gamma+\lambda C_T)E_0-(A-\lambda(C_l+C_s)))}{(8\lambda C_e\alpha^2+(\gamma+\lambda\beta C_T)(\gamma(1-3\alpha)-\lambda C_T(2\alpha-\beta(1-\alpha))))^2}$. In order to meet the boundary condition $E_0 \leq \frac{A-\lambda(C_l+C_s)}{\gamma+\lambda C_T}$ which guarantees that $E_s'^* < E_0$, $(\gamma+\lambda\ C_T)E_0-(A-\lambda(C_l+C_s))$ must be always negative. Thus, when $0 < \beta < \frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)}$, $(8\lambda\ C_e\alpha^2+(\gamma+\lambda\beta C_T\ )^2(\alpha-1))$ is positive and therefore $\frac{\partial E_s'^*}{\partial\beta} < 0$. Also when $\beta > \frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)}$, $(8\lambda\ C_e\alpha^2+(\gamma+\lambda\beta C_T\ )^2(\alpha-1))$ is negative and therefore $\frac{\partial E_s'^*}{\partial\beta} > 0$. This shows that $E_s'^*$ is minimum at $\beta = \frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)}$. First, $\frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)} \leq \frac{2\sqrt{\lambda C_e\alpha}-\gamma}{\lambda C_T}$ if and only if $\alpha \leq \frac{1}{3}$. In case $\alpha < \frac{1}{3}$, $\frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)}$ is positive if $\alpha > \frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e}$. Also, it is straightforward to verify that $\frac{\gamma\left(\sqrt{\gamma^2+32\lambda C_e}-\gamma\right)}{16\lambda C_e} < \frac{1}{3}$. When $\alpha < \frac{(\gamma+\lambda C_T)^2}{4\lambda C_e}$ then $\beta = \frac{2\sqrt{\lambda C_e\alpha}-\gamma}{\lambda C_T} < 1$, which guarantees that $\frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)} < 1$ as well. Moreover, by using the $(\gamma+\lambda C_T\ )^2 - 8\lambda C_e(1-\alpha) < 0$ condition derived previously for concavity of the LSP's profit function, we can further show that $\frac{(\gamma+\lambda C_T)^2}{4\lambda C_e} < 2(1-\alpha)$. Thus, when $\alpha < \frac{1}{3}$ the condition $\alpha < \frac{(\gamma+\lambda C_T)^2}{4\lambda C_e} < 2(1-\alpha)$ must hold to guarantee that $E_s'^*$ is minimum at $\beta = \frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)}$. Note that when $\alpha < \frac{1}{3}$ then $\alpha < 2(1-\alpha)$ and thus $\frac{1}{3} < \frac{(\gamma+\lambda C_T)^2}{4\lambda C_e} < \frac{4}{3}$ is a sufficient condition to ensure a minimum. In case $\alpha > \frac{1}{3}$, and $\frac{2\alpha^2}{1-\alpha} < \frac{(\gamma+\lambda C_T)^2}{4\lambda C_e}$ then $\beta = \frac{2\alpha\sqrt{2\lambda C_e(1-\alpha)}-\gamma(1-\alpha)}{\lambda C_T(1-\alpha)} < 1$, which guarantees that $\frac{2\sqrt{\lambda C_e\alpha}-\gamma}{\lambda C_T} < 1$ as well. Also note that $\frac{2\sqrt{\lambda C_e\alpha}-\gamma}{\lambda C_T}$ is positive when $\alpha > \frac{\gamma^2}{4\lambda C_e}$. Moreover, the condition

$(\gamma + \lambda C_T\ )^2 - 8\lambda C_e\,(1-\alpha) < 0$ for concavity of the LSP's profit function, implies that $\frac{(\gamma+\lambda C_T)^2}{4\lambda C_e} < 2(1-\alpha)$. Thus, when $\alpha > \frac{1}{3}$ the condition $\frac{2\alpha^2}{1-\alpha} < \frac{(\gamma+\lambda C_T)^2}{4\lambda C_e} < 2(1-\alpha)$ must hold to guarantee that $E_s'^{*}$ is minimum at $\beta = \frac{2\sqrt{\lambda C_e \alpha}-\gamma}{\lambda C_T}$. Note that in case $\alpha > \frac{1}{3}$, then $\frac{2\alpha^2}{1-\alpha} < 2(1-\alpha)$ holds if and only if $\alpha < \frac{1}{2}$ and thus $\frac{(\gamma+\lambda C_T)^2}{4\lambda C_e} = 1$ is a sufficient condition for a minimum $\blacksquare$.

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Chapter 4

Greening the Logistics Service Provider-Shipper Interface: A Game-Theoretic Analysis

4.1 Introduction

There are many reasons to believe that logistics must be a major contributor to the drastic reductions in CO_2 emissions required by 2050 to limit global temperature increase to 2^oC in 2100. In the transport sector, CO_2 emissions from freight transport are projected to rise 76 percent between 2015 and 2050; a reduction of 20-65 percent will be needed to contain the increase in global temperature as envisaged by the Paris Climate Agreement (SmartFreight Leadership, 2017).

Given the carbon intensity of logistics operations along the supply chain, Logistics Service Providers (LSPs) and their clients (shippers) are currently under pressure from external stakeholders, end-consumers, and government to reduce the environmental externalities associated with logistics. World-leading LSPs have announced ambitious plans for emissions abatement (Lieb and Lieb, 2010), even though a recent survey indicates that most LSPs believe their customers, i.e. shippers, *reluctant* to spend more for sustainable logistics services offerings (Colicchia et al., 2013). Martinsen and Bjorklund (2012) see this gap as "over-achievement" in that LSPs seem to be ahead of their clients in responding to environmental concerns and legislation. Despite their environmental ambitions, LSPs must adapt logistical services to customer demands and requirements, reflecting a *hierarchical* relationship between LSPs and shippers (Wolf and Seuring, 2010), as LSPs depend on shippers' collaboration to reduce the environmental impacts of logistics. In particular, any green logistics services are at the request of the shipper, who sets the conditions for coordination of green initiatives (Sallnäs, 2016). The general dependency of LSPs on shipper decisions about logistics services places LSPs in a "henchman" position (Wolf and Seuring, 2010), binding them to shipper's lack of interest in environmental protection.

Empirical evidence helps to explain why shippers hesitate to invest in environmental improvements and why they play an inactive role. Economic and operational performance indicators (e.g. price, quality requirements, service performance, and timely delivery) continue to play a central role in decisions to purchase third-party logistics (3PL) services (Selviaridis and Spring, 2007; Marasco, 2008; and Wolf and Seuring, 2010). The potential for synergies between economy and ecology is not well understood by shippers, and even by LSPs. Moreover, the shipper must implement potentially costly controls, such as direct supervision and external audits, to ensure against opportunistic behavior by LSPs (Kudla and Klass-Wissing, 2012).

Recent reviews of supplier selection based on sustainability criteria emphasize the critical role of a supplier's environmental capability (e.g., Genovese et al., 2013; Govindan et al., 2015; Zimmer et al., 2016), but little attention has been paid to the role of logistics (Martinsen and Björklund, 2012) and the inclusion of LSPs in supply chain decisions concerning environmental performance (Konur, 2017). Shippers are less engaged green logistics purchasing, reflecting the dominant regulatory, market and competitive pressures on shippers' internal, industry-related activities, as opposed to green logistics (e.g Jazairy and Haartman, 2020). The ecological impacts of logistics are less visible to the public, which may explain why shippers focus their environmental practices on raw material suppliers (Wolf and Seuring, 2010). Moreover, LSPs are recognized as the least integrated link in firms' supply chains (Lemoine and Skjoett-Larsen, 2004), playing a mere supporting role (Spens and Bask, 2002). As observed frequently in practice, inclusion of environmental content in an LSP-shipper interface often gives rise to disagreement over the shipper's expectations of the environmental performance of the logistics service. In this study, we aim, by considering an LSP's interaction with a shipper, to characterize the conditions under which an LSP can stimulate a shipper to respond to green logistics service offerings without compromising either party's financial position.

To this end, we develop game-theoretic models to analyze how an LSP (service supplier) and a shipper (buyer of logistics services) can collaborate to achieve environmental improvements. First, we examine the non-collaborative case, where the LSP is responsible for eco-efficient greening costs, but the shipper determines the environmental performance of the logistics service. We characterize the LSP's preferred environmental target when it holds negotiating power on product logistics. This enables us to characterize the conditions under which the LSP's environmental target exceeds the shipper's, i.e., the shipper's environmental target is suboptimal from the LSP's point of view. Next, drawing on the insights from an analysis of the parties' possible environmental discrepancy in a decentralized setting, we propose collaborative gain-sharing or cost-sharing mechanisms, and show when and how the parties can improve their joint environmental target while improving their financial performance. We study two collaborative mechanisms in which the LSP offers to the shipper: (1) a cost savings sharing contract; and (2), a monitoring cost sharing contract. We characterize the conditions under which the LSP can stimulate the shipper to respond to green logistics service offerings without compromising financial benefits, and in particular when collaboration will result in a *win-win-win* outcome covering not only the parties' profits but also the green efficiency of product logistics. We further discuss the implications of our analysis to further extend our model and analyze the parties' collaboration under two types of sharing contract: the parties' collaboration under two types of sharing contract: (1) Sharing Cost Savings and Revenue; (2) Sharing Monitoring and Greening Costs.

Our study adds a new dimension to the study of supplier-buyer environmental practices, emphasizing the LSP's (supplier's) dependency on the shipper's (buyer's) desire to collaborate to reduce the environmental impacts of logistics. The contributions of this study are threefold: (1) We build a methodological foundation that illustrates quantitatively the environmental goal misalignment between the shipper's and the LSP's desired environmental performance levels; (2) We consider the buyer (shipper) as the party who has power regarding the environmental performance of product/service (logistics) (unlike previous two-echelon models in green supply chain management research), asking whether and how a supplier can stimulate a buyer's response to green logistics in the supply chain; (3) We shed light on ways to improve environmental outcomes in freight delivery operations. Our analysis indicates how a gain or cost sharing mechanism can help both parties to improve the eco-efficiency of logistics. In particular, our study sheds light on the conditions that influence coordination on environmental practices that does not jeopardize the economic goals of the supply chain partners. We are confident that our study builds a foundation upon which to develop new collaborative mechanisms appropriate to the unique characteristics of the LSP-shipper interface.

The remainder of this paper is organized as follows. Section two explores the current body of literature to justify the importance of this study. Section three presents the main features, assumptions, and formulation of mathematical model and its development. Section four analyzes the economic model and discusses the insights it provides. Finally, key findings, conclusions, limitations and future research directions are presented in section five.

4.2 Literature Review

Our study mainly relates to three research domains; green logistics; supply chain contracting and/or coordination; and Green Supply Chain Management (GSCM).

Recent surveys of LSPs (e.g. Colicchia et al., 2013; Oberhofer and Dieplinger, 2014) indicate that most shippers are not committed to spend more for sustainable logistics services offerings and environmental efficiency was rated the lowest compared to other criteria such as price and delivery time (Lammgård and Andersson (2014). The current literature confirms that integrating environmental considerations into LSPs' offerings results in mismatch of supply and demand (Wolf and Seuring, 2010; Martinsen and Björklund, 2012; Isaksson and Huge-Brodin, 2013) in that the parties lack alignment on green targets (Jazairy, 2020). Despite the critical role the LSPs can play in delivering low carbon products by expediting the greening process of product logistics (Martinsen and Huge-Brodin, 2014), many organizational strategies to improve sustainability in the supply chain are based on a short-term perspective that has a little impact on processes and cost structure (Colicchia, 2013). It is difficult for parties to discern what is optimal from the both the environmental and the economic point of view (Colicchia, 2013).

Research on Green Supply Chain Management (GSCM) has received a growing attention and is aimed at integrating environmentally sound choices into supply chain problems. It has been claimed that Green Supply Chain Management (GSCM) is a *win-win* strategy through which economic benefits, such as long-term profits, can be achieved while maintaining ecological efficiencies (Zhu and Cote 2004; Zhu et al., 2008). Environmental content has been integrated into supply chain management problems by including regulatory measures on environmental impacts, costs associated with non-green operations, simultaneous consideration of environmental and economic performance indicators, green innovation/investment decisions, consumer sensitivity to ecological impacts of products/services, and environmental target decisions.

A review of current literature on GSCM indicates that this stream of research has been mainly influenced by environmental practices aimed at end-to-end sustainable manufacturing (Centobelli et al, 2017) or interactions of firms in a *horizontal* context (see, e.g., Luo et al, 2016; Zhu ands He, 2017). However, the interactions of firms in a *vertical* supply chain context remains largely unexplored. Analysis of single echelon models (i.e. horizontal context) has focused on green/sustainable supply chain problems, where a single player's decision process included environmental sustainability. In this line, while studies on green/sustainable supply chain problems take into account the interactions of different supply chain parties (e.g. carriers/suppliers of transportation and logistics) with regards to criteria mentioned above, they are not explicitly included in the decision-making process (see, e.g., Konur, 2014; Konur and Schaefer, 2014; Absi et al., 2016; Chen and Wang, 2016). In fact, little attention was paid to logistics purchasing/providing decisions (Lieb and Lieb, 2010; Lin and Ho, 2011; Davarzani et al., 2016; Jazairy and Haartman; 2020) and in particular to the interface between shippers and LSPs (Martinsen and Björklund, 2012; Martinsen and Huge-Brodin, 2014; Jørsfeldt et al., 2016). After many years of neglect, research into the environmental practices of LSPs is now gaining greater prominence (Isaksson and Huge-Brodin, 2013; Marchet et al., 2014; Sallnäs, 2016). Nevertheless, most of this research presents a descriptive explanation of the problem, providing little analytical insights on how the parties can achieve economic benefits while improving the greenness of product logistics.

For the most part, two-echelon supply chain models are vendor-buyer models in a Stackelberg game with a leader and a follower at either the upper or lower echelon, depending on the nature of the supply chain channel. The common approach in the study of such supply chain channels is to analyze and compare decentralized and centralized supply chain channels, and to develop cooperative mechanisms such as revenue sharing or cost sharing contracts (see, e.g., Swami and Shah, 2013; Ghosh and Shah, 2015; Zhang et al., 2015; Ouardighia et al., 2016). In this line, a limited number of studies have analyzed the interactions of supply chain members on the efforts invested in environmental performance (Yenipazarli, 2017) and in particular the buyer's monitoring efforts in auditing supplier's environmental activities. Moreover, in such setting, the leader (i.e. supplier) is the agent who usually holds the power to determine joint environmental performance and/or sharing the green investment costs, a decision that will not necessarily benefit the follower (i.e. buyer) (Konur, 2017).

Our game-theoretic analysis borrows some elements from the standard models mentioned above including their common assumptions, but is distinctive in that it:

(1) takes into account both parties' powers to determine the joint environmental decision of product logistics and their conflict over accountability for greening operations. We believe that our study is the first, emphasizing the buyer's (i.e. follower in a two-echelon supply chain setting) power to select the environmental performance of the supplier's product or service (i.e. leader);

(2) focuses on eco-efficient green investment to reduce the environmental impact of product logistics, using environmental performance improvement to increase end-consumer demand in an environmentally conscious market and decrease logistics operations costs (and penalty on environmental impacts of logistics). Our model setting allows us to consider governmental intervention in the form of penalty on associated ecological impacts of product logistics; and

(3) includes buyer's auditing activities to control the supplier's environmental performance of product logistics. Our study is the first to consider the buyer's costs incurred as a result of greening supplier's product or service.

4.3 Model and Assumptions

Our study considers a supplier-buyer supply chain model in a decentralized setting (a Stackelberg game) within the LSP-shipper interface. Our analysis is built upon the following key assumptions. In particular, we assume:

(1) Consumers' environmental consciousness as an additional component of demand that reflects the environmental performance of logistics: while sensitive to product retail price, customers also prefer products that are eco-friendly in their logistics;

(2) The green efficiency of the product logistics as the shipper's decision, taking consumers' environmental preferences and monitoring costs into account. Nevertheless, we characterize the LSP's target environmental performance in the supply chain it constitutes with shipper.

(3) Eco-efficient greening investment as a decision by the LSP to reduce the environmental impact of product logistics while using environmental performance improvement to increase end-consumer demand. An eco-efficient greening investment helps the LSP to save in logistics cost; and

(4) Monitoring costs as a decision by the shipper to control the LSP's conformance to green efficiency of product logistics.

The parameters of our economic analysis are presented in Table 1. To distinguish among parameters of LSP and shipper, we use subscripts l and s, respectively.

4.3.1 Consumer Pressures and Product Demand Function

We assume a positive correlation between the environmental impact of the shipper's logistics and consumer demand. Demand for a product increases as green efficiency of logistics increases. Of course, customers are sensitive to price. Thus, our additive demand function is [1]:

[1] The demand function and/or green investment cost functions we later introduce in 3.2 were first proposed by Tsay and Agrawal (2000) and have been adopted later by other studies in the economic modelling literature (see e.g. Swami and Shah (2013), among others).

Table 4.1: **Table 1: Notation**

Parameters	**Definition**
$D\left(P_s,\ G\right)$	Demand for product/logistics service
A	Potential market size
λ	Sensitivity of demand to price of product
γ	Sensitivity of demand to greenness of product
P_s	Price charged by shipper (per unit of product)
P_l	Price charged by LSP (per unit of product)
C_s	Procurement cost (per unit of product)
C_l	Logistics cost (per unit of product)
C_e	Cost coefficient of improving the green efficiency of product logistics
C_m	Cost coefficient of monitoring the LSP's compliance to green logistics
G	Environmental performance of product logistics
α	Proportion of cost savings sharing ratio taken on by shipper
θ	Proportion of monitoring cost sharing ratio taken on by LSP
π_l	LSP's profit in decentralized supply chain
π_s	Shipper's profit in decentralized supply chain

Decision Variables	**Definition**
G_l	Target environmental performance level from LSP's perspective
G_s	Target environmental performance from shipper's perspective
P_l	Optimal logistics service price
P_s	Optimal retail price

$$D\left(P_s,\ G\right) = A - \lambda P_s + \gamma G \tag{4.1}$$

where P_s is the product price and G is the per unit environmental performance of product logistics. In our model, we measure the environmental performance of product logistics according to emissions resulting from logistics activity. We defined the environmental performance score $G \in (0, 1)$ where $G = 1$ represents the highest possible environmental performance and corresponds to *zero-emissions* logistics of the product. Also, the parameters λ and γ, properties of the consumer market, λ and γ represent the sensitivities of the demand to price and to associated environmental impacts from logistics activities, respectively. Because of the derivative character of logistics services, we assume that the requirements for logistics service is equivalent to the demand for the product.

4.3.2 Investment Costs and Parties' Environmental Targets

In our study we use a green investment function to express the additional cost to reduce a product's environmental impacts as follows:

$$C_G\left(G\right) = C_e\left(G\right)^2 \tag{4.2}$$

where C_e is a coefficient for greening product logistics. According to (2), the cost for further reduction in environmental impact of product logistics increases as additional reductions are achieved. By focusing on a single product value chain, we assume that the average environmental impacts per unit of product is independent of the amount of shipment and is constant per unit of distance (km or mile). This condition is realized when the product shipments are carried out in fixed quantity, with fixed mode of transportation (e.g. road transport by truck), and over same distance. Investment in green initiatives mitigates logistics environmental impacts, and may increase revenue for both sides through an increase in demand for the product.

In our model, we also assume that monitoring cost is an investment that is required in order to achieve the environmental target for product logistics in the supply chain [2]. Thus, we use a green investment cost function that is common in literature to express the cost of monitoring the green efficiency of product logistics,

$$C_M\left(G\right) = C_m\left(G\right)^2 \tag{4.3}$$

where C_m is a coefficient for monitoring (controlling and auditing) the greenness of product logistics relative to the target environmental level[3]. According to (3), the cost for ensuring the achievement of desired green efficiency of product logistics increases in the target environmental performance. .

In our model, the target environmental performance level, G, is primarily decided by the shipper. Nevertheless, we characterize the LSP's input to the environmental performance of product to show that the shipper's decision is not necessarily aligned with what the LSP

[2] We build our assumption upon supplier sustainability risk which refers to the potential negative impacts on a buyer (shipper) from its supplier's (LSP's) ecological misconducts and requires buyers to *invest* substantial resources to monitor their suppliers' activities or to *collaborate* with them to mitigate the risk across the supply chain (Hajmohammad and Vachon, 2016). It is also in consistent with our earlier discussion on how the shipper's desire to ask for greener logistics might be affected by their need to implement potentially costly monitoring of the LSP's conformance to target environmental performance

[3] In order to ensure the existence and uniqueness of the supply chain decision in equilibrium, we assume throughout our analysis that the magnitude of the cost involved in monitoring the LSP's behavior is less than the cost the LSP incurs for greening logistics operations ($C_m < C_e$)

desires for the supply chain. For each party, a trade-off between costs and benefits determines the optimal strategy. For the shipper, paying a premium price for a green logistics offering by the LSP can result in increased revenue from demand expansion in the environmentally conscious market, while increasing the shipper's monitoring cost. For the LSP, investment in sustainable logistics operations LSP reduces the logistics cost and increasing demand in an eco-conscious marketplace.

4.3.3 LSP's and Shipper's Profit-Maximization Problems

Considering (1) and (2), the LSP's profit-maximization problem is:

$$maximize\ \pi_l\left(P_l, G\right) = D\left(P_s,\ G\right)\left(P_l - C_l(1-\delta G)\right) - C_e\left(G\right)^2 \tag{4.4}$$

$$s.t.\ G < \tfrac{1}{\delta}$$

Note that P_l is the logistics service price per unit, C_l is the LSP's unit cost to carry out the service[4], and δ is the coefficient of unit cost reduction of greening logistics of the product.

Similarly, based on (1)-(3), the shipper's profit maximization problem is:

$$maximize\ \pi_s\left(P_s, G\right) = D\left(P_s,\ G\right)\left(P_s - C_s - P_l\right) - C_m\left(G\right)^2 \tag{4.5}$$

$$s.t.\ G < \tfrac{1}{\delta}$$

[4]Our model allows to include a penalty such as Carbon Tax, levied by regulatory agencies for not improving environmental performance, in logistics cost. In such scenario the better environmental performance of logistics not only saves in cost, but also saves by paying less penalty.

Note that C_s represents the unit cost incurred by shipper to procure the product.

The target environmental level G in (3) and (4) is primarily decided by the shipper as the party who mostly initiates the request for the green logistics service and sets conditions for the inclusion of environmental practices[5]. However, in our model, we consider the LSP's decision making process to characterize the LSP's preferred environmental performance and define the environmental gap (i.e. misalignment) between the parties' environmental targeting decisions. We denote the target environmental level from the LSP's and the shipper's perspective by G_l and G_s, respectively. We refer to the models under which we derive G_s as *shipper-oriented model* and G_l as *LSP-oriented model*, respectively (See chapter 3).

In our primary setting (shipper-oriented model), the shipper maximizes its profit by deciding the optimal product retail price, P_s^*, and the optimal target environmental performance level, G_s^*, while the LSP decides the logistics service price, P_l. In our secondary setting, (LSP-oriented model), we suppose that the LSP maximizes its profit by deciding the optimal logistics service price, P_l^*, and optimal target environmental performance level, G_l^*, while the shipper decides the retail price, P_s.

Figures 1 and 2 illustrate the decision framework (i.e. order of decisions) that we analyze the problem under both settings.

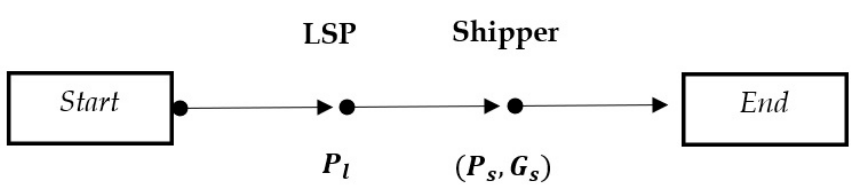

Figure 4.1: **Primary Setting: Shipper-Oriented Model (S)**

[5]Our setting is in consistent with much of the current literature discussing the shipper's power to decide the target environmental performance of product logistics

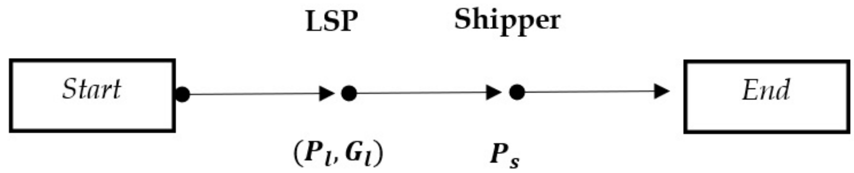

Figure 4.2: **Secondary Setting: LSP-Oriented Model (L)**

Thus, in the games we analyze, the LSP's decision always precedes the shipper's decision. The LSP always sets its price P_l in the first stage and the shipper always sets its price, P_s, in the second stage. In addition, each player sets its environmental target, G_i, in its own stage, where $i \in \{l, s\}$. In the shipper-oriented model, the shipper sets the target level G, G_s, in stage 2. In the LSP-oriented model, the LSP sets the target level G, G_l, in stage 1. Thus, strategy profiles in the in the primary and secondary games can be written (P_l; P_s, G_s) and (P_l, G_l; P_s), respectively.

4.4 Analysis and Results

In this section, we develop game-theoretic models to analyze how a Logistics Service Provider (LSP) and a shipper can collaborate to achieve environmental improvements. In particular, we consider a decentralized supply chain channel in which the LSP is the leader and the shipper is the follower. In this two-stage Stackelberg setting, we analyze both a *non-collaborative* and a *collaborative* supply chain.

First, we analyze the non-collaborative case, where the LSP is responsible for the greening costs, but the shipper determines the environmental target, taking monitoring costs and consumers' environmental preferences into account. We first characterize each party's profit-maximizing level of decisions when shipper has power over the target environmental performance level of product logistics (i.e. Figure 1). Second, we examine the implications on joint target environmental performance level if the LSP were in power, taking greening costs, green efficiency, as well as consumers' environmental consciousness into account (i.e. Figure 2). By comparing the shipper's and the LSP's target levels in the supply chain channel, we illustrate how the shipper's target environmental level might differ from the LSP's, creating an environmental gap.

Next, we study the collaborative case in which we analyze two possible remedies the LSP can apply to stimulate the shipper to respond to green logistics offers, which might increase both parties' profits simultaneously: (1) Offering a contract to share cost savings; and (2) Offering a contract to share monitoring costs.

4.4.1 Non-Collaborative Supply Chain

In the non-collaborative supply chain and in the primary setting we consider in our analysis (i.e. shipper-oriented model), the shipper decides the target environmental performance G_s. We analyze a two-stage sequential game backwards to derive the sub-game perfect equilibrium (P_l; P_s, G_s), and characterize the shipper's optimal environmental performance level, G_s^*, and the parties' resulting profits.

Lemma 4.1. *Given $A - \lambda(C_l + C_s) > 0$ and $G < \frac{1}{\delta}$, if $\gamma^2 - 4\lambda C_m < 0$ the shipper's optimal environmental target is*

$$G_s{}^* = \frac{\gamma C_m(A - \lambda(C_l + C_s))}{8\lambda {C_m}^2 - 2\gamma C_m\left(\gamma + \lambda\delta C_l\right) + \gamma^2 C_e} \tag{4.6}$$

and the firms' resulting profits in equilibrium are

$$\{\pi_l{}^*, \pi_s{}^*\} = \left\{ \frac{C_m{}^2 (A - \lambda(C_l + C_s))^2}{8\lambda C_m{}^2 - 2\gamma C_m (\gamma + \lambda\delta C_l) + \gamma^2 C_e}, \frac{C_m{}^3 (4\lambda C_m - \gamma^2)(A - \lambda(C_l + C_s))^2}{(8\lambda C_m{}^2 - 2\gamma C_m (\gamma + \lambda\delta C_l) + \gamma^2 C_e)^2} \right\} \tag{4.7}$$

Proof: See Appendix A. □

The condition $\gamma^2 - 4\lambda C_m < 0$ ensures that the shipper's profit function is concave. Thus, in the absence of consumer environmental pressure ($\gamma = 0$), the shipper has no financial incentive to monitor the LSP's green behavior; the costs of green logistics outweighs its benefit for the shipper.

Proposition 4.1. *Given the conditions of Lemma 1:*

1. G_s^* *is increasing in* C_m *if and only if* $C_m \in (0, \frac{\gamma\sqrt{C_e}}{2\sqrt{2\lambda}})$
2. G_s^* *is increasing in* C_l *if and only if* $C_m \in (0, \frac{\gamma((A-\lambda C_s)\delta+\gamma+\sqrt{((A-\lambda C_s)\delta+\gamma)^2-8\lambda C_e)}}{8\lambda})$
3. G_s^* *is always decreasing in* C_e*;*

Proof: See Appendix B. □

Proposition 1 (Part 1) explains that there is a unique value of monitoring cost C_m, $\frac{\gamma\sqrt{C_e}}{2\sqrt{2\lambda}} = \bar{C_m}$, at which the shipper's target environmental performance $G_s{}^*$ is a maximum and any higher monitoring costs beyond the threshold will result in inferior environmental performance. The shipper's maximum environmental target reflects the interaction of monitoring costs and consumer sensitivity to environmental impacts of product logistics and monitoring costs; the target environmental performance is increasing in monitoring cost C_m, but only up to the point (i.e. $\bar{C_m}$) at which additional monitoring costs to seek better environmental performance (greener product logistics) are offset by the benefits of market expansion. Thus, the more sensitive the customer with respect to environmental impact of product logistics ($\frac{\gamma}{\sqrt{\lambda}} > 1$) (as opposed to its retail price), the higher environmental ambition of the shipper and the more effort she is willing to put into monitoring the LSP. In other words, in a market characterized by low sensitivity of consumers with respect to environmental performance of product logistics, the shipper has less incentive to ask for greener logistics operation (as higher monitoring costs are involved): the range of values for monitoring costs at which the shipper can target a better environmental performance expands with γ. Thus, in the absence of consumer environmental pressure ($\gamma = 0$), the shipper has no economic incentive to incur the monitoring cost resulting from greener logistics operations; the shipper's maximum target environmental performance approaches zero. Also note that the higher cost of greening the product logistics, C_e, the higher monitoring costs the shipper is ready to bear when increasing its target environmental performance. In fact, the higher cost of greening logistics implies a higher price the shipper is required to pay for green logistics service, justifying greater monitoring costs to ensure the LSP's compliance to target environmental performance.

Proposition 1 (Part 2) indicates that shipper's target environmental performance is increasing in logistics cost C_l when monitoring cost C_m is not sufficiently high: the shipper's higher target environmental performance benefits the party by reducing the LSP's logistics cost which in turn lower the logistics service price. Consistent with Part 1, the range of values for monitoring costs at which the shipper's environmental target increases in C_l expands with γ. Moreover, the range of values for monitoring costs under which the shipper's environmental target is increasing in C_l expands with δ but shrinks in C_e: the higher greening cost cancels the savings in logistics cost, making the greener logistics less attractive. Finally, Proposition 1 (Part 3) is intuitive in a sense that increasing cost of greening logistics, C_e, implies a higher logistics cost the shipper should pay for a premium service, disincentivizing the party to seek a better environmental performance.

In section 4.1.1, we turn to our secondary setting to examine the implications on joint environmental target for product logistics and firm-level profits when the LSP decides the target environmental performance, G.

4.4.1.1 LSP's Favorable Action and Environmental Gap

If the LSP has the power to decide the target emissions level G (i.e. LSP-oriented model; Figure 4.2), the joint target environmental performance, and thus the parties' resulting profits, are affected. We analyze the two-stage sequential game backwards to derive the subgame perfect equilibrium (P_l, G_l; P_s) and, characterize the LSP's optimal emission level, G_l^*.

Lemma 4.2. *If the LSP has the power to decide the joint environmental performance of the product logistics, then the joint performance target is*

$$G_l{}^* = \frac{(\gamma + \lambda\delta C_l)\,(A - \lambda(C_l + C_s))}{8\lambda C_e - (\gamma + \lambda\delta C_l)^2} \tag{4.8}$$

and the firms' resulting profits in equilibrium are

$$\{\pi_l{}^*, \pi_s{}^*\} = \left\{ \frac{C_e(A-\lambda(C_l+C_s))^2}{8\lambda {C_e}^2 - (\gamma+\lambda\delta C_l)^2}, \right. \\ \left. \frac{(4\lambda {C_e}^2 - C_m(\gamma+\lambda\delta C_l)^2)(A-\lambda(C_l+C_s))^2}{8\lambda C_e - (\gamma+\lambda\delta C_l)^2} \right\} \tag{4.9}$$

when $(\gamma+\lambda\delta C_l)^2 - 8\lambda C_e < 0$.

Proof: See Appendix C. □

Under these conditions, when the shipper does not have the power to decide the joint environmental performance, the shipper has no incentive to monitor the LSP's compliance to green standards due to the additional costs involved ($C_m = 0$). Note that the shipper's choice of joint-environmental target of product logistics in Lemma 1, G_s^*, is not necessarily aligned with what the LSP desires, G_l^*, in the supply chain channel. We now explore the conditions under which the LSP's choice of with respect to environmental performance target for product logistics differs from the shipper's.

Proposition 4.2. *Given the conditions of Lemma 1 and Lemma 2, the LSP targets better environmental performance than the shipper ($G_l^* > G_s^*$) if and only if:*

1. *when* $C_e > 2C_m$

- *if* $\gamma \leq \frac{2C_m\sqrt{2\lambda}}{\sqrt{C_e}}$ *and* $C_l > \frac{\gamma(C_e-C_m)}{\lambda\delta C_m}$.
- *if* $\frac{2C_m\sqrt{2\lambda}}{\sqrt{C_e}} < \gamma \leq 2\sqrt{C_m\lambda}$ *and* $C_l > \frac{8\lambda C_m-\gamma^2}{\gamma\lambda\delta}$.

2. *when* $C_m < C_e < 2C_m$

- *if* $\gamma \leq 2\sqrt{C_m \lambda}$ *and* $C_l > \frac{\gamma(C_e - C_m)}{\lambda \delta C_m}$.

Proof: See Appendix D. $\square$

The Proposition 2 implies that depending on consumer sensitivity with respect to environmental impacts of product logistics γ, there is a unique value of logistics cost, C_l, at which the shipper and LSP both target the same environmental performance ($G_s^* = G_l^*$). In other words, depending on consumer market preferences, when the logistics cost is sufficiently high, the LSP seeks a better environmental performance in the supply chain. In fact, the shipper's target environmental performance is not sufficient to fully realize the potential benefit (i.e. cost savings) resulting greener logistics of the product.

The common characteristics of the thresholds defined for C_l is that they are decreasing in δ, cost reduction effectiveness of greener logistics operations. Thus, the better efficiency of greener logistics operation, the lower the logistics cost above which the LSP desires to target a better environmental performance. However, the critical values beyond which the LSP targets a better environmental performance changes with market forces differently. When consumers' sensitivity with respect to environmental impacts of product logistics is relatively low (high), the corresponding threshold is increasing (decreasing) in γ. This implies that when consumer environmental pressure is relatively low, the LSP targets a better environmental performance only in the presence of greater cost savings (i.e. higher logistics cost) as a result of greener logistics: the benefit from market expansion is marginal. However, the more sensitive the customer with respect to environmental impact of product logistics (as opposed to its retail price), the LSP is more environmentally ambitious than the shipper when smaller cost savings (i.e. lower logistics cost) are expected as a result of greening logistics service. Under this condition, the marginal increase in product demand is more significant, offsetting the lower savings costs.

Note that when the relative value of monitoring cost to greening cost increases (Part 2), there is only a unique value of logistics cost, C_l at which both parties reach to consensus regarding the target environmental performance: Under this condition the area under which the shipper remains profitable shrinks and the agreement point occurs only for lower range of consumer environmental pressures.

The results from Proposition 2 implies that in a Stackelberg game setting between a supplier and buyer, the leader is the agent who commonly holds the power to determine joint target environmental performance, a decision that will not be necessarily in favor of the follower. The results of Proposition 2 shed light on the fact that the shipper is the agent who typically holds the power to determine joint environmental performance of product logistics, a decision that will not necessarily benefit the LSP. We refer to this disagreement as the *environmental gap.* The notion of environmental gap between the two parties implies the need to provide the shipper with monetary incentives, thus stimulating its response to green logistics service offerings while simultaneously improving both parties' profitability.

4.4.2 Collaborative Supply Chain

In the collaborative supply chain, we consider the shipper-oriented Stackelberg model (i.e. primary setting) where the shipper holds the power over the environmental performance of product logistics in the supply chain channel. Under each scenario, we examine the conditions where improving the shipper's target environmental performance results in a *win-win-win* outcome, targeting both parties' financial performance.

4.4.2.1 Cost Savings Sharing Contract

Under a cost savings sharing contract, the LSP offers the shipper a proportion of cost savings, α, achieved as a result of collaboration for greener logistics. Assuming a shipper-oriented model, the primary setting we consider in our analysis, we analyze a two-stage sequential game backwards to derive the sub-game perfect equilibrium (P_l; P_s, G_s) in the presence of incentives, and characterize the shipper's optimal environmental performance level $G_s^*(\alpha)$ and the parties' resulting profits; $\{{\pi_l}^*(\alpha), {\pi_s}^*(\alpha)\}$. We then discuss the conditions under which such strategy will improve environmental performance and benefit both parties simultaneously.

Lemma 4.3. *Given $A - \lambda(C_l + C_s) > 0$ and $E < \frac{1}{\delta}$, if $(\gamma + \alpha\lambda\delta C_l)^2 - 4\lambda C_e < 0$ then in the presence of cost savings sharing incentives, the optimal environmental decision for product logistics is*

$$G_s^*(\alpha) = \frac{C_m(\gamma + \alpha\lambda\delta C_l)(A - \lambda(C_l + C_s))}{8\lambda {C_m}^2 - 2C_m(\gamma + \alpha\lambda\delta C_l)(\gamma + \lambda\delta C_l) + (\gamma + \alpha\lambda\delta C_l)^2 C_e} \tag{4.10}$$

and firm-level resulting profits in equilibrium are

$$\begin{aligned}\{{\pi_l}^*(\alpha), {\pi_s}^*(\alpha)\} = &\left\{ \frac{{C_m}^2(A - \lambda(C_l + C_s))^2}{8\lambda {C_m}^2 - 2\gamma C_m(\gamma + \lambda\delta C_l)(\gamma + \alpha\lambda\delta C_l) + (\gamma + \alpha\lambda\delta C_l)^2 C_e}, \right. \\ &\left. \frac{{C_m}^3(4\lambda C_m - (\gamma + \alpha\lambda\delta C_l)^2)(A - \lambda(C_l + C_s))^2}{(8\lambda {C_m}^2 - 2\gamma C_m(\gamma + \lambda\delta C_l)(\gamma + \alpha\lambda\delta C_l) + (\gamma + \alpha\lambda\delta C_l)^2 C_e)^2} \right\}\end{aligned} \tag{4.11}$$

Proof: See Appendix E. □

Lemma 3 defines the optimal level of environmental performance, and the firm-level profits as a function of the cost savings-sharing level, α. In contrast to Lemma 1, it can be seen that cost savings-sharing ratio impacts the profits of the LSP and shipper, as well as the shipper's target environmental performance. Note that in the absence of cost savings sharing parameter (i.e. $\alpha = 0$) our results fall exactly at what we defined in Lemma 1.

Proposition 4.3. *When a proportion of cost savings, α, resulting from investment in green logistics is shared with the shipper:*

1. *${G_s}^*(\alpha)$ is a maximum at $\alpha = \frac{2C_m\sqrt{2\lambda}-\gamma\sqrt{C_e}}{\lambda\delta C_l\sqrt{C_e}} = \alpha_e^*$*
2. *${\pi_l}^*(\alpha)$ is a maximum at $\alpha = \frac{\lambda\delta C_l C_m-\gamma(C_e-C_m)}{\lambda\delta C_l C_e} = \alpha_l^*$ where $\alpha_l^* < \alpha_e^*$.*
3. *There is a unique value of α, $\alpha = \alpha_s^*$, at which ${\pi_s}^*$ is a maximum and $\alpha_s^* < \alpha_l^* < \alpha_e^*$.*

Proof: See Appendix F. □

Proposition 3 implies that transferring the fraction ${\alpha_s}^*$ of cost savings to the shipper results in a *win-win-win* outcome: both parties' profits, and the green efficiency of the product logistics, improve simultaneously. Figure 3 is representation of Proposition 3, showing that offering a proportion of cost savings can stimulate the shipper's response to greener logistics operations and benefit both parties financially.

Note that that the joint target environmental performance, ${G_s}^*(\alpha)$, is increasing in the proportion of costs savings α transferred by the LSP to the shipper when $\alpha < \alpha_e^*$. This implies that offering a proportion of the LSP's costs savings to the shipper can effectively stimulate the shipper to target greener logistics operations. However, the extent to which an increase in green efficiency of product logistics benefits the parties depends on their positions in the supply chain channel: The parties' profits are a maximum at different levels of the cost savings-sharing ratio, α. In particular, the shipper (follower) requires a lower proportion of the savings than what LSP wants to share in order to reach its optimum level ($\alpha_s^* < \alpha_l^*$); the shipper's benefit resulting from sharing of cost savings is proportionate to that of the LSP's.

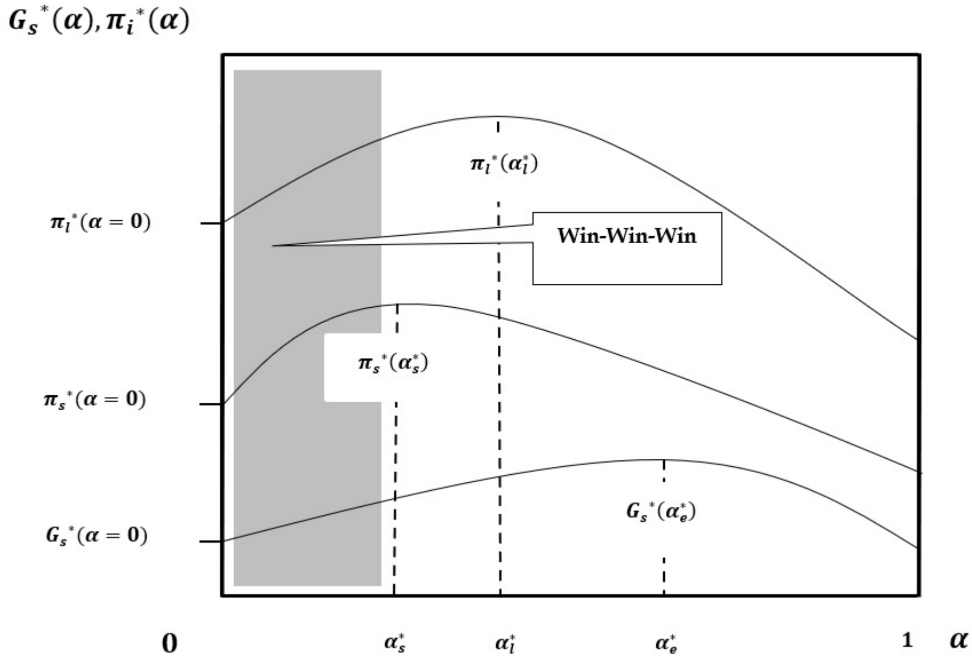

Figure 4.3: **Cost Savings Sharing: A Win-Win-Win Outcome**

We evaluate the effectiveness of cost sharing savings approach in changing shipper's behavior (target environmental level) by analyzing the LSP's (i.e. leader's) optimum level α_l^*. Note that the sharing ratio that optimizes the LSP's profit (α_l^*) is decreasing in consumer sensitivity with respect to environmental performance of product logistics (γ) and green investment cost (C_e), but increasing in consumer sensitivity with respect to retail price (λ), logistics cost (C_l), cost reduction effectiveness of greener logistics (δ), and monitoring costs (C_m). These results are intuitive. First, in the presence of environmentally conscious consumers, and consistent with the results of Proposition 1, a smaller incentive from the LSP is required to improve the environmental target. Moreover, the higher the cost of green investment, the less the LSP is able to share the cost savings with the shipper. In addition, the higher the logistics cost and the cost reduction effectiveness of greener logistics, the more the LSP is willing to stimulate the shipper's environmental ambition through sharing a portion of cost savings. Moreover, the higher the cost of monitoring, the more cost savings required by the shipper to augment its target environmental performance.

4.4.2.2 Monitoring Cost-Sharing Contract

Under a monitoring cost sharing contract, the LSP offers to take on a proportion, θ, of the monitoring cost incurred by the shipper. Assuming a shipper-oriented model, we analyze a two-stage sequential game backwards to derive the sub-game perfect equilibrium (P_l; P_s, G_s) in the presence of incentives, and then characterize the shipper's optimal environmental performance level $G_s^*(\theta)$ and the parties' resulting profits; $\{{\pi_l}^*(\theta), {\pi_s}^*(\theta)\}$. We then discuss the conditions under which the sharing of monitoring cost will improve environmental performance and benefit both parties simultaneously.

Lemma 4.4. *Given $A - \lambda(C_l + C_s) > 0$ and $E < \frac{1}{\delta}$, if $\gamma^2 - 4\lambda C_m(1-\theta) < 0$ then in the presence of monitoring cost sharing incentive, the optimal environmental decision for product logistics is*

$$G_s^*(\theta) = \frac{\gamma C_m(1-\theta)(A - \lambda(C_l + C_s))}{8\lambda {C_m}^2(1-\theta)^2 - 2\lambda\gamma\delta C_l C_m(1-\theta) + \gamma^2(C_e + C_m(3\theta - 2))} \tag{4.12}$$

and the firms' resulting profits in equilibrium are:

$$\{\pi_l{}^*(\theta), \pi_s{}^*(\theta)\} = \frac{{C_m}^2\,(1-\theta)^2 (A-\lambda(C_l+C_s))^2}{8\lambda {C_m}^2\,(1-\theta)^2 - 2\lambda\gamma\delta C_l C_m\,(1-\theta) + \gamma^2\,(C_e + C_m\,(3\theta-2))}, \frac{{C_m}^3 (1-\theta)^3\,(4\lambda C_m\,(1-\theta) - \gamma^2)\,(A-\lambda(C_l+C_s))^2}{(8\lambda {C_m}^2\,(1-\theta)^2 - 2\lambda\gamma\delta C_l C_m\,(1-\theta) + \gamma^2\,(C_e + C_m\,(3\theta-2)))^2} \tag{4.13}$$

Proof: See Appendix E. □

Lemma 4 defines the optimal level of environmental performance and the firm-level profits as a function of the monitoring cost sharing level, θ. In contrast to Lemma 1, it can be seen that monitoring-sharing ratio unequivocally impacts the profit of the LSP and shipper as well as the shipper's target environmental performance.

Proposition 4.4. *When a proportion of monitoring cost, θ, is taken on by LSP:*

1. $G_s{}^*(\theta)$ *is a maximum at* $\theta = 1 - \frac{\gamma^2 (C_e + C_m)}{\gamma C_m \sqrt{2\lambda(C_e+C_m)}} = \theta_e{}^*$
2. $\pi_l{}^*(\theta)$ *is a maximum at* $\beta = \frac{2\lambda\delta C_l C_m - \gamma(2C_e - C_m)}{C_m(3\gamma + 2\lambda\delta C_l)} = \theta_l{}^*$ *where:*

   $\theta_l{}^* < \theta_e{}^*$ *if and only if* $3\gamma + 2\lambda\delta\ C_l < 4\sqrt{2\lambda(C_e + C_m)}$. .
3. *There is a unique value of θ, $\theta = \theta_s{}^*$, at which $\pi_s{}^*$ is a maximum, where $\theta_s{}^* < \min\{\theta_l{}^*, \theta_e{}^*\}$.*

Proof: See Appendix F. □

Proposition 4 suggests that the LSP taking on the proportion $\theta_s{}^*$ of monitoring costs by the LSP results in a *win-win-win* outcome: simultaneously product logistics are greener and both parties are better off. Table 2 summarizes the results brought by the two collaborative mechanisms we present in Propositions 3 and 4.

Table 4.2: **Environmental Target and Parties' Profits under Two Collaborative Mechanisms**

Cost Savings Sharing	Environmental Target	${G_s}^*(\alpha)$ is a maximum at $\alpha = \frac{2C_m\sqrt{2\lambda}-\gamma\sqrt{C_e}}{\lambda\delta C_l\sqrt{C_e}} = \alpha_e^*$
	LSP's Profit	${\pi_l}^*(\alpha)$ is a maximum at $\alpha = \frac{\lambda\delta C_l C_m-\gamma(C_e-C_m)}{\lambda\delta C_l C_e} = \alpha_l^*$ where $\alpha_l^* < \alpha_e^*$.
	Shipper's Profit	${\pi_s}^*$ is a maximum at $\alpha = \alpha_s^*$ where $\alpha_s^* < \alpha_l^* < \alpha_e^*$.
Monitoring Cost Sharing	Environmental Target	${G_s}^*(\theta)$ is a maximum at $\theta = 1 - \frac{\gamma^2(C_e+C_m)}{\gamma C_m\sqrt{2\lambda(C_e+C_m)}} = {\theta_e}^*$
	LSP's Profit	${\pi_l}^*(\theta)$ is a maximum at $\theta = \frac{2\lambda\delta C_l C_m-\gamma(2C_e-C_m)}{C_m(3\gamma+2\lambda\delta C_l)} = {\theta_l}^*$ where: ${\theta_l}^* < {\theta_e}^*$ if and only if $3\gamma + 2\lambda\delta\ C_l < 4\sqrt{2\lambda(C_e+C_m)}$.
	Shipper's Profit	${\pi_s}^*$ is a maximum $\theta = {\theta_s}^*$ where ${\theta_s}^* < \min\{{\theta_l}^*, {\theta_e}^*\}$

Our results are in line with the conditions recommended by Proposition 3. First, the joint target environmental performance, ${G_s}^*(\theta)$, rises in proportion of monitoring costs, θ, taken by the LSP, provided $\theta < \theta_e^*$. Similar to the insight provided by Proposition 3, an increase in green efficiency of product logistics can benefit the parties but to a different extent: The parties' profits are maximized at different levels of the monitoring cost-sharing ratio, θ. In particular, the shipper (follower) benefits less and thus prefers a lower proportion of the monitoring cost to be taken by the LSP in order to reach its optimum level ($\theta_s^* < \theta_l^*$); the shipper's benefit resulting from sharing of monitoring costs is proportionate to that of the LSP's.

We evaluate the effectiveness of cost sharing savings approach in changing shipper's behavior (target environmental level) by analyzing the LSP's (i.e. leader's) optimum level θ_l^*. Note that the proportion of monitoring-sharing ratio that optimizes the LSP's profit (θ_l^*) is decreasing in consumer sensitivity with respect to environmental impacts of product logistics (γ) and green investment cost (C_e), and increasing in consumer sensitivity with respect to retail price (λ), logistics cost (C_l), cost reduction effectiveness of greener logistics (δ), and monitoring costs (C_m). Our results are intuitive. First, in the presence of environmentally aware consumers and in consistent with results brought by Proposition 1, the LSP is required to provide less of an incentive to stimulate the shipper's response to green logistics offerings. Moreover, the higher is the cost of green investment, the less the LSP is able to take on the monitoring costs. Second, the higher the logistics cost and cost reduction effectiveness of greener logistics, the more LSP is willing to stimulate the shipper's environmental ambition through taking on a portion of monitoring costs. Moreover, the higher the cost of monitoring, the higher portion of monitoring costs needs to be taken on by the LSP to augment shipper's target environmental performance.

The results of Propositions 3 and 4 are informative, but do not produce an equilibrium, as at any critical points in parts 2 and 3 of the propositions 3 and 4, the parties are motivated to deviate from their current situation to achieve higher profit. This is a particularly important insight as it provides a foundation for a gain/cost sharing mechanism that the upstream party (i.e. LSP or supplier) may offer to the downstream party shipper (buyer) with a goal of having no party to deviate.

4.5 Concluding Remarks

As observed frequently in the literature, environmental practice in an LSP-shipper interface often gives rise to disagreement, where the shipper is the party who holds power over environmental performance of the logistics service. The dominance of traditional performance objectives in shippers' decision making process can be ascribed to: 1) the parties' lack of understanding of the potential for synergies between economy and ecology, and 2) the costly controls the shipper must sometimes implement (e.g. direct supervision and external audits) to prevent hidden actions (e.g. opportunistic behavior). As a consequence, green logistics offerings are less attractive to shippers.

By considering an LSP's position in its interaction with the shippers , this research has focused on building a foundation on which a collaborative gain-sharing or cost-sharing mechanism can be developed, to show when and how the parties can improve their joint environmental target while improving their financial performance. In particular, our study seeks to address a critical question that arises in the context of mounting pressures to improve environmental outcomes in freight transportation activities: what can be done to achieve *mutually* beneficial LSP-shipper consensus on improved environmental performance levels (i.e. emissions levels)?

To this end, we develop game-theoretic models to analyze how an LSP and a shipper can collaborate to achieve environmental improvements. First, we analyze the non-cooperative (non-collaboration) case, where the LSP is responsible for the *eco-efficient* greening costs, but the shipper determines the environmental performance of the logistics service, taking monitoring costs and consumers' environmental preferences into account. We characterize the shipper's target environmental performance and show that the extent to which a shipper is willing to put efforts in monitoring the LSP's environmental performance heavily depends on the benefits the shipper can achieve as a result of market expansion due to greener logistics of its product. The shipper's willingness to bear higher monitoring costs depends on the relative importance of green product logistics to its retail price in the final market. However, the shipper's target environmental level increases in logistics cost when monitoring cost is sufficiently small. *eco-efficiency* (i.e. savings) achieved by the parties can achieve as a result of greener logistics in the supply chain channel encourages a better environmental target. However, the shipper's target environmental performance is decreasing in the green investment costs, reducing the shipper's willingness to pay extra for green logistics solutions in its supply chain; higher greening costs cancel potential savings in logistics costs.

We further characterize the LSP's favorable environmental target decision if it holds the negotiation power in making the joint environmental decision of the product logistics. By considering the parties' target decisions in a decentralized setting as a possible disagreement point, we explicate the gap between their environmental targets. In particular, we show that the level of consumer sensitivity the environmental impact of product logistics determines a unique threshold for logistics costs at which the parties can reach a consensus on their joint target environmental performance level in the supply chain. In other words, depending on consumer market preferences, there is a unique threshold for logistics cost above which the LSP targets a better environmental performance than the shipper. In fact, the shipper's target environmental performance is not optimal, so that the parties can fully realize the potential eco-efficiency resulting from greener logistics of the product. The better the cost efficiency of greener logistics operations, the lower the logistics cost beyond which the LSP desires better environmental performance. Moreover, the lower the consumer environmental pressure, the greater the logistics cost savings (i.e. greater logistics cost) required to make the LSP more environmentally ambitious than the shipper.

The results of our study help to define an important line of research to explain how the *misalignment* between the parties' favorable environmental action might lead to a *bargaining* process that could end in a desirable equilibrium. Thus, when neither party has enough power to determine the joint target environmental performance on its own, there exists a unique target environmental performance that meets both parties' financial preferences simultaneously. Such target environmental performance lies in a middle range, indicating a balance between the parties' economic and environmental goals in the supply chain.

Next, by referring to the parties' environmental discrepancy in a decentralized setting, we study collaboration in which the LSP provides incentives, such as Cost Savings Sharing Contract or Monitoring Costs Sharing Contract), to the shipper. We characterize conditions under which the LSP stimulates the shipper's response to green logistics service offerings without compromising financial benefits. We also characterize conditions under which the collaboration between the two parties results in a *win-win-win* situation- simultaneous improvement of both parties' profits and the green efficiency of product logistics. We show that the benefit earned by the shipper (follower) earns in the presence of an incentive is proportionate to what the LSP (leader) can realize in the supply chain. Then We evaluate the effectiveness of these approaches in influencing the shipper's target environmental level by analyzing the LSP's (i.e. leader's) optimum level under each strategy.

In fact, both strategies lead to similar results. The more environmentally conscious the consumers, the lower the inventive required to augment the shipper's environmental target, reflecting that the shipper is already under consumer pressures to reduce the environmental impacts of its product logistics. Moreover, the LSP tends to share a lower proportion of cost savings in the presence of high green investment cost. On the other hand, the incentive provided by the LSP is increasing in logistics cost, cost reduction effectiveness of greener logistics, and monitoring costs. In the presence of greater eco-efficiency, the LSP is willing to provide a greater incentives to stimulate the shipper's target environmental level, which in turn result in greater savings in the supply chain channel. Second, the LSP must provide a greater incentive to the shipper when monitoring cost is sufficiently high, incentivizing the shipper for greening the logistics of product.

In particular, we show that offering to share a portion of cost savings due to greener logistics of products or reducing the shipper's burden of monitoring the LSP's environmental performance can simultaneously stimulate the shipper's response to green logistics offerings and increase financial performance. Nonetheless, our analysis indicates that the outcome is not an equilibrium, giving at least one of the parties an incentive to deviate to achieve greater financial benefit. In other words, improved financial results for both parties and improved environmental performance can be realized in the presence of cost savings sharing or monitoring cost sharing, but incongruence between financial benefits and environmental considerations cannot be avoided without other measures. Thus, our results underscore the importance of policy maker intervention by means of incentives (subsidies) or penalties to further stimulate shipper's green behavior and thereby realize synergies between ecology and economy in logistics of product in the supply chain.

In an extension to current study we consider the study of two collaborative mechanisms to further extend our model and analyze the parties' collaboration under two types of sharing contract: (1) Sharing Cost Savings and Revenue; (2) Sharing Monitoring and Greening Costs. We believe that such further analysis is helpful to characterize an equilibrium between the parties' decisions. We address when characterizing when and how collaboration between the two parties in greening logistics operation may not only result in equilibrium but also a *win-win-win* situation covering both parties' profits and their joint environmental decision. In future, We aim to analyze the implications on parties' financial and environmental performance of an *emissions offset mechanism* between the two parties in which the customer (i.e. shipper) has the option to choose a lower price for the LSP's green service offering(s) along with the obligation to invest in CO_2-reduction programs offered by the LSP.

Supply chains will always have an environmental impact because they depend on transportation but, we believe, the environmental performance of supply chains can be maximized through innovation. Our study builds a foundation toward development of new collaborative mechanisms which suit the unique characteristics of the LSP-shipper interface.

4.6 Appendix

4.6.1 Appendix A. Proof of Lemma 1

We analyze a two-stage sequential game to derive the sub-game perfect equilibrium. In the second stage, the shipper (follower) decides retail price P_s^* and desired emission reduction target G_s^* to maximize its profit for any logistics service price P_l offered by LSP. Consider the shipper's profit in (5), $\pi_s(P_s, G) = D(P_s, G)(P_s - C_s - P_l) - C_m(G)^2$. Take the first derivative of the profit with respect to price and solve for P_s; we obtain P_s^*: $\frac{\partial \pi_s(P_s,G)}{\partial P} = 0 \Leftrightarrow P_s^*(P_l,G) = \frac{A+\gamma G}{2\lambda} + \frac{1}{2}(C_s + P_l)$. The second derivative is $-2b < 0$ and therefore the optimal price is a maximum. By substituting P_s^* into the shipper's payoff function for P_s and simplifying we can rewrite $\pi_s(G)$ as $\pi_s(G) = \frac{1}{4\lambda}(A + (\gamma G - \lambda(C_s + P_l)))^2 - C_m(G)^2$ where the demand function is $D(P_l, G) = \frac{1}{2}(A + (\gamma G - \lambda(C_s + P_l)))$. Take the first derivative of $\pi_s(G)$ with respect to emission level and solve for G, obtaining $G_s{}^*$:$\frac{\partial \pi_s(G)}{\partial G} = 0 \Leftrightarrow G_s{}^*(P_l) = \frac{\gamma(A- \lambda(C_s+P_l))}{4\lambda C_m - \gamma^2}$. Taking the second derivative, we have $\frac{\partial^2 \pi_s(G)}{\partial G^2} = \frac{1}{2\lambda}(\gamma^2 - 4\lambda C_m)$. In case $\gamma^2 - 4\lambda C_m < 0$ (second derivative negative) $G_s{}^*$ is a maximum. In the second stage, the LSP (leader) sets the logistics service price P_l^* to maximize its profit. The shipper's optimal emission level, $G_s^*(P_l)$, is dependent on the LSP's optimal price that is calculated based on shipper's decision on its' price and emission level. Thus, $P_l^* = \frac{\gamma^2(-A+\lambda C_s)C_e + \gamma(\gamma(A+\lambda(C_l-C_s)) + 2\lambda C_l(A-\lambda C_s)\delta)C_m - 4\lambda(A+\lambda(C_l-C_s))C_m{}^2}{\lambda\left(\gamma^2 C_e + 2\gamma C_m(\gamma+\lambda\delta C_l) - 8\lambda C_m{}^2\right)}$. The second derivative is negative when $8\lambda C_m{}^2 - 2\gamma\, C_m(\gamma + \lambda\delta C_l) + \gamma^2 C_e$ is positive. Substituting the LSP's optimal price into the shipper's optimal emission level defined in the first stage, we have $G_s^* = \frac{\gamma C_m(A-\lambda(C_l+C_s))}{8\lambda C_m{}^2 - 2\gamma C_m(\gamma+\lambda\delta C_l) + \gamma^2 C_e}$, as stated in Lemma 1. The parties' profits in equilibrium are: $\pi_{l(S)}^* = \frac{C_m{}^2(A-\lambda(C_l+C_s))^2}{8\lambda C_m{}^2 - 2\gamma C_m(\gamma+\lambda\delta C_l) + \gamma^2 C_e}$ and $\pi_{s(S)}^* = \frac{C_m{}^3(4\lambda C_m - \gamma^2)(A-\lambda(C_l+C_s))^2}{(8\lambda C_m{}^2 - 2\gamma C_m(\gamma+\lambda\delta C_l) + \gamma^2 C_e)^2}$ ■.

4.6.2 Appendix B. Proof of Proposition 1

Taking the first derivative of the shipper's optimal environmental performance level, G_s^* we defined in Lemma 1, with respect to shipper's monitoring cost, C_m, we obtain: $\frac{\partial G_s^*}{\partial C_m} = \frac{\gamma(A-\lambda(C_l+C_s))(\gamma^2 C_e - 8\lambda C_m{}^2)}{(8\lambda C_m{}^2 - 2\gamma C_m(\gamma+\lambda\delta C_l) + \gamma^2 C_e)^2}$. It follows that Thus, when $0 < C_m < \frac{\gamma\sqrt{C_e}}{2\sqrt{2\lambda}}$ the quantity $\gamma^2 C_e - 8\lambda C_m{}^2$ is positive and therefore $\frac{\partial G_s^*}{\partial \alpha} > 0$. Also when $C_m > \frac{\gamma\sqrt{C_e}}{2\sqrt{2\lambda}}$, the quantity $(\gamma^2 - 8\lambda\, C_e\alpha^2)$ is negative and, therefore $\frac{\partial G_s^*}{\partial \alpha} < 0$. We conclude that G_s^* is concave in C_m and therefore will have a unique maximum at $C_m = \frac{\gamma\sqrt{C_e}}{2\sqrt{2\lambda}} = \bar{C_m}$.

Taking the first derivative of the shipper's optimal environmental performance level, G_s^* we defined in Lemma 1, with respect to logistics cost, C_l, we obtain the first derivative expression as: $\frac{\partial G_s^*}{\partial C_l} = -\frac{\lambda\gamma C_m(\gamma^2 C_e - 2\gamma(\gamma+(A-\lambda C_l)\delta)C_m + 8\lambda {C_m}^2)}{(8\lambda {C_m}^2 - 2\gamma C_m(\gamma+\lambda\delta C_l)+\gamma^2 C_e)^2}$. It follows that when $0 < C_m < \frac{\gamma((A-\lambda C_s)\delta+\gamma+\sqrt{((A-\lambda C_s)\delta+\gamma)^2 - 8\lambda C_e)}}{8\lambda}$ the quantity $\gamma^2 C_e - 2\gamma(\gamma + (A - \lambda\ C_l)\delta)C_m + 8\lambda {C_m}^2$ is negative and therefore $\frac{\partial G_s^*}{\partial C_l} > 0$. Otherwise, when C_m places beyond the thresholds defined above, the quantity $\gamma^2 C_e - 2\gamma(\gamma + (A - \lambda\ C_l)\delta)C_m + 8\lambda {C_m}^2$ is positive and, therefore $\frac{\partial G_s^*}{\partial C_l} < 0$.

Lastly, taking the first derivative of the shipper's optimal environmental performance level, G_s^* in Lemma 1, with respect to green investment cost, C_e, we obtain the first derivative function: $\frac{\partial G_s^*}{\partial C_e} = \frac{-\gamma^3(A-\lambda(C_l+C_s))C_m}{\left(8\lambda {C_m}^2 - 2\gamma C_m(\gamma+\lambda\delta C_l)+\gamma^2 C_e\right)^2}$ which is always negative and thus $\frac{\partial G_s^*}{\partial C_e} < 0$ ■.

4.6.3 Appendix C. Proof of Lemma 2

We analyze the two-stage sequential game backwards to derive the sub-game perfect equilibrium. In the second stage, the shipper (follower) decides the optimal product price P_s^* to maximize its profit. Consider the shipper's payoff function in (5), $\pi_s(P_s, G) = D(P_s, G)(P_s - C_s - P_l) - C_m(G)^2$, and take the first derivative with respect to price, and solve for P_s, We obtain P_s^*: $\frac{\partial \pi_s(P_s,G)}{\partial P} = 0 \Leftrightarrow P_s^*(P_l, G) = \frac{A+\gamma G}{2\lambda} + \frac{1}{2}(C_s + P_l)$. The second derivative is $-2b < 0$ and therefore the optimal price is a maximum. Consider the LSP's payoff function defined in (4), $\pi_l(P_l, G) = D(P_s,\ G)(P_l - C_l(1 - \delta G)) - C_e(G)^2$. Anticipating the shipper's best response for product retail price, in the first stage the LSP (leader) sets the logistics service price P_l^* and the desired emission reduction target G_l^* to maximize its profit. Taking the first derivative of the LSP profit with respect to logistics service price and solving for P_l, we obtain ${P_l}^*$:$\frac{\partial \pi_l(P,G)}{\partial P} = 0 \Leftrightarrow P_l^*(G) = \frac{A+\gamma G}{2\lambda} + \frac{1}{2}(C_l(1 - \delta G) - C_s)$. The second derivative is $-2b < 0$ and therefore the optimal price is a maximum. By substituting P_l^* into the LSP's payoff function for P_l and simplifying we can rewrite $\pi_l\left(P_l, G\right)$ as $\pi_l\left(G\right) = \frac{1}{8\lambda}\left(A + (\gamma G - \lambda(C_l(1-\delta G) + C_s))\right)^2 - C_e\left(G\right)^2$ where the demand function is $D\left(G\right) = \frac{1}{4}(A + (\gamma G - \lambda(C_l(1-\delta G) + C_s)))$. Taking the first derivative of $\pi_l\left(G\right)$ with respect to emission level and solving for G, we obtain G_l^*: $\frac{(\gamma+\lambda\delta C_l)(A-\lambda(C_l+C_l))}{8\lambda C_e-(\gamma+\lambda\delta C_l)^2}$. Taking the second derivative, we have $\frac{\partial^2\pi_l(G)}{\partial G^2} = \frac{1}{4\lambda}((\gamma+\lambda\delta C_l)^2 - 8\lambda\ C_e)$. In case $(\gamma+\lambda\delta C_l)^2 - 8\lambda\ C_e < 0$ (second derivative negative) $G_l{}^*$ is a maximum and we characterize G_l^* as stated in Lemma 2. The parties' profits in equilibrium are: $\pi_{l(L)}^* = \frac{C_e(A-\lambda(C_l+C_s))^2}{8\lambda C_e-(\gamma+\lambda\delta C_l)^2}$ and $\pi_{s(L)}^* = \frac{(4\lambda C_e{}^2-C_m(\gamma+\lambda\delta C_l)^2)(A-\lambda(C_l+C_s))^2}{8\lambda C_e-(\gamma+\lambda\delta C_l)^2}$. Note that the LSP's profit is always positive given the condition defined for concavity of the LSP's profit function. The shipper's profit is always positive when $4\lambda C_e{}^2 - C_m\left(\gamma+\lambda\delta C_l\right)^2 > 0$ ■.

4.6.4 Appendix D. Proof of Proposition 2

Referring to the optimality conditions defined for both parties' desired environmental performance (Lemmas 1 and 2), we focus our analysis on the intersection between optimal emission level G_l^* and G_s^*. We always consider the conditions that ensure the concavity and positivity of profit functions as characterized in Lemmas 1 and 2. In particular, we characterize the conditions that make $\Delta G = |G_s^* - G_l^*|$ either zero (matches) or positive (gaps). $\Delta G = |G_s^* - G_l^*| = |\frac{(A-\lambda(C_l+C_s))\left(\gamma^2+\lambda\gamma\delta C_l-8\lambda C_e\right)(\lambda\delta C_l C_m+\gamma(C_m-C_e))}{\left(8\lambda C_e-(\gamma+\lambda\delta C_l)^2\right)\left(8\lambda C_m{}^2-2\gamma C_m(\gamma+\lambda\delta C_l)+\gamma^2 C_e\right)}|$. Now we analyze the critical points at which $G_s^* = G_l^*$. By considering the $G_s^* - G_l^*$ expression stated above, it is straightforward to see that there are three critical points at which $G_s^* = G_l^*$: $C_{l_1} = \frac{8\lambda C_m-\gamma^2}{\gamma\lambda\delta}$, $C_{l_2} = \frac{\gamma(C_e-C_m)}{\lambda\delta C_m}$, and $C_{l_3} = \frac{A-\lambda C_s}{\lambda}$. The third possible value for regulatory measures , C_{l_3}, is excluded from our analysis since it corresponds to the maximum level of logistics cost under which both parties can operate profitably when decreasing the environmental impact of their operations (see Lemmas 1 and 2). By taking the feasibility conditions of Lemmas 1 and 2 we can show that when $2C_m < C_e$: 1) if $\frac{\gamma^2}{4C_m} \leq \lambda < \frac{\gamma^2 C_e}{8{C_m}^2}$ then $G_l^* > G_s^*$ if and only if $C_{l_1} > \frac{8\lambda C_m - \gamma^2}{\gamma\lambda\delta}$; 2) if $\frac{\gamma^2 C_e}{8{C_m}^2} \leq \lambda$ then $G_l^* > G_s^*$ if and only if $C_{l_2} > \frac{\gamma(C_e - C_m)}{\lambda\delta C_m}$. This implies that when $2C_m < C_e$ then : 1) if $\frac{2C_m\sqrt{2\lambda}}{\sqrt{C_e}} < \gamma \leq 2\sqrt{C_m\lambda}$ and $C_l > \frac{8\lambda C_m - \gamma^2}{\gamma\lambda\delta}$ then $G_l^* > G_l^*$; 2) if $\gamma \leq \frac{2C_m\sqrt{2\lambda}}{\sqrt{C_e}}$ and $C_{l_2} > \frac{\gamma(C_e - C_m)}{\lambda\delta C_m}$ then $G_l^* > G_l^*$. Now we examine the situation under which $C_e < 2C_m$. Note that $C_e > C_m$ must always hold so the match points can occur at C_{l_2}. Under this condition, the area under which the shipper's profit function reaches a maximum shrinks: when $C_m < C_e < 2C_m$ then $2\sqrt{C_m\lambda} < \frac{2C_m\sqrt{2\lambda}}{\sqrt{C_e}}$ and $G_l^* > G_l^*$ if $C_{l_2} > \frac{\gamma(C_e - C_m)}{\lambda\delta C_m}$. We obtain the conditions under which $|G_s^* - G_l^*| \neq 0$ as stated in Proposition 2 ■.

4.6.5 Appendix E. Proof of Lemma 3

Under a cost savings sharing contract, the LSP offers a proportion of cost savings, α, achieved as a result of collaboration for greener logistics operations. We re-define the LSP's profit function in (4) and shipper's profit function in (5) as follows: $\pi_l\left(P_l, G\right) = D\left(P_s,\ G\right)\left(P_l - C_l(1-(1-\alpha)\delta G)\right) - C_e\left(G\right)^2$ and $\pi_s\left(P_s, G\right) = D\left(P_s, G\right)\left(P_s - C_s - P_l + \alpha\delta G C_l\right) - C_m\left(G\right)^2$, respectively. Following the steps of Lemma 1 we derive the parties' optimal decisions and their respective profits in equilibrium as stated in Lemma 3 ■.

4.6.6 Appendix F. Proof of Proposition 3

Drawing on the results brought by Lemma 3, we examine the implications on joint environmental decision and parties' profits when a proportion of green efficiency achieved as the result of greener logistics is transferred. Taking the first derivative of joint environmental decision, $G_s^*(\alpha)$, with respect to cost savings sharing parameter , α we obtain: $\frac{\partial G_s^*(\alpha)}{\partial\alpha} = \frac{\lambda\delta C_l C_m(A-\lambda(C_l+C_s))(8\lambda {C_m}^2 - C_e(\gamma+\alpha\lambda\delta C_l)^2)}{(8\lambda {C_m}^2 - 2C_m(\gamma+\alpha\lambda\delta C_l)(\gamma+\lambda\delta C_l)+(\gamma+\alpha\lambda\delta C_l)^2 C_e)^2}$. Solving for α we have: $\alpha_1 = \frac{-(2C_m\sqrt{2\lambda}+\gamma\sqrt{C_e})}{\lambda\delta C_l\sqrt{C_e}}$ and $\alpha_2 = \frac{2C_m\sqrt{2\lambda}-\gamma\sqrt{C_e}}{\lambda\delta C_l\sqrt{C_e}}$. This implies that $\frac{\partial G_s^*(\alpha)}{\partial\alpha} > 0$ when $\alpha_1 < \alpha < \alpha_2$, otherwise it is negative. Thus, $G_s^*(\alpha)$ is a maximum at $\alpha = \alpha_2 = \alpha_e^*$.

Taking the first derivative of the LSP's profit, ${\pi_l}^*(\alpha)$, with respect to cost savings sharing parameter, α we obtain: $\frac{\partial {\pi_l}^*(\alpha)}{\partial\alpha} = \frac{(A-\lambda(C_l+C_s))^2 {C_m}^2(-2\lambda\delta C_l C_e(\gamma+\alpha\lambda\delta C_l)+2\lambda\delta C_l(\gamma+\lambda\delta C_l)C_m)}{(8\lambda {C_m}^2-2C_m(\gamma+\alpha\lambda\delta C_l)(\gamma+\lambda\delta C_l)+(\gamma+\alpha\lambda\delta C_l)^2 C_e)^2}$. Solving for α we have: $\alpha = \frac{\lambda\delta C_l C_m-\gamma(C_e-C_m)}{\lambda\delta C_l C_e} = \alpha_l$. This implies that $\frac{\partial {\pi_l}^*(\alpha)}{\partial\alpha} > 0$ when $\alpha < \alpha_l$ and is negative when $\alpha > \alpha_l$. Thus we show that ${\pi_l}^*(\alpha)$ is maximum at $\alpha_l^* = \frac{\lambda\delta C_l C_m-\gamma(C_e-C_m)}{\lambda\delta C_l C_e}$ and the LSP's profit function is concave (second derivative expression not provided for brevity). By comparing α_e^* and α_l^* we have: $\alpha_l^* = \frac{\lambda\delta C_l C_m-\gamma(C_e-C_m)}{\lambda\delta C_l C_e} < \frac{2C_m\sqrt{2\lambda}-\gamma\sqrt{C_e}}{\lambda\delta C_l\sqrt{C_e}} = \alpha_e^*$ if and only if $\gamma+\lambda\delta C_l < 2\sqrt{2\lambda C_e}$ which must always hold. First, recall that in order for shipper's profit function to be concave we had $\gamma+\alpha\lambda\delta C_l < 2\sqrt{\lambda C_m}$; when $\alpha = 1$ then $\gamma+\lambda\delta C_l$ is maximum and should be less than $2\sqrt{2\lambda C_m}$. Second, $\sqrt{\lambda C_m} < \sqrt{2\lambda C_e}$ always holds when $C_m < C_e$. This implies that $\alpha_l^* < \alpha_e^*$.

Taking the first derivative of the shipper's profit, ${\pi_s}^*(\alpha)$, with respect to cost savings sharing parameter, α we characterize the first derivative function as follows: $\frac{\partial {\pi_l}^*(\alpha)}{\partial\alpha} = \frac{2\lambda C_l\delta {C_m}^3(A-\lambda(C_l+C_s))^2(C_e(\gamma+\alpha\lambda\delta C_l)^3-8\lambda C_e(\gamma+\alpha\lambda\delta C_l)C_m-8\lambda^2\delta C_l(-1+\alpha){C_m}^2)}{(8\lambda {C_m}^2-2C_m(\gamma+\alpha\lambda\delta C_l)(\gamma+\lambda\delta C_l)+(\gamma+\alpha\lambda\delta C_l)^2 C_e)^3}$. In order to analyze the first derivative function behavior with respect to α we focus on $C_e(\gamma+\alpha\lambda\delta C_l)^3 - 8\lambda\ C_e(\gamma+\alpha\lambda\delta\ C_l)C_m - 8\lambda^2\delta\ C_l(-1+\alpha){C_m}^2$ expression. Solving for α we get three potential roots where one of the roots (i.e. α_s^* maximizes the shipper's profit function ${\pi_s}^*(\alpha)$ (three roots and second derivative not provided for brevity). Substituting α_l^* into the first derivative function (i.e. $\frac{\partial {\pi_l}^*(\alpha)}{\partial\alpha}$) we have: $\frac{\partial {\pi_l}^*(\alpha)}{\partial\alpha} = -\frac{2\lambda\delta C_l C_e(A-\lambda(C_l+C_s))^2 C_e(\gamma+\lambda\delta C_l)}{(8\lambda C_e-(\gamma+\lambda\delta C_l)^2)^2}$ which is always negative. This implies that $\alpha_s^* < \alpha_l^*$. Thus we obtain the results as stated in Proposition 3 ■.

4.6.7 Appendix G. Proof of Lemma 4

Under a cost savings sharing contract, the LSP offers a proportion of cost savings, α, achieved as a result of collaboration for greener logistics operations. We re-define the LSP's profit function in (4) and shipper's profit function in (5) as follows: $\pi_l\left(P_l, G\right) = D\left(P_s, G\right)\left(P_l - C_l(1-\delta G)\right) - \left(C_e + \theta C_m\right)\left(G\right)^2$ and $\pi_s\left(P_s, G\right) = D\left(P_s, G\right)\left(P_s - C_s - P_l + \alpha\delta G C_l\right) - (1-\theta)C_m\left(G\right)^2$, respectively. Following the steps of Lemma 1 we derive the parties' optimal decisions and their respective profits in equilibrium as stated in Lemma 4 ■.

4.6.8 Appendix H. Proof of Proposition 4

Drawing on the results brought by Lemma 4, we examine the implications on joint environmental decision and parties' profits when a proportion of green efficiency achieved as the result of greener logistics is transferred. Taking the first derivative of joint environmental decision, $G_s^*(\theta)$, with respect to monitoring costs sharing parameter , θ we obtain: $\frac{\gamma C_m(A-\lambda(C_l+C_s))(8\lambda {C_m}^2(-1+\theta)^2-\gamma^2(C_e+C_m))}{(8\lambda {C_m}^2(1-\theta)^2-2\lambda\gamma\delta C_l C_m(1-\theta)+\gamma^2(C_e+C_m(3\theta-2)))^2}$. Solving for θ we have: $\theta_1 = 1 - \frac{\gamma^2(C_e+C_m)}{\gamma C_m\sqrt{2\lambda(C_e+C_m)}}$ and $\theta_2 = 1 + \frac{\gamma^2(C_e+C_m)}{\gamma C_m\sqrt{2\lambda(C_e+C_m)}}$. This implies that $\frac{\partial G_s^*(\alpha)}{\partial\alpha} < 0$ when $\theta_1 < \theta < \theta_2$, otherwise it is positive. Thus, $G_s^*(\theta)$ is a maximum at $\theta = \theta_1 = \theta_e^*$.

Taking the first derivative of the LSP's profit, ${\pi_l}^*(\theta)$, with respect to cost savings sharing parameter, θ we obtain: $\frac{\partial {\pi_l}^*(\theta)}{\partial\theta} = \frac{\gamma {C_m}^2(A-\lambda(C_l+C_s))^2(-1+\theta)(2\gamma C_e+2\lambda\delta C_l(-1+\theta)y+\gamma(-1+3\theta)C_m)}{(8\lambda {C_m}^2(1-\theta)^2-2\lambda\gamma\delta C_l C_m(1-\theta)+\gamma^2(C_e+C_m(3\theta-2)))^2}$. Solving for θ we have: $\theta_1 = \frac{2\lambda\delta C_l C_m-\gamma(2C_e-C_m)}{C_m(3\gamma+2\lambda\delta C_l)}$ and $\theta_2 = 1$. This implies that $\frac{\partial {\pi_l}^*(\theta)}{\partial\theta} > 0$ when $\theta < \theta_l$ and is negative when $\theta_1 < \theta < \theta_2 = 1$. Thus we show that ${\pi_l}^*(\theta)$ is maximum at

$\theta_l^* = \frac{2\lambda\delta C_l C_m - \gamma(2C_e - C_m)}{C_m(3\gamma + 2\lambda\delta C_l)}$ and the LSP's profit function is concave (second derivative expression not provided for brevity). By comparing θ_e^* and θ_l^* we have: $\theta_l^* = \frac{2\lambda\delta C_l C_m - \gamma(2C_e - C_m)}{C_m(3\gamma + 2\lambda\delta C_l)} < 1 - \frac{\gamma^2(C_e + C_m)}{\gamma C_m \sqrt{2\lambda(C_e + C_m)}}$ if and only if $3\gamma + 2\lambda\delta C_l < 4\sqrt{2\lambda(C_e + C_m)}$.

Taking the first derivative of the shipper's profit, ${\pi_s}^*(\theta)$, with respect to cost savings sharing parameter, θ we characterize the first derivative function as follows: $\frac{\partial {\pi_s}^*(\theta)}{\partial \theta} = \frac{(\gamma(A - \lambda(C_l + C_s))^2(-1+\beta)^2 {C_m}^3(3\gamma^3 C_e + \gamma(2\lambda(8C_e + \gamma\delta C_l)(-1+\theta) + 3\gamma^2\theta)C_m + 16\lambda(-1+\theta)(\lambda\delta C_l(-1+\theta) + \gamma\theta){C_m}^2))}{(8\lambda {C_m}^2(1-\theta)^2 - 2\lambda\gamma\delta C_l C_m(1-\theta) + \gamma^2(C_e + C_m(3\theta - 2)))^3}$. Solving for θ we get two roots in which the shipper's profit is a maximum at the smaller root: $\frac{(-3\gamma^3 - 2\lambda\gamma^2 C_l\delta + 32\lambda^2 C_l\delta C_m + \gamma(16\lambda(C_e - C_m) \pm \sqrt{9\gamma^4 + 12b\gamma^3 C_l\delta + 4\lambda\gamma^2(-24C_e + \lambda {C_l}^2 w^2 - 24C_m) - 128\lambda^2\gamma C_l\delta(C_e + C_m) + 256\lambda^2(C_e + C_m)^2}))}{32\lambda C_m(\gamma + \lambda\delta C_l)}$. This implies that $\frac{\partial {\pi_s}^*(\theta)}{\partial \theta} < 0$ when $\theta_1 < \theta < \theta_2$ and is positive otherwise. Thus we show that ${\pi_s}^*(\theta)$ is maximum at θ_l^* (i.e. smaller root) as stated above; the shipper's profit function is concave (second derivative expression not provided for brevity). Substituting θ_e^* and θ_l^* into the first derivative function (i.e. $\frac{\partial {\pi_s}^*(\theta)}{\partial \theta}$) we have: $\frac{\partial {\pi_s}^*(\theta_l^*)}{\partial \theta} = -\frac{4(A - \lambda(C_l + C_s))^2(3\gamma + 2\lambda\delta C_l)^2 C_m}{(-32\lambda C_e + (3\gamma + 2\lambda\delta C_l)^2 - 32\lambda C_m)^2}$ which is always negative. Moreover, we also obtain $\frac{\partial {\pi_s}^*(\theta_e^*)}{\partial \theta} = -\frac{2\gamma(A - \lambda(C_l + C_s))^2 {C_m}^3(3\sqrt{2}\gamma^3 C_m + 2\sqrt{2}\lambda\gamma^2\delta C_l C_m - 8\lambda\delta C_l\sqrt{\lambda\gamma^2 {C_m}^2(C_e + C_m)} + 4\gamma(4\sqrt{2}\lambda C_m(C_e + C_m) - 5\sqrt{\lambda\gamma^2 {C_m}^2(C_e + C_m)})))}{(-\sqrt{2}\gamma(3\gamma + 2\lambda\delta C_l)C_m + 8\sqrt{\lambda\gamma^2 {C_m}^2(C_e + C_m)})^3}$ which we show is always negative given the conditions we defined earlier (i.e. $3\gamma + 2\lambda\delta C_l < 4\sqrt{2\lambda(C_e + C_m)}$ and $\theta_l^* < \theta_e^*$ or $3\gamma + 2\lambda\delta C_l > 4\sqrt{2\lambda(C_e + C_m)}$ and $\theta_e^* < \theta_l^*$) . This implies that $\theta_s^* < \theta_l^* < \theta_e^*$ or $\theta_s^* < \theta_e^* < \theta_l^*$. Thus we obtain the results as stated in Proposition 4 ■.

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Chapter 5

Conclusions and Future Research Directions

To green supply chains, environmental initiatives are a necessity for supply chain parties who must respond to the environmental concerns of governments, end-consumers, and other stakeholders. Firms must take initiatives aimed at greening supply chain and reducing carbon footprints. To adapt to these requirements, firms must effectively achieve eco-efficiency in their operations, simultaneously meeting both economic and environmental goals. To a great extent, feasibility depends on leveraging these steps as a marketing lever to maintain market share.

Recent studies of the interactions of LSPs and their customers, the shippers, suggest friction between them on green logistics services as offerings or requirements; in other words, the parties' goals on environmental issues are misaligned. Content analysis of the literature in research on this area displays a general consensus that buyers influence the adoption of green initiatives and the purchasing decision process. However, there has been little analysis of how this influence can translate into adoption of collaborative environmental initiatives.

In the **First Essay**, content analysis of green supply chain research demonstrates that the general dependency of LSPs on shippers – the power/interdependence structure – plays a central role in the adoption of green initiatives in that the shipper is the party who ultimately sets conditions on coordination of environmental practices. In fact, the parties' environmental goal misalignment stems from a gap between the LSP's green offerings and the shipper's perceived value of those opportunities. The shipper's intra-organizational misalignment (i.e. contradictory objectives among shipper's organizational/functional units) transfer into an inter-organizational misalignment between LSPs and shippers on environmental issues. Thus, if environmental performance indicators are not compatible with economic/operational indicators, green initiatives will not be undertaken. Drawing on inter-organizational theories (resource dependence theory), we propose contracts based on new revenue models or pricing schemes that link environmental criteria to operational requirements. The shipper's perception of the LSP's green practices may change when such initiatives are integrated into the LSP's general offerings, increasing awareness of the impact of green logistics on economic and operational metrics. However, the lack of a standard methodology to measure the environmental impacts of logistical activities remains a key impediment to the realization of environmental collaboration in the LSP-shipper interface; LSPs may simply be unable to communicate the value of environmental improvements.

The analysis of market pressures on a shipper's environmental ambition demonstrates that the shipper's environmental behavior mainly reflects market pressures on shipper's internal, industry-related activities, as opposed to green logistics activities. Moreover, the environmental impacts of shipper's logistical activities are usually less visible to the public, making it less critical for shippers to invest in green logistics. This is particularly relevant to those shippers operating in B2B markets, as opposed to those operating in B2C markets. In addition to the weak environmental consciousness of customers and consumers, the transport industry faces an unclear regulatory framework that is broadly aimed at reducing the environmental impacts of logistics with respect to CO_2 emissions. More importantly, it is unclear which party should pay the marginal costs of logistics activities on the eco-system and the community. Given the dependence structure of LSP and shipper on the one hand, and the shipper's low exposure to the public on the other, our study suggests two key policies: 1) Penalty Distribution; and 2) Carbon Labelling of products, inclusive of logistics. These measures will increase transparency by making the shipper's impact on ecology more visible, and will change the interdependence structure in the LSP-shipper interface, making the shipper more reliant on the LSP's green capabilities and thus motivating closer collaboration toward achieving green targets.

Consistent with our earlier discussion, the dependence structure in the LSP-shipper interface and the shipper's low perceived risk for non-green logistics activities propel a shipper toward a non-collaborative strategy to mitigate monitoring risk, involving direct supervision and external auditing. The LSP's lack of an environmental measuring system increases the shipper's transaction costs in a way that makes green logistics offerings more costly and less attractive. This implies that investment in ICT encourages green collaboration between LSP and shipper. In other words, investing in increasing the visibility of logistics activities helps the LSP collect environmental data linked to economic and operational metrics, reducing the shipper's transaction costs and making it easier to reach a mutual agreement about sharing the costs and benefits of green initiatives.

Our study presents an agenda for future research, beginning with an overview of theoretical issues that must be addressed to enable LSPs and shippers to collaborate on environmental initiatives. Our conceptual framework and its implications will serve as a reference for practitioners and policy-makers as they move toward a less carbon-intensive freight transport industry. We point out the urgent need for further studies on development of a standard methodology for measuring the environmental impacts of product logistics along the supply chain. Such a method is a prerequisite to transition to greener logistics:

1) It facilitates gain-sharing or cost-sharing contracts between the LSP and shipper, based on environmental improvements and their implications on economic and operational metrics;

2) It makes possible the carbon-labelling of products, thereby increasing transparency on negative externalities of product shipments;

3) It is critical to alleviation of transactions costs resulting from the shipper's sustainability risk, including agency problems or opportunistic behaviors, thereby facilitating closer collaboration between the parties.

In addition, and in line with resource dependence theory and stakeholder theory, there is a need for empirical evidence on how consumer and regulatory pressures can affect the parties' behavior. In particular, the moderating impact of market pressures (consumer environmental pressures and transparency) on power/dependence imbalances and environmental collaboration is worth examining. First, does consumer environmental consciousness and increasing awareness of the environmental impacts of product logistics change purchasing behavior? Second, when and how can regulatory measures be imposed on the parties help to change their attitudes, reducing the environmental gap?

In line with agency theory and transactions cost economics, the impact of measures to reduce transaction costs, have not yet been examined. This is surprising, in view of the attention of academics and practitioners paid to revolutionary technologies, such as Blockchain and IoT, that have this effect. In other words, the mediating impacts of new technologies on parties' environmental collaboration is worth considering; adoption of new technologies that reduce transactions costs and limit opportunistic behavior (i.e. hidden actions), will certainly facilitate closer supply chain relations and environmental collaboration on product logistics.

In the **Second Essay**, we operationalize the insights from our conceptual framework by demonstrating analytically that the parties' actions in support of a target level of environmental performance may differ depending on which party holds the power to make joint emissions target decision. The mismatch between the parties' desired environmental performances results from differences in their perceptions of consumers' environmental pressure and policy measures, as well as friction regarding the sharing of investment costs for greening product logistics.

When policy measures are strong enough, LSP always seeks better environmental performance regardless of the shipper's level of contribution to green logistics. But when regulatory measures are moderate, the shipper targets lower emissions levels and increases its contribution to green investment only up to the point where the additional cost is offset by the gain at the final market. Another observation is that, in the presence of a carbon tax, the more environmentally conscious the consumers, the more likely the shipper aims for better environmental performance. Increasing consumer environmental pressure pushes both parties to reduce their target emission levels equally, even though part of the LSP's profit is spent on carbon tax, making the LSP's response to consumer pressures weaker than the shipper's.

To quantify the discrepancy between the parties over responsibility for green investment costs, we characterize each party's optimal contribution to green investment, which may be determined by either party, or by negotiation. If the setting is decentralized, then no matter which party decides the joint environmental target level for product logistics, each party's optimal level of green investment is suboptimal from the other party's perspective; agreement to share responsibility for green investment is impossible. If the green investment cost is large enough, negotiation – modelled by Nash Bargaining – allows the parties to reach a consensus on sharing green investment, with the agreement point between their optimal contributions in the absence of bargaining.

We respond to debates on policy measures in the logistics industry by analyzing the implications for parties' environmental decisions by analyzing the implications for parties' environmental decisions when they share responsibility for a carbon tax. When a portion of that tax is imposed on the shipper, the LSP's emission target remains unchanged. We argue that the shipper's desire to increase the product price is offset by the LSP's willingness to reduce the logistics price to reflect the carbon tax distribution. Under this condition, the shipper increases its green investment to achieve better environmental performance. Our analysis indicates that the optimal proportion of carbon tax to be imposed on the shipper depends on the shipper's level of contribution to green investment, which ultimately reflects consumer consciousness of the environmental impacts of product logistics.

One important limitation of our model is that there is no attempt to capture explicitly the operational aspects of greening logistics. We focus on green technologies and make no allowance for how logistics operations are managed. This allows us to develop a stylized supplier-buyer game model, which permits us to analyze the strategic incentives of the LSP (supplier) and the shipper (buyer) over green investment, in the face of consumer environmental pressures and, possibly, a carbon tax. In particular, we assume that the logistics operation is optimally eco-efficient for any given level of green investment. Effectively, our model assumes that the parties have agreed to adopt Green Vehicle Technologies that achieve the highest potential abatement and maximally reduce the carbon intensity of logistics operations. We hope that future research will throw some light on the impact of less-than-optimal eco-efficiency on parties' environmental targets.

We model a two-echelon supply chain consisting of one service supplier (LSP) and one buyer (shipper). Despite this, we are confident that our conclusions are appropriate to many other settings, such as the interaction of one LSP with multiple shippers, provided one shipper (buyer) uses the majority of the LSP's resources. In other words, our analysis holds when the shipper is the major customer of the LSP and dominates the market in which it delivers its product; in other words, the competition between shippers is not fierce. In this setting, eco-efficiency is an issue, as the LSP may not be able to share with other clients the resources that it dedicates to the dominant shipper. In this case, the parties' environmental targets are limited to their one-to-one interactions; other shippers are not powerful enough to affect their decisions.

In the case of multiple shippers who compete in the final market, the insights of our analysis generally hold, but a few changes are to be expected. When the LSP serves multiple shippers producing and delivering a similar product, all shippers are under the same industry, market, and regulatory pressures, and thus can be expected to take similar approaches to managing logistics operations and environmental impact. The LSP perceives the environmental ambition (target) of its clients, which acts as a baseline for the LSP and may or may not be aligned with its own target. However, in this setting, the expected return to LSP would be higher than the situation where the LSP serves a single shipper. In other words, it would make more sense for the LSP to target a better environmental performance than the situation where it serves only one shipper; the LSP is likely to achieve more benefit from its one time investment in green technologies because the resources can be shared across multiple shippers. However, we expect that, from the LSP's point of view, the impact from market expansion is marginal compared to serving one dominant player (shipper) because the aggregate demand across multiple shippers may now shift between different players at the final market, so that the LSP's environmental target is more affected by the factors directly affecting the LSP (i.e. Carbon Tax, logistics cost, green investment). In other words, competing on target environmental performance may shift demand from one shipper to another one at the final market, but it does not necessarily affect aggregate demand function; The demand in the LSP profit function is for logistic services across all shippers. Therefore, the impact on the LSP is negligible because consumers are simply shifting among firms, whereas for the firm (shipper) changes in environmental performance can shift their demand function.

The imposition of an explicit trade-off or weight between the two dimensions of sustainability (profit and environment) is not directly modeled in our analysis.An alternative approach to analyze the environmental gap is to model the interactions between LSP and shippers in a structure where each party has a weighted profit function with economic and environmental objectives. Thus, the parties' decisions are the weights to be placed on each objective (economic vs. environment). In this situation, each player has the same arguments (objectives) in its profit function, but with different weights which may cause an environmental gap. The model can be extended to a structure where either the LSP or the shipper, or both, have a fixed weight on either economic or environmental objectives; depending on parties' power structure one party is obligated to follow the dominant player's decision. Otherwise, the parties may enter into a negotiation where each party has a fixed cap for its environmental (economic) objectives. Thus, in case each party has its own economic/environmental objectives and the power structure is in balance, the parties may end up an equilibrium between their economic/environmental objectives, in other words, deciding how much profit to give up for the environment and vice versa.

In this context, the alternative model can measure parties' "environmental ambition" in which a firm wants to have a better environmental outcome at the expense of profit. In comparison to the alternative model discussed, in our model, we implicitly assign a (positive or negative) weight to Corporate Social Responsibility (CSR) in parties' profits. We weight environmental concerns against profit by putting a monetary value attached to different factors constituting the parties' profits; carbon tax (cost efficiency), market impact or consumer sensitivity to logistics emissions, green investment, etc. In fact, the financial burden of green logistic is defined as additional costs incurred by parties to green their operations, plus any penalty levied by regulatory agencies for failing to achieve environmental standards (i.e. reduced cost efficiency as a result of not greening operations) or any loss as a result of reduced demand due to non-green logistics of product. Thus, our model does capture the interaction between above economic and environmental objectives and show how the parties put higher importance (weight) to environment (by targeting a lower or higher emission level/environmental performance) when based on revenue and costs when maximizing their profits.

A numerical study would help to further illuminate the results brought by our analysis. In particular, numerical study would help to examine the impact of a change in cost parameters (including carbon tax), and consumer sensitivities to price and products logistics emissions or their relative values on firms' target environmental performance levels, the environmental gap, logistics service and product retail prices, and the parties' respective profits. It would also help to demonstrate the parties' conflict over responsibility over green investment; it illustrates how the share of green investment between the parties may change with a change in aforementioned parameters when either LSP, shipper, or negotiation between the parties determine the relative share of green investment in the supply chain.

As observed frequently in the current literature, environmental practice in an LSP-shipper interface often gives rise to disagreement, when the shipper is the party who holds power over environmental performance of the logistics service. In future research, our main focus will be to characterize the conditions under which the parties' emissions target decisions in a decentralized setting approach the environmental goals that would ideally be achieved in a centralized setting. In particular, by considering the parties' emissions target decisions in a decentralized setting as a possible disagreement point, we are working to develop a collaborative gain-sharing or cost-sharing mechanism to allow parties to reduce the environmental gap in the LSP-shipper interface, showing when and how the parties can achieve their joint environmental targets while improving their financial performance.

The **Third Essay** extends the insights of the Second Essay by analyzing the LSP's interaction with the shipper, shedding light on conditions under which the parties can improve their joint environmental target while simultaneously improving their financial performance. We show when and how the parties can achieve mutually beneficial consensus on improving environmental performance levels. We show analytically that the shipper's behavior with respect to the environmental performance of product logistics reflects a trade-off between shipper's monitoring efforts and the economic benefits the party achieves due to market expansion driven by greener product logistics, provided green product logistics are sufficiently important to the retail price in the final market. When monitoring cost is low, the shipper's target environmental performance reflects a trade-off of greening investment cost against the eco-efficiency achieved as a result of greener logistics in the supply chain channel: the greater the relative efficiency of green logistics to its costs, the better environmental performance the shipper seeks in the supply chain. The shipper's behavior reflects the LSP's tendency to offer a lower price when eco-efficiency resulting from greener product logistics compensates for the associated costs.

The analysis of LSP's environmental actions in a decentralized setting demonstrates that, when logistics cost is high enough, the shipper's target environmental performance is not necessarily aligned with that of the LSP; the shipper's environmental actions may sometimes prevent the parties from reaping the eco-efficiencies that green logistics can deliver. The LSP's relative environmental ambition is stronger in the presence of greater consumer environmental pressure and greater cost effectiveness of green logistics, reflecting that adopting green logistics creates greater potential savings and other benefits.

Thus, the shipper's low environmental preferences create inefficiencies that bind the LSP and necessitate its action to promote the shipper's response to green logistics offerings while simultaneously helping the parties to achieve economic benefits, a win-win-win outcome. In particular, we show analytically that offering to share a portion of the cost savings due to greener product logistics, or reducing the shipper's burden of monitoring the LSP's environmental performance, can effectively stimulate the shipper to respond to green logistics offerings and increase financial performance in the supply chain. Our analysis indicates that the LSP's incentives to the shipper are affected by the extent of consumer environmental consciousness, the logistics cost (or cost reduction effectiveness of greener logistics), and the monitoring cost. Hence, in the presence of greater eco-efficiency, the LSP is willing to provide greater incentives to stimulate the shipper's target environmental level, which in turn results in greater savings in the supply chain channel; the LSP must provide even greater incentives to the shipper when monitoring cost is high, which tends to make the shipper lose interest in greening product logistics.

First, we note that, since the basic premises on which these models are built are similar to those in the second essay, much of what was said about limitations and future research directions could be repeated here. Instead, we comment on the promising conclusions from our analysis, that financial and environmental benefits can be realized simultaneously, but only in the presence of external measures. The intervention of policy makers, with incentives or penalties, is critical to stimulate green behavior by shipper and to establish synergies between ecology and economy. In other words, the parties need help to make favorable, and aligned, environmental decisions at the same time as they maintain or improve their economic performance.

The results of our study help to define an important line of research that may be able to explain how the misalignment of the parties' environmental targets may lead to a bargaining process that could end in a desirable, and stable, outcome. Thus, when neither party has enough power to determine the joint target environmental performance on its own, there exists a unique target environmental performance that meets both parties' financial preferences simultaneously. Such target environmental performance lies in a middle range, indicating a balance between the parties' economic and environmental goals in the supply chain.

In an extension to the current study we consider two collaborative mechanisms to further extend our model and analyze the parties' collaboration under two types of sharing contract: (1) Sharing Cost Savings and Revenue; (2) Sharing Monitoring and Greening Costs. We believe that such further analysis is helpful to characterize an equilibrium between the parties' decisions. We characterize when and how collaboration between the two parties in greening logistics operation may not only result in equilibrium but also a win-win-win situation covering both parties' profits and their joint environmental decision. In future, we aim to analyze the implications on parties' financial and environmental performance of an "emissions offset mechanism" in which the shipper has the option to choose a lower price for the LSP's green service offering(s), but is obliged to invest in CO_2-reduction programs offered by the LSP.

The environmental performance of supply chain logistics is becoming an important concern and that misalignment of objectives of shippers and LSPs remains a problem, making it difficult for the parties to achieve a consensus on improved environmental targets. Our studies contribute to the current literature on green supply chain management by theoretical and analytical models that give insight into why the environmental targets are not aligned, and what measures might be taken to improve the situation.