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Eco-Innovation Drivers and the Adoption of Wind Propulsion Technologies in the Shipping Industry

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Summary

Denne oppgaven forsøker å svare på spørsmålet: Hvilken blanding av miljøinnovasjonsdrivere vil påvirke raskere innføring av Wind Propulsion Technologies (WPT) i skipsfartsindustrien? For å gjøre dette ble det gjennomført en systematisk gjennomgang av litteraturen om miljøinnovasjon i samsvar med en innholdsanalyse som målte bransjeperspektivet, for deretter å lage et forslag som var grunnlaget for utviklingen av en undersøkelse basert på Delphi-metoden. Undersøkelsen har evaluert miljøinnovasjon innen skipsfartsbransjen fra fire perspektiver: Miljø, markedsbasert, reguleringsmessig og teknologisk. Resultatene fra denne avhandlingen fant at innen rederinæringen, på grunn av dens modne natur, var blandingen av miljøinnovasjonsdrivere som fremkalte adopsjon av WPT, først og fremst regulatoriske og markedsbaserte påvirkninger. Resultatet av denne analysen danner en hypotese som en Agent-Based Model (ABM) kan baseres på i fremtiden. Forskningen bidrar til den pågående dialogen om miljøinnovasjon og bærekraftig utvikling ved å synliggjøre den maritime næringens engasjement og fortsatt ambisjon for å bekjempe klimaendringer gjennom samarbeidet mellom markedsaktører, myndigheter og teknologiprodusenter.

Preface

This master thesis denotes the culmination of my Master of Science program in Energy Management. As part of a joint degree with Nord University and Moscow State Institute of International Relations (MGIMO), this program has provided an opportunity to experience life from two vastly different perspectives. I am sincerely grateful for the fellowship, guidance, and support received from my professors and peers.

I am also extremely gracious for the support from the Centre for High North Logistics to participate in their collaboration with the WASP (Wind Assisted Ship Propulsion) project as part of the Interreg North Sea Europe Program.

A special appreciation is necessary for my supervisor Dr. Roberto Rivas-Hermann, whose unparalleled academic and research guidance has had an enormous impact on not only this thesis but also my entire time at Nord University. His dedication and commitment provide immense value to the institution and numerous opportunities for the students under his tutelage.

Bodø, May 31, 2020

Abstract

This thesis attempts to answer the question: What mix of eco-innovation drivers will influence higher adoption rates of Wind Propulsion Technologies (WPT) in the shipping industry? To do so, a systematic literature review on eco-innovation was conducted in concert with a content analysis measuring an industry perspective to then create propositions that were the basis for the development of a survey implementing the Delphi methodology. The survey evaluated eco-innovation within the shipping industry from four perspectives: Environmental, Market based, Regulatory, and Technological. The results of this thesis found that within the shipping industry, due to its mature nature, the mix of eco-innovation drivers eliciting adoption of WPTs was primarily regulatory and market-based influences. The culmination of this analysis formed a hypothesis on which an Agent-Based Model (ABM) could be constructed in the future. The research contributes to the ongoing dialogue regarding eco-innovation and sustainable development by highlighting the maritime industry's involvement and continued ambition towards combating climate change through the cooperation between market players, regulators, and technology producers.

Key Words

Shipping Industry; Eco-Innovation; Environmental Technologies; WASP (Wind Assisted Ship Propulsion); Wind Propulsion Technologies (WPT); Agent-Based Modeling (ABM); Market Push; Technology Push; Regulatory Push/Pull; Delphi Method

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List of Abbreviations

ABM	Agent-Based Model
B2B	Business to Business
CHNL	Center for High North Logistics
CO2	Carbon Dioxide
CSR	Corporate Social Responsibility
EMS	Environmental Management Systems
EU	European Union
GHG	Greenhouse Gas Emissions
IMO	International Maritime Organization
LNG	Liquified Natural Gas
NOx	Nitrous Oxide
OECD	Organization for Economic Co-operation and Development
RINA	Royal Institution of Naval Architects
SME	Small Medium Enterprises
SNAME	Society of Naval Architects and Marine Engineers
WASP	Wind Assisted Ship Propulsion
WPT	Wind Propulsion Technology

Motivation

Throughout my time studying at Nord University, I have been exposed to various topics within the Energy Management Master's Program such as arctic governance, circular economics, energy business, geo-politics, and innovation and change management. While I initially entered to gain an understanding of and eventually start a career in the renewables sector, during my second semester class in circular economics I became fascinated with this concept and sustainable development in general, which led me to apply for the thesis fellowship opportunity to study eco-innovation and in particular wind propulsion technology. There is no doubt that as the years pass more attention and investment will be directed towards combating climate change and it gives me great pride that this work can be used in the movement towards sustainability.

1.0. Introduction

Over the past decade, firms have become increasingly more climate conscious. It is well established that greenhouse gasses cause climate and other air pollutants which trigger a variety of health issues for humans. When accounting for international shipping, roughly 2.7% of the world's total CO2 emissions can be attributed to the industry and this number continues to increase due to the rapid development of trade (Ballini, Ölçer, Brandt, & Neumann, 2017). Another climate factor to consider within the shipping industry is that of port emissions and energy management. Ports across the globe have come under pressure to reduce emissions. This has seen ports attempt to mitigate emissions through energy reductions and increased energy efficiency schemes (Martínez-Moya, Vazquez-Paja, & Gimenez Maldonado, 2019). Due to regulatory and market-based pressures, the maritime industry is seeking solutions to mitigate green-house gases (GHG), air pollution, and other climate externalities. Presently, numerous options such as energy efficiency improvements (cost-effective operational measures), renewable energy sources (wind propulsion), lower carbon content fuel usage (biofuels, liquified natural gas (LNG)), and emission reduction technologies (scrubbers, carbon capture and storage) are being considered and implemented to transition the industry towards a low carbon future (Rehmatulla, Calleya, & Smith, 2017). Throughout history wind energy has been a key source of propulsive power, although in recent times when viewed as a renewable energy resource which is abundant and free, it has not been adequately utilized in the shipping industry (Talluri, Nalianda, Kyprianidis, Nikolaidis, & Pilidis, 2016). When considering renewable energy sources, maritime eco-innovations such as WPT (Wind Propulsion

Technologies)/WASP (Wind Assisted Ship Propulsion) has presented itself as a promising option. These innovations are designed to reduce fuel, thus decreasing costs while also cutting emissions. A study conducted in 2018 specified that the installation of Flettner rotors on commercial vessels would potentially produce up to a 20% cost savings relating to fuel consumption while simultaneously reducing CO2 and NOx emission levels by 20% (Talluri, Nalianda, & Giuliani, 2018). However, there are structural barriers impeding the diffusion and development of WASP technologies such as a lack of policies and schemes promoting wind propulsion, lack of financial resources, inadequate collaboration among actors, as well as conservative attitudes within the maritime industry (Rojon & Dieperink, 2014). These structural barriers have so far outnumbered the drivers within the industry. Even so, the Secretary-General of the International Windship Association Gavin Allwright stated *"Wind propulsion solutions are a very important technology segment for the decarbonization of shipping. The propulsive energy provided is substantial and this is delivered directly to the ship with no need for new infrastructure. That secures a significant portion of ship owners fuel requirement at zero cost, creating an element of certainty in a volatile and increasingly insecure market in the future."*

Green product innovation is a method for firms to experience growth and to integrate sustainability into their business models (Dangelico & Pujari, 2010). Due to this and increased environmental awareness from consumers along with social and governmental pressure placed on firms to become more environmentally conscious, firms have focused their attention towards products incorporating that address these issues (Janine Fleith De Medeiros, Ribeiro, & Cortimiglia, 2014). As such, eco-innovations which aim to use natural resources in an effective way, address existing environmental problems, and further reduce environmental impacts (Hermann & Wigger, 2017) have received increased attention from firms and researchers alike. Prior literature regarding eco-innovation pointed to several driving factors such as market pull, regulatory push/pull, and technological push (Kesidou & Demirel, 2012). The market pull is generally understood as the impact consumer choices, responses and decisions incentivize research and development of greener technologies, The regulatory push/pull are standards, policies, regulations, and laws presently administered to address environmental externalities; and technological push refers to industry-specific processes, practices, and operations; (Horbach, Rammer, & Rennings, 2012; Kesidou & Demirel, 2012; Rennings, 2000). Furthermore, more recent findings have shown that these drivers, catalyze operations so as to exploit opportunities stemming from new regulations, market leanings, and technology (Hermann & Wigger, 2017). With regard to the shipping industry and specific eco-innovations, (Talluri et al., 2016) showed how a techno-economic approach can be used to evaluate various traditional propulsion systems (diesel engine and gas turbine) in cases where such implementations like WASP (Wind Assisted Ship Propulsion) technologies can be operated in conjunction with these traditional systems. Although, as (Florida et al, 2001) distinguished, two organizational factors must be present to influence eco-innovation; namely, organizational resources and performance monitoring systems.

Previous research has been focused on eco-innovation determinants and their environmental impacts (Horbach et al., 2012), the dynamics and interactions underlying various drivers in the adoption of innovative environmental technologies (Hermann, 2017), as well as why and how eco-innovation evolves in value-creating networks (Hermann & Wigger, 2017). This paper attempts to shed light on the drivers influencing the decision-making processes of firms engaging in eco-innovation by investigating the following research question:

1.1. Research Question

What mix of eco-innovation drivers will influence higher adoption rates of Wind Propulsion Technologies in the shipping industry?

Eco-innovation, refers to product and process developments which contribute to reductions of environmental externalities (OECD, 2009) As such, it is embedded in sustainable development so much so that it allows for necessary industrial/product recalibrations to transpire in an environmentally conscious manner. For example, the implementation of Flettner rotors has been predicted to potentially reduce emissions by up to 60%, when used as a complement to conventional technologies (Traut et al., 2014). However, these installations are costly and depending on the type of contract and future fuel costs, could disincentivize adoption from ship owners or ship charterers. Moreover, this incongruence may be alleviated through changing policies and regulations. Despite this, regulators, shipping firms, and shipping suppliers are collaborating on projects to determine the viability of eco-innovations like WASP technologies. Throughout this paper, the analysis will focus on the influencing factors of drivers and determine how the adoption of eco-innovations can proliferate.

This paper will provide insight into the strategic processes of firms in different sectors before then relating these characteristics back to the shipping industry. In examining this, the paper elaborates on the literature of eco-innovation across many sectors. Eco-innovation in the shipping industry is an interesting industry due to its global appeal and impact on climate change. Technologically, the shipping industry is mature and while a change to a low carbon path is historically uncharted, WPT/WASP technologies have the ability to improve ship performance while resolving some environmental issues (Karslen, Papachristos, & Rehmatulla, 2019).

1.2. Thesis Structure

The structure of this paper is as follows: To start, a literature review is presented on the implementation, effectiveness in GHG emission and fuel reduction of WASP technology and its prevailing policy, eco-innovation drivers and push-pull factors, along with literature on ABM (agent-based modeling) and how it has been used in the shipping industry specifically regarding eco-innovation. The next section presents methods and data. In this section a systematic literature review is conducted, followed by a content analysis gauging the industry perspective before both of those aspects are utilized to create propositions for the development of a survey implementing the Delphi methodology. The survey will evaluate eco-innovation within the shipping industry from four perspectives: environmental, market based, regulatory, and technological. The following section discusses the results of the systematic literature review and survey at hand. Finally, the last sections present the theoretical relevance of the results and conclusions.

2.0. Literature Review

Introduction to theories

In this section, I will discuss the current state of WASP technology, eco-innovations, and how ABMs have been used to research and predict their implementation. The WASP section gives a brief overview followed by implementations and the current policy structure. The next section introduces eco-innovation, further delves into the drivers of eco-innovation, and finishes with the push/pull factors accompanying eco-innovation generally. The last section provides insights into ABM, previous examples of ABM usage in the shipping industry, before ending with their potential application for sustainable development and WPT technologies.

2.1. WASP Technology

2.1.1 WASP Overview

WASP (Wind Assisted Ship Propulsion) technologies are comprised of several options: Flettner rotors, kites, and sails (Rehmatulla, Parker, Smith, & Stulgis, 2017). Current literature regarding WASP revolves around techno economic and environmental analysis, along with health costs and economic impact reports. According to (Talluri et al., 2016) a techno economic approach supports evaluations of various traditional propulsion systems (diesel engine and gas turbine) in cases where new environmentally friendly technology like a vertical axis wind turbine is operated in conjunction with these traditional systems. From a different angle, (Bentin et al., 2016) demonstrate that due to the political and economic pressure to reduce fuel consumption of the shipping industry, one path forward to accomplish such an aim would be by increasing efficiency through optimizing routes and introducing new technologies such as WPTs (Wind Propulsion Technologies). Wind technologies can offer legitimate savings on new and existing ships which allow ship owners to compete more broadly (Rehmatulla, Parker, et al., 2017). The focus on resource usage, emissions, and efficiency should be reduced at the source rather than after the fact. This is primarily where WASP technology would address the issues facing the shipping industry. WASP technology is nestled under the "clean technology" category, which is seen as a preventive, process-integrated approach with focus on reduction and reuse (Hermann, 2017) On the other side of environmental protection/technology rests preventive environmental protection. This involves two different types of technologies; process-integrated and end-of-pipe technology. Process-integrated technology can be defined as process and productions method adjustments that ultimately reduce pollution, and resource/energy usage (Ekins, 2010). Whereas, end of pipe is defined by (Ekins, 2010) as "isolating or neutralizing polluting substances after they have been formed". The distinctions in these technologies have differing benefits for the adopting company as end of pipe technology tends to be administered through environmental regulations due to the benefits being primarily environmental as opposed to economic (Hermann, 2017).

2.1.2 Implementation

Implementation of shipping innovations including wind propulsion technologies such as Flettner rotors can complement conventional technologies while simultaneously having the potential to reduce emissions by 10-60%, if the operational speed, technology and wind conditions are favorable (Traut et al., 2014). These energy efficiency technologies are appropriate for ships operating on short term time charter contracts, due to the split incentives and imperfect information barriers (Rehmatulla, Parker, et al., 2017). Moreover, energy efficient technologies sometimes encounter market failures which prevent the adoption of these technologies due to split incentives where contractual or organizational arrangements misalign, and imperfect and asymmetrical information caused by dissemination issues (Rehmatulla, Parker, et al., 2017). Time charter contracts see ship charterers foot the fuel costs whilst operational and capital costs (including energy efficiency investments) are covered by shipowners; This however disincentives shipowners to invest in energy efficiency upgrades and other fuel cost reductions due to the limited potential revenue increases garnered from higher time charter rates (Adland, Alger, Banyte, & Jia, 2017). However, in the contracts for chartering ships, ship-owners can influence the eco-efficiency stipulations and in turn improve environmental performances of different types of ships (Hermann, 2017). Understandably so, the concerns from ship owners and operators are primarily revolved around technical risks, hidden costs, and the potential of unproven technology; these rational justifications are understandable in the lack of investment currently seen in the wind technology sphere (Rehmatulla, Parker, et al., 2017).

These problems may rest on the current policies and the subsequent barriers causing this incongruence between the environment and profitability. The difficulty arises because this low carbon path is an historically uncharted one, with little prior knowledge to draw on due to previous shipping transitions moving from low carbon to more carbon intensive (Karslen et al., 2019). This difficulty leads to an implementation gap, also referred to as the "energy efficiency gap" which is the different of energy efficiency measurements and cost-effectiveness levels from the perspective of an investing entity's in a techno-economic context (Brown, 2001). These gaps can be explained by energy efficiency barriers, which are divided into three categories: economic, organizational, and behavioral (Rehmatulla, Parker, et al., 2017). Other key barriers slowing the implementation of WPT technologies are related to two factors; the lack of practical knowledge, stemming from a small sample size of sea trials testing the technology, and risk adverseness of the industry as a whole where the incentive is to allow the competition test out the technology first before sinking investment into the unproven technology (Rojon & Dieperink, 2014). What further impairs the implementation of such technologies is the heterogeneity of the shipping sector and split incentives, which depends largely on the sectors, firm size, and varying levels of charter contract arrangement exposure (Rehmatulla, Parker, et al., 2017). However, (Mander, 2017) has shown that alternative ship propulsion technology are utilized as hybridization and add-on patterns, which when implemented with niche technologies have the ability to foster symbiotic relationships with traditional technology so long as they improve performance and resolve environmental issues (Karslen et al., 2019). Niche shielding has been used in the shipping industry previously through the proliferation of slow steaming and wind propulsion in order to experiment with technological innovations to combat CO2 emissions (Mander, 2017). Shielding involves various forms of network actors mutually supporting demonstration projects of new technologies while providing the space for technological experimentation as well as supporting actor expectations regarding these niche technologies such as wind assisted propulsion (Karslen et al., 2019). Shielding in the shipping industry can take the form of utilizing shipping routes with favorable wind conditions such as in the North Sea.

2.1.3 Policy

As (Karslen et al., 2019) model exhibited that if fuel prices increased from $400/mt to $600/mt by 2050 there would be pressure on the present socio-technical regime which would increase expected fuel savings utilizing rotor technology; however, shipowners tend to underestimate profits from rotor technology because of imperfect information and limited charter premiums combined with low fuel costs and as such perceive this technology as uneconomical. This was also supported by (Adland et al., 2017). One way to quell these tempered expectations is through carbon pricing, which would improve rotor technologies economic performance while also increasing experiment participation; further demonstrating that carbon pricing, when used as a financial instrument can facilitate the mitigation of split incentive barriers (Karslen et al., 2019). This is caused because the fuel increases signify an opportunity window for niche innovations such as WASP technologies to gain market share (Schot and Geels, 2008), thus further supporting the diffusion of such technology by providing positive feedbacks which subsequently reduce barriers. Additionally, voluntary participation in programs aimed at sharing information with B2B customers regarding environmental performances of vessels has increased due to the fact that they creates incentives for environmentally friendly technological installations (Horbach et al., 2012). However, financing is also a major hurdle in the adoption of wind technologies. There are different financing models that can facilitate the adoption of such fuel-efficient technology for various types of ships. In one such model, shipowners would secure upfront capital investment for the retrofitting costs from third party financiers, who would in turn recoup their investment through fuel-cost savings generated from the technologies installed which would have a baseline fuel consumption established on the ship (Rehmatulla, Parker, et al., 2017). Having said that, funding from various sources (national, supra national, or international) through trial and demonstration programs can provide the catalyzing trigger for the proliferation of wind technologies by generating thorough and vigorous measurements of performances in full scale trials (Rehmatulla, Parker, et al., 2017)

2.2. Eco-innovation

2.2.1 Eco-Innovation Defined

From a managerial perspective the innovation development process has been described by its complexities and the uncertainties stemming from the process itself and the market which require that various challenges and obstacles be overcome (Del Río, Peñasco, & Romero-Jordán, 2016). Innovation from a contemporary viewpoint is seen as the outcomes of processes which yield a certain level of application usefulness and also a degree of newness from a change; building off of this (Granstrand & Holgersson, 2019) defined an innovation ecosystem as "the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors". Nestled within innovation, is eco-innovation. The term eco-innovation is defined by the OECD (Organization for Economic Co-operation and Development) as "the development of products (goods and services), processes, marketing methods, organizational structure, and new or improved institutional arrangements, which, intentionally or not, contribute to a reduction of environmental impact in comparison with alternative practices" (OECD, 2009). Eco-innovation is embedded in sustainable development in that it allows for necessary industrial/product iterations of change to occur while doing so in an environmentally friendly manner. As such, in order to meet the development goals of countries, companies, and individuals, sustainability must be prioritized. Sustainability is meeting the needs of the present without compromising the needs of future generations (UNWCED, 1987). Hence, it is in the interest of the entire shipping industry to innovate in an ecological manner in order to first, stay ahead of competition and second, to decrease its carbon footprint. Both of these points center on the fact that businesses in general that operate in such a manner which not only causes ecological damage but also destabilizes the very context in which they operate in illustrates their inherent unsustainability (Unerman, Bebbington, &

O'Dwyer, 2010). It has also been shown that when considering regulation standards for technologies, environmental regulations that are strong increase the eco-innovation potential of impacted firms (Hermann, 2017).

As stated in the 2009 Sustainable Manufacturing and Eco-Innovation report from the OECD, eco-innovation is generally understood to have three dimensions: targets, mechanisms, and impacts, which are then analyzed in accordance to each target (the center focus), mechanisms (procedures for initiating alterations in the target) and impacts (primarily environmental effects) (OECD, 2009). Viewed through the lens of the shipping industry these can be identified as decreased fuel usage and increased profitability (targets), phasing in of new WPT-fitted ships into fleets (mechanisms), and as a result (reduced emissions (impacts). The targets can be said to be influenced by the increase in resource scarcity and depleting reserves in addition to environmental and regulatory pressure from governments and the public. Hence, resource efficiency (sustainably utilizing the earth's resources while minimizing the environmental impacts by doing more with less, while mainstreaming sustainability at a strategic level throughout all core levels of operations) is a way for businesses to tackle such issues while simultaneously increase their ability to access new markets, enrich product quality and technical capacity, and expand profitability (Bossle, Dutra De Barcellos, Vieira, & Sauvée, 2016). Additionally, the shipping industry as a whole displays vast differences depending on the technological compliance resources used, the route type, and or other aspects specific to the ships (Hermann, 2017). When factoring this in, an eco-innovation approach provides a solution that can benefit stakeholders from an economic, environmental, and social standpoint.

2.2.2 General Drivers for Innovation and Eco-Innovation

The current literature regarding eco-innovation provides several drivers; among those included are market pull, regulatory push/pull, and technological push (Rennings, 2000). The regulatory push/pull are existing laws, regulations, standards and policies currently in place or anticipatorily put in place to address certain environmental externalities; Technological push relates to industry/sector specific knowledge entrenched in the firms' specific processes, practices, and operations; Market pull can be understood as the influence of demand side responses and decisions that incentivize research and development of greener technologies (Horbach et al., 2012; Kesidou & Demirel, 2012; Rennings, 2000). Another influencing factor of eco-innovation are internal business aspects. Depending on firms' internal dynamics they may be more inclined to adopting eco-innovations than others (Rubik, 2005). However, the challenges when implementing international regulations are real. For example, as an international industry, the shipping industry faces practical difficulties due to regimes complying on three different levels (international, national, local) and enforcement of IMO (International Maritime Organization) international environmental conventions can be hindered by member states lacking effective communication mechanisms as well as establishing programs that can enforce and monitor these conventions (Comtois and Slack, 2007).

However, according to (Porter, 1991), regulation is not always seen as an undesirable cost factor but as an impetus for innovativeness which would lead to a first-mover advantage in the eco-innovation marketplace. Additionally, some stakeholders have viewed environmental regulation and technology as added costs while others see it for the potential it has in providing value to their customers, depending upon where an actor falls on the along the value chain (Hermann, 2017). This is further supported by (Grubb and Ulph, 2002) by showing that more innovative firms adopted eco-innovations to venture into new markets, while less innovative firms utilized eco-innovations as merely a means to decrease production costs and adhere to the minimum level of environmental standards. Demand side factors also play an influential role in eco-innovation and adoption. When looking at German manufacturing firms, one important determinant of eco-innovations was the expectation of increases in firm turnover (Horbach, 2008). Moreover, consumer activists and associations comprised of environmentally concerned stakeholders are vital in influencing firms to cooperate with consumer protection associations which can lead to eco-innovative products (Wagner, 2007). However, this acquiescence to regulations and consumer concerns can also be seen as "green signaling", in which case only the minimum investment into eco-innovations would be administered to legitimize their practices and bolster their green perception (Suchman, 1995). On the other side of things, the technological push is generally impacted by supply side dynamics. While technology can be devices it is also organizational knowledge, products, and techniques, which pushes firms in different ways due to the fact that these firms will have varying capacities of knowledge, organization, products, and technique (Hermann, 2017). However, (Kemp et al, 1992) asserted both market pull and technological push are interlinked and complementary while also claiming that a firm's capacity to capitalize on R&D, influences said firm's trajectory. When comparing eco-innovation to innovation in general, different studies have indicated that eco-innovators respond more positively to regulatory pulls in the form of environmental regulations and supply tiered instruments like subsidies in Germany (Horbach et al., 2012), but in a country like Spain, studies have shown that environmental regulation is a demand side pull eco-innovation driver as opposed to general innovation (Del Río et al., 2016).

From a resource based view, the competitiveness of firms' eco-innovative practices are largely contingent on the quality and quantity of the resources available along with the ability to optimize such resources (Testa, Iraldo, & Frey, 2011). Moreover, a resource-based view stresses the tangible and non-tangible assets of firms, which mutually ascertain the know-how, inimitable assets, and valuable resources harnessed that provide a competitive advantage for firms (Helfat, Peteraf, 2003). Consequently, firm characteristics such as organizational measures like integrated environmental management systems (EMS) intertwined within business strategies, and implementable eco-innovative practices by way of life cycle analysis, end-of-pipe solutions, integrated cleaner technologies signify a vital role in the enhancement of corporate environmental performance (Guoyou, et al, 2013).

2.2.3 Push/Pull Factors

It has also been shown that investment in eco-innovations tend to be contingent upon the capabilities of the firm; more specifically, firms that harness practices and competencies in source reduction, pollution prevention, and green product design have higher proclivities towards eco-innovations (Georg et al, 1992; Kemp et al, 1992). Additionally, the dual impact of environmental policies; first, drives least involved eco-innovation firms towards such activities so as to enhance efficiency while reducing production costs; and second, energizes firms that are already investing in eco-innovations to increase these actions to seize a first mover's advantage in the green technology and product marketplace (Kesidou & Demirel, 2012). Within these firms (Florida et al, 2001) revealed that there are two organizational factors influencing eco-innovations – organizational resources and performance monitoring systems. These factors are present within the shipping industry but specifically performance monitoring systems, as more stringent emissions regulations are set in place. This provides the firms with larger resource bases an increased incentive to further invest in eco-innovations. Another benefit highlighted by (Porter, 1991) is the 'win-win' scenario which suggests that regulations have the influence to force firms into various forms of environmental research and development investments that can cut down environmental compliance costs while simultaneously incentivizing firms to undertake eco-innovations that will reduce production costs and/or provide an avenue to expand into new markets for eco-products. However, (Kesidou & Demirel, 2012) indicates that factors like CSR (Corporate Social Responsibility) and consumer requirements for eco-friendly products do not influence the amount of investments into eco-innovation; while firms do undertake minimum investments on such activities in response to social pressure and market requirements, the amounts invested are limited. Consequently, the existing governmental policies like centralized green public procurement plans whose goal is to expand eco-innovations through demand side pressure must be appropriately supported by regulatory frameworks which align pollution abatement and innovation platforms so firms receive the needed support to fully harness their organizational capabilities (Kesidou & Demirel, 2012). The figure below adapts the traditional eco-innovation driver model for the shipping industry.

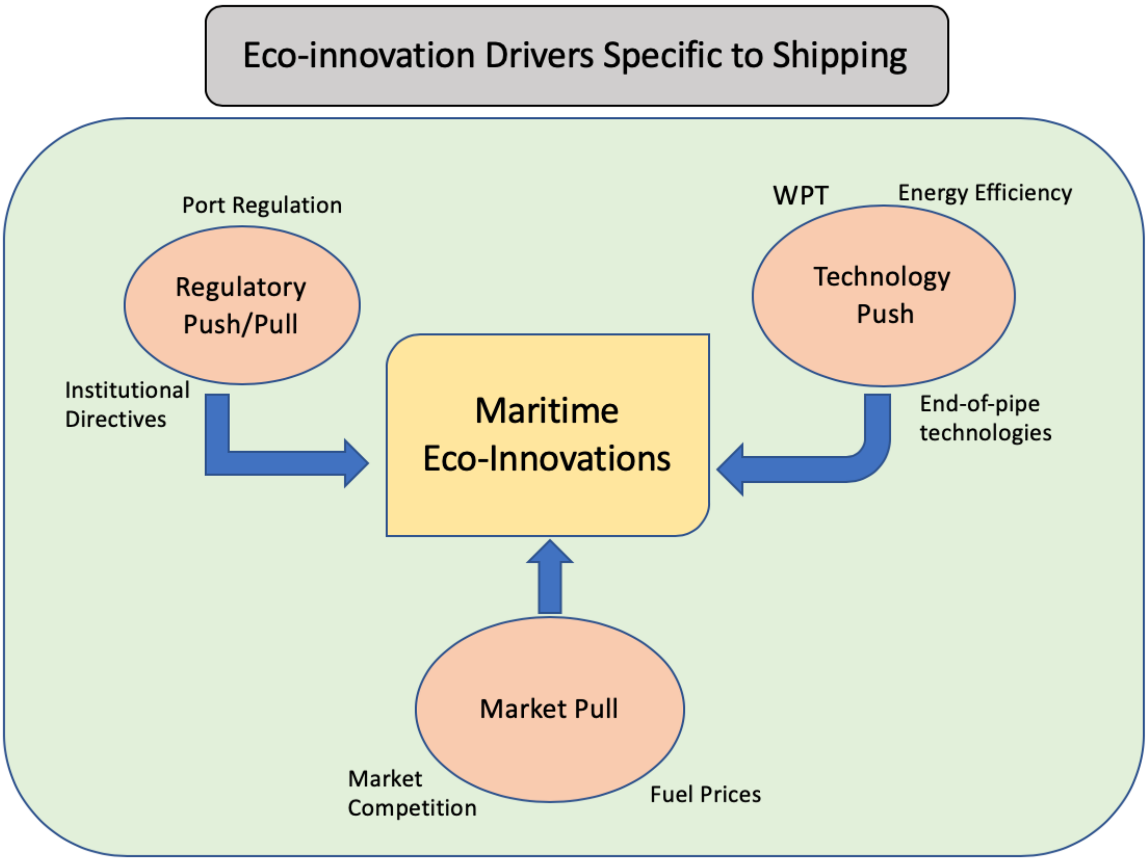

Figure 1: Eco-innovation Drivers Specific to Shipping

Source: Adapted from Hermann, R.R. (2017)

2.3. Agent Based Modeling

2.3.1 Introducing ABM

The use of Agent-based models (ABM) is generally implemented in social sciences to denote individual or group actors in dynamic adaptive systems; these systems can take the form of marketplaces, organizations, or other systems that can be grouped together through individual collective actions (Garcia, 2005). The agents are represented by autonomous decision making entities that interact with each other and/or their environment based on specific rule sets dictating the behavior choices of the agents (Zhang, Gensler, & Garcia, 2011). In this way, an ABM methodology is a useful tool to understand eco-innovation and new product development, specifically in the shipping industry. There are three steps in an ABM. It follows a theoretical model development also known as a hypothesis, then running software and collection of empirical data, and finally validation (Karslen et al., 2019). Throughout this thesis I will use a qualitative approach to develop a theoretical model regarding eco-innovation drivers and their influence on WPT adoption. Such a model have been found to increase the effectiveness of ABM models in systems of heterogeneous individuals due to the increases in a system or network the more important that system becomes; thus, improving the adaptiveness and evolution of the system itself over time (Garcia, 2005). These heterogeneous entities help provide a model for the behaviors of the agents by analyzing the repeated interactions that can then be extrapolated to understand global, macrotrends and behavior evolution within an industry. Even though agents may seem to act collectively, in fact each micro-decision is being influenced by the collection of individuals; as seen in the ABM applications studying insect behavior, traffic-flow dynamics, urban systems, and civil violence (Rauch, 2002). An ABM model can demonstrate the implemented strategies to understand manufacturers resource allocations in regard to research and development. An ABM model is ideally deployed in seven primary areas. These are seen when:

1. where the natural unit of analysis is an individual (consumer, firm, employee, industry), and when the micro/macro levels of behavioral patterns from their interactions are of relevance,
2. When social systems can be described by "What-if" scenarios (organizational cultures),
3. When emergent phenomena can be observed (innovation emergence),

4. The coevolving system interactions in the same environment (competitive markets),
5. When adaption or learning occurs within the system (R & D collaborations),
6. The physical and temporal space is of interest (Supply chain networks), and
7. When the population is heterogeneous or the topology of such interactions are heterogonous and complex (social networks) (Garcia, 2005).

Modeling innovation strategies have legitimate applications in ABMs due to the fact that innovation, imitation, and process enhancements are not deterministic processes which makes the entire system highly non-linear (Debenham, John and Wilkinson, 2003). This is why ABMs are a sound methodology to determine various strategies during the innovation process. Utilizing external knowledge sources is a vital product development strategy which is why innovation benefits from collaborative partnerships within innovation networks through the dynamic and heterogeneous unit nexuses, because each part harnesses different collections of expertise (Gilbert, Ahrweiler, & Pyka, 2007). However, in order to appropriately design an ABM one must define the research question. Within organizations exploration and exploitation activities compete for scarce resources, and as such decisions must be made explicitly regarding allocation policies between different types of projects (explorative or exploitative) (Garcia, 2005). However, (Solís-Molina, Hernández-Espallardo, & Rodríguez-Orejuela, 2018) showed that the trade-off of conducting explorative operations to the detriment of exploitive operations, have been found to suffer the experimentation costs without receiving the benefits of such endeavors and or potential bankruptcy; contrariwise engaging in exploitative rather than explorative operations may lead to a lack of learning making them obsolete. (Garcia, 2005) findings showed that firms can be profitable in highly competitive environments by identifying and building niche products. This method is relevant in determining the eco-innovative drivers within the shipping industry to understand how/which strategic decisions were employed to adopt WPTs.

2.3.2 ABM Applications in the Shipping Industry

With their research (Köhler & Senger, 2012) introduce an agent-based simulation model for innovation processes. The model used focuses on the research and development decisions of shipyards and the investment decision making process of shipping companies to determine the technological change in shipping. Substantial improvements in emissions performance requires demand side pressure, namely for green logistics providers and an influx of investments to begin processes of change (Köhler & Senger, 2012). The impact international trade has on CO2 emissions is major. Due to this, it has been shown that as much as a 60% reduction in CO2 allocation to countries is possible through allocating emissions based on responsibility by consumption (Peters, et al. 2009). Additionally, the OECD showed that shipping contributed between 2 and 4% of global CO2 emissions and greenhouse gas emissions; these could be diminished through mitigation technologies and development of an international policy regime for emissions reduction (OECD, 2010). However, due to the international shipping industry conducting the majority of its operations in international water, this may prove to be difficult since they are outside the regions of national legal jurisdiction (Peters, et al. 2009). At the time of publication, the OECD projected that the rapid growth of international transport would lead to an increase in emissions from shipping and intensified pressure for rapid action unless emission efficiency drastically improves. If not mitigated CO2 emissions have the potential to increase 50-250%, and reach 10-25% of global emissions if other sectors begin to decarbonize (Smith et al., 2014) The efficiencies needed can take the form of energy efficiency hulls, more efficient propulsion systems (these possibilities have been discussed and developed including wind based technologies), changing fuels, and through operation measures (whereby slow steaming offers the most direct reductions) (Köhler & Senger, 2012).

2.3.3 ABM and Sustainable Development

The method (Köhler & Senger, 2012) employ is a sectoral system of innovation analysis used to identify the types of actors involved whereby they implement the ideas of transition theory to consider possible change processes towards international transport sustainability According to (Grin, Rotmans, & Schot, 2011), transition theory argues that radical changes in society are imperative in moving towards a sustainable society, and that these transitions to sustainability originate from niches of economic and social activity which exhibit radical alternatives to the current paradigm. This relates directly to shipping because the majority of the industry is dominated by steel hull based designs with low speed diesels operating in a fixed structure, however small sectors such as offshore support and short sea routes have demonstrated considerable change over the past several decades (Köhler & Senger, 2012). The short sea route sector's implementation of eco-innovation and particularly larger WPT adoption could prove to be one of the driving transition niches in the shipping industry. This is also largely due to wind technologies offering zero carbon propulsion, which has exhibited its effectiveness in medium sized freighters operating at slower speeds which allow for smaller engines and fuel optimization, further increasing costs savings for both container and bulk/liquid carriers (Köhler & Senger, 2012). Looking at this issue from another view, the regulatory and technological push/pull factors also play a role in development and eventual adoption of eco-innovations. The extent to which strong environmental regulations motivate eco-innovation is unclear especially as ship-owners have voiced concerns regarding high costs of cleaner technology, which implies a resistant attitude towards innovation in general (Ekins, 2010). This is further supported by (Hermann, 2017), demonstrating that due to current market conditions adoption of environmental technologies will be challenging and ship-owners will not be motivated enough to implement such technologies if not pressured by regulations. However, due to the maturity of the industry, (Köhler & Senger, 2012) found that one of the fundamental roles spurring innovation in the shipping industry was played by shipbuilders and suppliers, which was in direct response to investment decisions throughout the shipping markets.

3.0. Methods

In order to more deeply explore the drivers of eco-innovation, a systematic review is conducted along with a content analysis of the shipping industry. These two aspects will then be combined together to create propositions. The propositions are designed to guide the question development as part of a Delphi method survey. The survey can be found in appendix 1. The aim of this was to develop a specific model including all possible drivers, in all three areas to identify primary drivers and motivations of firm's adoption of eco-innovations.

In a systematic literature review, a researcher conducts an extensive search on a specific research field and upon grouping sources into categories of relevance, one can then provide a step by step process outlining the methods used to derive at the conclusion (Tranfield, Denyer, & Smart, 2003). This procedure can be found in figure 2. The results from the systematic review could then be adapted and subsequently used to craft a Delphi questionnaire. The main reason to apply a systematic review in the context of eco-innovation is caused by the specific goal of attempting to identify primary drivers, motivations, ands barriers that have been shown to lead firms to adopt (or not) eco-innovations. As such, a systematic review should adopt a strict and scientific method for searching and assessing literature so as to allow for the search process to be easily comprehendible and replicable (Tranfield et al., 2003). For this study the review followed procedures described by (Petticrew & Roberts, 2006), and (Tranfield et al., 2003), while some methods were altered to fit this particular review.

Research Question: *What mix of eco-innovation drivers will influence higher adoption rates of Wind Propulsion Technologies in the shipping industry?*
1. Identify database; define keywords and search strategies: Science Direct; Eco-innov*; drivers; adoption;
2. Studies Identified search in field of topic (n=529)
3. Inclusion Criteria: Review Articles, Research articles Years 2013-2020
4. Studies Identified search in field of topic (n=349)
5. Further inclusion Criteria: Journal of Cleaner Production; Ecological Economics; Journal of Engineering and Technology Management
6. Studies Excluded due to journal relevance (n=185)
7. Studies Identified search in field of topic (n= 164)
8. Studies excluded for relevance after reading titles and/or abstracts (n=151)
9. Studies usable for systematic review (n=13)
10. Analyze and evaluate articles critically
11. Prepare summary encapsulating all analysis
12. Delineate main findings

Figure 2: Systematic Literature Review: Research Protocol Design

Source: Adapted from Bossle et al, (2016)

In general, the papers reviewed all used a similar definition of eco-innovation which follows the basic framework of the OECD's designation. This refers to any innovation (whether product, process, or organizational) which brings forth environmental benefit and or reduces the attrition placed upon it. Figure 3 displays the eco-innovation definition of each article used in the systematic review. It should be noted that (Bossle et al., 2016) highlighted a firm's intentionality is left out when using this definition. However, in several instances eco-innovation was presented through a specific country's lens, which covered current barriers and also various ways to improve environmental efficiency or develop regulations that would stimulate greater adoption. Another important designation brought forth by (Aloise & Macke, 2017) was the division of internal and external eco-innovation frontiers, classified as — activities predicated on effective and efficient processes of eco-innovation such as management, production, and development of new products; the organization's "green" and sustainable public presentation in reference to its relationship with suppliers, regulatory agencies and the demands of the market respectively.

Author(s)	Eco-Innovation Defined
Aloise, P. G., & Macke, J.	The creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives- (OECD, 2009)
Arranz, N., Arroyabe, M. F., Molina-García, A., & Fernandez de Arroyabe, J. C	Aims to develop new processes, products and techniques to avoid environmental damage; includes new knowledge and organizational innovation; innovation for sustainability; innovations that generate environmental improvements; obtain an additional value for the producer and consumer; net environmental improvement- numerous
Bitencourt, C. C., de Oliveira Santini, F., Zanandrea, G., Froehlich, C., & Ladeira, W. J.	Developing new products, processes and services, which generates value for the company and for the customer, along with a reduction in environmental impact (Den hond, 1998)
Bossle, M. B., Dutra De Barcellos, M., Vieira, L. M., & Sauvée, L.	The development of products (goods and services), processes, marketing methods, organizational structure, and new or improved institutional arrangements, which, intentionally or not, contribute to a reduction of environmental impact in comparison with alternative practices- OECD 2009
Cai, W., & Li, G.	The creation, transformation, and transcendence of technologies, organizations, and institutions for the coordination of the relationship between man and nature when humans face resource depletion, environmental degradation, and ecological damage. In essence, as a subset of economic system innovation, eco-innovation has many of the characteristics of traditional innovation, but it focuses more on technologies, processes, and product innovation activities involving the reductions of raw material and energy consumption as well as environmental pollution- (Horbach et al 2012, Kemp and Pearson, 2007)
Chen, J., Cheng, J., & Dai, S.	Reduce the usage of natural resources (including raw material, energy, water, and land) and decrease the release of harmful substances by introducing a newly or significantly improived product (good or service) , process, organizational change or market programs- (EIO, 2012)

de Jesus, A., & Mendonça, S.	New or improved socio-technical solutions that preserve resources, mitigate environmental degradation and/or allow recovery of value from substances already in use in the economy. EI is understood as a systemic problem-solving tool for enabling a holistic and transformative departure from the current unsustainable state-of-play
Hojnik, J., & Ruzzier, M.	Production, application or exploitation of a good, service, production process, organizational structure, or management or business method that is novel to the firm or user and which results, throughout its lifecycle, in a reduction of environmental risk, pollution and the negative impacts of repources use (including energy use) compared to relevant alternatives- (Kemp and Foxon, 2000)
Pacheco, D. A. de J., Caten, C. S. ten, Jung, C. F., Navas, H. V. G., & Cruz-Machado, V. A	Eco-innovation is considered a new product or process that adds value to the business and to the customer, significantly decreasing the environmental impact- James (1997) It is the productions, application or exploration of goods, services, production process, organizational or management structure or method of business that is new to the company or to the user. The results are the reduction of environmental impact, less pollution or negative impacts from the utilization of resources, compared with corresponding alternatives- (Rennings, 2000; Kemp & Foxon, 2007) It is defined as the innovation that is capable of attracting green income in the market, reducing the net environmental impact, and creating value for the organizations- (Anderson, 2008) It is the creation of new and competitive efforts of products, processes, systems, services and procedures conceived to meet the human needs and to provide a better quality of life for everyone, with as little as possible utilization of the life cycle of natural resources and release of toxic substances- (Reid & Miedzinski, 2008) It is the production, assimilation or exploration of a product, production process, service or method of management or business that is new to the organization (developing or adopting it) which results, over its life cycle, in the reduction of environmental risks, pollution and other negative impacts from the use of resources, including power, compared with corresponding alternatives- (Kemp & Pearson, 2008) It represents an innovation that brings about a reduction of the environmental impact whether such effect is intentional or not- (OECD, 2009)
Sáez-Martínez, F. J., Díaz-García, C., & Gonzalez-Moreno, A.	The production, assimilation or exploitation of a product, production process, service or management or business method that is novel to organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental

	risk, pollution and other negative impacts of resources used (including energy use) compared to relevant alternatives- (Kemp and Foxon, 2000)
Triguero, A., Moreno-Mondéjar, L., & Davia, M. A.	The introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that re- duces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle of the product.
Del Río, P., Peñasco, C., & Romero-Jordán, D	Eco-innovation is innovation that results in a reduction of the environmental impact of consumption and production activities, no matter whether or not that effect is intended- OECD 2010
Hazarika, N., & Zhang, X	Finding new or between ways to attain higher functionality with lesser resources, new technological designs, and overall systematic changes in the process of construction and renovation-(EIO, 2011)

Figure 3: Systematic Review → Eco-Innovation Defined

Source: Independently designed by author

3.1. Data Collection

This project aims to understand the drivers and forces that will potentially influence shipowners to adopt or not adopt WASP technologies. As stated before, through the responses of experts in the fields of business, eco-innovation, education, regulation, and shipping, I aim to gain an insight into how these actors perceive the world in reference to my research question. Since the goal of the research is to discern the underlying drivers of WASP adoption as opposed to quantifying the likelihood or extent of adoption by shipowners, my thesis will lean more heavily on qualitative data.

The options for data collection were aided by my participation in the WASP (Wind Assisted Ship Propulsion) project as part of the Interreg North Sea Europe Program, for which Nord University is a partner. Inclusion in this program allowed me access to academics, professionals, regulators, and others previously involved in EU funded WPT (wind propulsion technologies) projects. The population chosen for the expert and practitioner survey were selected from this grouping along with professionals from business, education, industry, and research arenas whom were not associated with prior EU funded WPT projects. These individuals have been willingly available, and extremely valuable for my thesis.

To conduct the systematic review, I relied upon the database Science Direct. This database provides some advantages due to its repository of high-quality and relevant research. In order to conduct this search, identification of key words and terms were implemented to collect relevant articles. I carried out a preliminary inspection of previous reviews on "innovation" and "eco-innovation". After this, I broadened the search to also include other search terms such as "adoption" OR "Drivers" and to include other qualifiers such as "innov*", and "eco-innov*". The results from this search, were then used to create a final list of key terms in order to cover all possible existing literature relating to eco-innovation and the underlying drivers which catalyze adoption rates.

3.2. Content Analysis

The data imputed for this content analysis was derived from the shipping magazine Lloyd's List. The basis for this was to conceptualize the general consensus of eco-innovations and how it is being discussed by industry insiders. To compile these articles, the assistance of someone with access to the Lloyd's list database was needed. Fortunately, with the assistance of the Centre for High North Logistics (CHNL) I was able to obtain these articles through a query. The query used certain keywords to identify which articles would be used. The keywords searched for were "clean technology", "eco-technology", "Flettner Rotors", "green innovation", "WASP". This search returned 47 mentions of the above terms in various articles dating back to the year 2008. These topics were listed in in terms of applicability and relevance to eco-innovation. Once placed into relevant categories, these articles were utilized as an industry centric counterbalance to the academia focused systematic literature review on eco-innovation. The result of this content analysis formed one aspect of the proposition framework upon which the Delphi method survey was constructed.

3.3. Sample Characteristics

The survey completed by practitioners examining eco-innovation from spheres of business, education, industrial, and research backgrounds were collected in two ways. The first group of participants were selected by their previous involvement with WASP projects and or EU backed shipping demonstration initiatives. These individuals were deemed suitable due to their knowledge of the shipping industry in general, prior exposure to shipping eco-innovations, and their continued commitment to fostering sustainable development signified by their involvement in previous demonstration projects. It was important to use individuals who think within this framework because they're devoted to bringing shipping emissions down while also maintaining profitability for firms operating within the shipping industry. The maritime sector is a vital part of the world's economic engine but in moving forward, it is necessary to make environmental alterations to how business is conducted. The other cohort of participants were selected from related academic articles pertaining to innovation, eco-innovation, green innovation, WASP technologies, and the shipping industry. It was deemed necessary to expand the scope of participants to ensure a wide casted net of competently knowledgeable individuals. Also, from a sample population perspective, the aim was to include participants from around the EU and world. The countries from which the participants hailed included Belgium, Brazil, Denmark, France, Germany, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Turkey, and the US. These participants held positions in educational institutions, governmental organizations, shipping companies, and consultancies with job titles like professor, researcher, head of research unit, port logistics director, dean, special projects manager, director, consultant, and CEO. From a sample of 111 selected participants (11 of which were undeliverable due to old, expired, or malfunctioning email addresses), 19 respondents completed the survey, representing a response rate of 19%. All responses were completed in full and used in the survey analysis data.

The survey was designed to accumulate information on driving factors of eco-innovative behavior, and performance. The survey was comprised of 10 questions relating to the various drivers like technology push, regulatory pull, and market push with a focus on environmental performance. The questions were screened and verified by my advisor to ensure validity, clarity, structure, and appropriateness. In doing so, the survey aimed to incorporate a qualitative as well as quantitative research method. The questions were constructed and assembled to measure four aspects of firm focused eco-innovation; environmental consciousness, market/demand influences, regulatory effectiveness, and technological capability sway. The questions were formulated and collected to utilize a Likert-type scale. Respondents were asked to complete all ten questions by using a five-point Likert scale ranging from 1 = Strongly Disagree to 3 = do not agree nor disagree, to 5 = Strongly Agree.

Qualitative research methods attempt to uncover how people think and feel regarding specific phenomenon, and the motivations behind their actions. In the words of (Easterby-Smith, Thorpe, & Jackson, 2015) “Qualitative research is a creative process, which aims to understand the sense that respondents make of their world”. An aspect that characterizes and separates qualitative methods from quantitative methods is the selection of data sets or populations due to the populations tending to be smaller while providing softer datasets. Quantitative research methods aim to express the evidence found through the use of numbers, with their main features is the volume of data collected. More acutely, (Easterby-Smith et al., 2015) express quantitative methods as “identifying what features tell the best story about the data (summarizing the data), while also looking for patterns in the data that can be used to draw conclusions about the study’s research questions (inferences about populations based on sample data)”. The benefit of implementing quantitative methods is that the data extracted is more easily applicable and can be used to depict data in finer detail. Since my research will take the form of an online survey through the implementation of the Delphi method, I will combine qualitative and quantitative research methods. A Delphi method can be characterized as a consensus building-tool in which a researcher or surveyor investigates stakeholders’ opinions regarding the current state of a situation or phenomenon (Geist, 2010). Given the circumstances surrounding the Covid-19 pandemic with borders closing and countries shutting down, this information gather tool can be ideally deployed in light of these geographical barriers. By analyzing the expert’s responses, I will extrapolate a consensus based upon the questions asked in the survey to support or reject my propositions.

3.4. Reliability and Validity

To ensure a high standard of research quality, it is vital to establish and maintain reliability and validity throughout the report. This section is designed to introduce and discuss how reliability and validity will be implemented during this research endeavor. The areas of focus are reliability, validity, internal validity, and external validity.

Reliability, as defined by (Easterby-Smith et al., 2015) is “the consistency of measurement in a composite variable formed by combining scores on a set of items; it can be measured using a Cronbach’s alpha coefficient.” The Cronbach alpha coefficient is an index about the internal consistency of composite variables which combine a set of items (Easterby-Smith et al., 2015). To ensure reliability I formulated the questions in the survey to be quantified on a Likert scale. A Likert scale is an ordinal category scale that measures attitudes ranging from very positive to very negative (Easterby-Smith et al., 2015). This allows a true reading of the scores because all answers are levelized. Reliability works in concert with validity which will be presented in the following paragraph.

Validity, as defined by (Easterby-Smith et al., 2015) is “the extent to which measures and research findings provide accurate representation of the things they are supposed to be describing.” In the context of this study, the aim was to improve validity through the use of experts in the field of eco-innovation. The implementation of a Delphi method vindicates the data through the consensus of all respondents. In order to ensure understanding of the questions in the survey, an informational section was sent within the email asking for respondent participation. Additionally, at the top of the survey more specific information regarding specific definitions or framing of questions were provided to respondents. These sections attempted to define, clarify, and generally inform all participants to ensure a baseline level comprehension regarding the framing of questions, so as to avoid confusing or misunderstanding during the responses. If a respondent was unclear on a specific question or definition used, correspondence was initiated to clarify the confusion. This also leads into internal and external validity which will be discussed next.

Internal validity assures that the results found during an experiment are true and the conclusions landed upon are correct through the elimination of systematic sources of potential bias (Easterby-Smith et al., 2015). This study aimed to increase internal validity through ensuring the experts were exactly that, experts in the fields of business, eco-innovation, research, regulation, and technology. The systematic factors that may bias internal validity relate to the transferability of eco-innovations factors from different sectors or industries. However, to combat this, some academics were specifically chosen due to their knowledge within eco-innovation but little to no prior exposure to the shipping industry. The ensuing data will facilitate external validity and generalizability of the results which will be dissected in the following segment.

External validity determines whether the results obtained from research can be generalized within other settings or contexts (Easterby-Smith et al., 2015). The results of the survey and subsequent discussion of this thesis aim to bring forth a consensus relating to eco-innovation in the shipping industry generally. The takeaway should be aptly applied around the world, and not specific to the Northern Sea area but through the shipping sector. Eco-innovation within shipping has been studied before and these results aim to facilitate the further understanding of how and why certain drivers lead to larger adoption. However, it should be noted that one form of bias is the EU institution itself, seeing that it is a strong institution and the edicts prescribed are enforceable; this may not be the case in other regions of the world. Ultimately the purpose of reliability and validity is to ensure appropriate standards are maintained throughout the research so the results can be used to further science in general.

3.5. Methodological Limitations

There were several challenges faced during this research. First, the original planned method of data collection was supposed to be gather through interviews. The intended interviews would have been with the WASP project partners whom were comprised of ship owners, regulators, technology supplies, and other researchers. However, due to the timing of this thesis and the WASP project itself, it was incompatible to conduct interviews within the timeframe necessary to hand in this report. Additionally, due to the circumstances revolving around Covid-19 data collection and responses may have been limited. The analysis, therefore, relied on the use of a survey sent out to professionals previously involved in EU funded WPT projects as well as other professionals and academics not associated with EU projects found through reading research articles during the systematic review phase. Secondly, in order to develop a comprehensive analysis of eco-innovation drivers within the shipping industry, it was necessary to include a collection of other dimensions regarding innovation and eco-innovation generally. Any analysis of eco-innovation would be incomplete without examining the diverse scope of research in the field.

3.6. Ethical considerations

One of the most important aspects of comprehension and understanding as researchers is reflexivity. Reflexivity as defined by (Alvesson & Sköldberg, 2018) is the ability to step outside of our prejudices to put ourselves into another's place and is the prerequisite to understanding them. This is an essential component of conducting research as it allows for both the researcher and the participants to gain perspectives previously not considered. The reflexion taking place instills an empathic approach to provides keen awareness to how linguistic, social and political aspects are interwoven during the knowledge development and data collection phases of research. When conducting qualitative research, it is imperative that certain perspectives and subjectivities are propagated to provide the reader with appropriate contextual standpoint to comprehend the research's findings. It is precisely for this reason that disclosures are a necessary part of the research process. The disclosures can take the form of financial backing, political views, or personal biases and conflicts of intertest. These disclosures may provide insight into how or why specific conclusions were landed upon from the data generated, and as such, the audience has a right to be aware of these when interpreting the data for themselves. Other considerations must be given to how, when, and where data is being collected, and stored, because these have impacts beyond just the researcher and his/her participants. The next paragraph will discuss the ethical considerations taken throughout this study.

In order to conduct research within an ethical framework, certain behaviors are necessary to avoid any transgressions. The consensus theory of ethics is defined by (Benton & Craib, 2011) as the ethical judgements arrived at through communicative rationality. It is important to ensure the integrity of myself, the institution, and the science community as a whole. When sending out the survey, it was necessary to first obtain clearance from Meldeskjema. This was accomplished by completing an online form outlining the nature and purpose of survey. Depending on the type of research being conducted, different levels of scrutiny are applied. Due to the fact that the data collected such as respondents name, email address, place of employment, and potentially their position can be classified as sensitive, questions regarding consent, and storage were raised. To maintain compliance, this information will be kept on a separate storage device and once this thesis is completed all unnecessary information will be destroyed. Also, when sending out initial emails to elicit survey responses, specific actions were taken to establish consent. Potential respondents were informed about the data being collected, their right to not participate, their right to not store certain information, their right to have any information deleted at any time if they so choose. This helped to ensure that respondents were in control of their data and that the research being conducted followed the appropriate edicts from Meldeskjema.

4.0. Systematic Review Results

4.1. Eco-Innovation Drivers Found During Systematic Review

Drivers of eco-innovation are catalyzed by internal and external organizational factors. Eco-innovation products have trended to mainly be driven through environmental regulation, company size, R&D, and the firm's green capabilities; while process innovation is more closely driven by regulation, environmental management systems, demand pull factors, market research, and company size (Bitencourt, de Oliveira Santini, Zanandrea, Froehlich, & Ladeira, 2020; Hojnik & Ruzzier, 2016; Triguero, Moreno-Mondéjar, & Davia, 2013). Other drivers, such as external factors are comprised of regulation, political and or institutional components and also stakeholder intervention, while resources, organizational capabilities and competencies are internal factors which deliver competitive advantages for stakeholders (Aloise & Macke, 2017). These internal and external factors are then broken down further into specific categories, as will be delineated below.

4.1.1 Regulatory push/pull

The research (Aloise & Macke, 2017) conducted focused on eco-innovations in developing countries, with specific consideration for the Manaus Free Trade Zone in Brazil, and found that a leading factor for eco-innovation products in this particular case was the Amazonian biodiversity which could develop products that utilize phytotherapics (medicinal plants) and bio-technologies/pharmaceuticals/cosmetics. Unfortunately, certain barriers like regulations are currently hindering the development due to the fact that legal restrictions on foreign companies have little effect because the firms' internal requirements are more restrictive than the state legislation (Aloise & Macke, 2017). This does support research by (Triguero et al., 2013) that stated eco-innovation drivers of SME in Europe are not influenced at the firm level by access to subsidies nor tax incentives. This was further confirmed by (Arranz, Arroyabe, Molina-García, & Fernandez de Arroyabe, 2019) by concluding that EU funding does not significantly develop eco-innovations despite the fact that such polices have been aimed at financing projects for new environmental technologies along with emboldening the creation of business and technology centers in Europe. However, the conventional theory argues that regulations and environmental protection policies have a crucial influence and can steer firms towards eco-innovations (Rennings, 2000). Although when it comes to industrial waste, wastewater treatment, recycling, and other environmental product innovations, the strictness of environmental legislation has been identified as an inductor for eco-innovations (Aloise & Macke, 2017) In this way, environmental and innovation policy must be integrated in a considered way so firms are able to internalize the technological environmental characteristics at the industry level and apply them at the company level (Bossle et al., 2016). However, adoption of eco-innovations have been shown to be a scenario of "action to comply with the law and other regulations" instead of out of the firm's own volition, but even though other factors have displayed relevance to trigger eco-innovation, regulatory pressure stills functions as the predominant driver (Huang et al., 2009). The severity of this regulatory pressure from stakeholders can catalyze eco-innovation and is also linked to research and development activation which go on to create leaders in the marketplace (Bossle et al., 2016). These regulatory instruments, along with managerial concerns and organizational initiative, positively impact eco-innovation adoption by firms which further mediates the relationship between regulatory tools and firm level concern for future adoption which has the likelihood for profitability down the line (Hazarika & Zhang, 2019).

4.1.2 Technological push

When looking at the research and development of firms, these technological capabilities have trended to show a positive relationship with eco-innovation because it facilitates the technological adaptations that are necessary to evolve clean technologies (Bitencourt et al., 2020). Although, due to product life cycles' decreasing, firms have turned to increasing their investments towards a focus on environmental innovations to better compete on the marketplace; however to rationalize these investments of research, development, and implementation an appropriate prospect of future market relevance must be present (Green et al., 1994; Azzone and Noci, 1998). The age and size of a firm also relates positively to eco-innovation adoption because this characteristic is linked to maturity with regard to technological capabilities (Carrillo-Hermosilla, Del Río, & Könnölä, 2010). Additionally, because eco-innovation is subject to various levels of volatility, and oftentimes vast amounts of resources must be consumed during the process, governments can play an important role through facilitating the development of new campaigns targeted towards consumers in the market to increase environmental awareness (Bossle et al., 2016). This can be seen as a shared sense of costs because the awareness of such products has the potential to drive demand for those products, thus justifying the initial investments from the firm's perspective. As such, the technological capabilities of a firm have significant positive influences on eco-innovative behavior because environmental competence takes full advantage of knowledge spillover in a specific industry network cluster which increases the propensity to eco-innovate (Cai & Li, 2018). However, if regulations relayed down from governments such as command and control instruments are too rigid in terms of technological and pollution restraints on firms it may have the opposite effect and instead stifle eco-innovation (Cai & Li, 2018). Another consideration to take into account is the availability of technical solutions. This is an essential component for harmonizing product durability, efficiency, quality, and for designing optimal life-cycles of new processes and products (de Jesus & Mendonça, 2018). Depending on the age of a firm, the technological trajectory was a significant driver for eco-innovation, although (Sáez-Martínez, Díaz-García, & Gonzalez-Moreno, 2016) found that demand and market-driven innovative behavior was more important to influence and spur eco-innovation for primarily small and mediums firms.

4.1.3 Market pull (demand side and supply side)

Some of the demand factors which firms are influenced by are corporate social responsibility (CSR), and market based instruments that use financial incentives to achieve the desired pollution reduction goals and these induce positive incentives for eco-innovation (Cai & Li, 2018; Kesidou & Demirel, 2012). It should also be noted that market turbulence has been linked to the hostility where a firm is located. This hostility would be defined as firmed differentiating themselves, and by doing so forces them to turn to innovative concepts (Hofstra & Huisingh, 2014). Corporate strategy has also been shown to positively link with eco-innovation because strategic thinking is predicated on bringing about competitive advantages over market competitors (Bitencourt et al., 2020). The importance of market leadership for internationally competitive firms demonstrates how they pull the market towards greener productions and as such firms should ear mark their resources to cultivate and develop internal factors that would aggregate more future value to the firm (Bossle et al., 2016; Brunnermeier & Cohen, 2003). Other external factors like normative pressures and market demand from consumers are important to consider and (Bossle et al., 2016) reiterated that firms face demands from suppliers, consumers, competitors, non-governmental organizations, research centers, financial institutions which can all lead to eco-innovation. The customers in the market play an integral part in eco-innovation because products deliver value directly to customers and as more consumers become climate conscious they are more willing to pay for ecological products and services (Cai & Li, 2018); in the this thesis, shipowners would be considered consumers, so it should be stated that due to the high retrofitting costs they would be more sensitive to costs than a product/service based consumer. However, (Sáez-Martínez et al., 2016) have argued that generally the market does not provide an ample drive of demand pull for eco-innovation because the relationship between eco-innovation and the important market factors that act as barriers to innovation such as established firm domination are non-existent.

4.1.4 Internal Firm and Specific Factors

Internal factors to the firm are in reference to internal resources, prerequisites and qualities of the firm that elicit an eco-innovative outlook; specifically when C-level managers make commitments to environmental issues but also have techno-logical competencies , and the financial resources at their disposal to engage in eco-innovative endeavors (Del Río et al., 2016) In a study (Arranz et al., 2019), found that firms which assert a high degree of internationalization in their activities conduct eco-innovations roughly 67% more frequently. These dynamic capacities are a firm's ability to integrate, build, and reconfigure internal and external competencies to appropriately tackle rapidly changing environments (Arranz et al., 2019). Hence, these dynamic capabilities are represented as specific and recognizable processes which dictate the behavioral patterns of firms and show how an organization will manage its resources with the aim of sustained success (Eisenhardt and Martin, 2000). Additionally, information sources present positive relationships with eco-innovation due to the context of existing knowledge necessary to promote process and products (Triguero et al., 2013).

Another specific internal factor is the use of eco-management systems which encourage the development and deployment of eco-innovation due to its strong link to organizational capabilities (Kesidou & Demirel, 2012). However, while cost savings were seen to be the most motivating factor other neglected influences to be considered are international factors (Bossle et al., 2016). These may include the influence of customers in foreign markets, international regulations, international sources of funding, cooperation with international institutions and the presence of foreign equity in firms (Del Río et al., 2016). Also, to consider are cultural effects, which relates to the relationship between individualism and collectivism. It was shown that the link between eco-innovation and firm performance was higher in cultures with lower levels of individualism (Bitencourt et al., 2020). This could be caused by collective cultures feeling more tied to the environment as opposed to individualistic societies which view the world as something to consume.

4.1.5 Institutional and/or Political Factors

Due to regime and or zeitgeist change, certain political factors, as well as a lack of an innovation framework, specifically in developing nations, can either stifle or influence the development of eco-innovations. Some of the factors (Aloise & Macke, 2017) identified were a lack of incentives and support, bureaucratic processes, poor governance, lack of coordinated planning and actions among governments, academia, and firms, conflicts within research sects and markets, as well as uncertainties regarding a country's technological development including poor definitions of public policies for innovation, and a deficit of studies on technological trends. It is unfair to assume that firms innovate on their own. There are many different actors present during the interactive process. It is for this reason that the National Innovation Systems (NIS) functions as a facilitator between private firms, researchers, and institutional actors (Wicki & Hansen, 2017). Additionally, for this thesis, the governing body Interreg functions in a similar manner by bringing together Educational institutions, private firms, independent researchers, and regulators. The main benefit of these types of collaborations is that the interactions allow program partners to distribute costs, risks, and resources to demo projects, cut down on product development time while simultaneously increasing access to knowledge and marketplace information (Arranz et al., 2019).

Due to the delineation of information, eco-innovative decisions may be affected by new regulations, certifications, technologies, and or marketplace necessities. It is because of this that information is so vital to a firm and can be one of the strongest incentives for firms when considering eco-innovative endeavors (Arranz et al., 2019). A secondary factor is the cooperation and collaboration agreements between firms, organizations, and or institutions. These value-creating networks are special because of all participating parties, particularly end-users involved in the innovation process, who must be clear about the strategy to develop joint-value propositions and creating experience and knowledge spillover from each other (Hermann & Wigger, 2017). Other factors like environmental regulations have been linked as external factor that impact eco-innovation investments because firms are pressured by stakeholders to invest in greener systems so as to reduce pollution, GHG, and resource consumption (Bitencourt et al., 2020). Although from a regulator perspective these policies are generated to stimulate network cooperation with market players while also upgrading the technological capabilities of participating firms to effectually contribute to improving the environmental impact of specific sectors (Sáez-Martínez et al., 2016).

4.1.6 Barriers

The barriers to innovation generally and eco-innovation specifically, relate to forces or obstacles preventing or challenging the development and promotion of such products or services. Barriers and obstacles reveal themselves from the uncertainty of the process and the marketplace; innovation outcomes are uncertain as is the time invested during the research and development phases which then causes difficulties for the firm when deciding to engage in innovation (Tidd et al., 2005). If the firm predicts that an uncertainty in innovation developments will cause a deviation budgeting, due to an unsuccessful product or process deployment, then more resources, capital, and time will have to be utilized than expected causing undue duress (Arranz et al., 2019). Another group of obstacles are comprised from the complexity of the eco-innovation process management. As (Arranz and Arroyabe, 2009) have shown, the development exploration and exploitation operations in a firm is heavily involved during the innovation process. This occurs because, exploration necessitates experimentation and seeking operations to discover novel and emerging technological innovations that will provide future sources of revenue (Gilsing et al., 2008).

If firms are to engage in eco-innovation, they also need to consider the environmental benefits caused by a potential product or process. Additionally, firms must development systems of management in order to obtain novel market information to stay abreast with the latest technology. Furthermore, the exploitation process of innovation forces firms to further extend and refine existing technologies, paradigms, and competencies (Rothaermel and Deeds, 2004). In this way, firms must hire or train appropriate staff with the competence level commensurate for the needs of said exploitation; even so, the oversight of both exploration and exploitation have been shown in various studies to combine and balance effectively (Arranz et al., 2019). When firms consider the management of conflicting organizational and strategic aims, tensions internally are bound to arise. Something else to consider when discussing uncertainties, is that they oftentimes occur due to the ignorance of consumers in relation to an innovative product or service (Hagedoorn, 2006). Specifically, when examining ecological products in the agro-food industry, these products tend to have included costs thus making their final purchase price higher compared to non-ecological products (Janine Fleth de Medeiros, Lago, Colling, Ribeiro, & Marcon, 2018). Due to this, the consumer must be willing to pay the higher price for the ecological product only if their perception of the quality + cost is acceptable. This is inclusive of the environmental and economic costs. However, it was observed that with an increase in the intangible value of the products (due to their ecological designation), the additional costs create uncertainty for the firm which causes them to engage in further actions to gain market acceptance for this specific product (Rehfeld, Rennings, & Ziegler, 2007; Sala et al., 2017). Although, when a market is dominated by established firms (such as in the shipping industry) this process becomes more difficult, resulting in challenges for new entry of products and firms (Arranz et al., 2019). Additionally, this is why competing firms attempt to mimic or copy the first innovator and thus avoid the costs from the exploration, and development phases of innovation. Barriers limit eco-innovation because they pose a high risk due to financial constraints, limited access to materials, and uncertain demand (Bitencourt et al., 2020).

5.0. Propositions Development

Regulations have historically been an emphasized driver of eco-innovation due to its double externality distinctiveness, which leads to technical and environmental overlaps (Rennings, 2000). This further underpins the win-win scenario Porter's hypothesis submits, that regulatory pressures incentivize firms into engaging in environmental investments aimed at reducing R&D costs to remain in compliance with environmental regulation benchmarks (Kesidou & Demirel, 2012). It should be mentioned that firms attempting to undergo or continue eco-innovation must also aim to condense production costs while exploiting their new eco-innovation products/services with promotional marketing strategies to inform the public (Kesidou & Demirel, 2012). By imposing regulations, governments, ports, municipalities, and other authority agencies can force firms to behave in more sustainable ways, and as a result also nudge these firms towards eco-innovative products and/or services, which can ultimately provide new streams of revenue. Something to consider however, is that although companies under regulations are developing and adopting eco-innovations, their orientation is still primarily geared towards minimum compliance with standards (Bossle et al., 2016). Conversely, firms that are already eco-conscious and exceeding regulatory measures before they're even implemented see advantages in being first movers (Hojnik, Ruzzier, & Manolova, 2018). Furthermore, as more literature is disseminated proving that the advantages of eco-innovations are not only environmental but also economical, firms will begin to innovate and create products and services without the push from regulators.

In the absence of internal motivations from firms, acutely attuned environmental regulations are needed to trigger such eco-innovations. However, (Rennings, Ziegler, Ankele, & Hoffmann, 2006) illustrated that within ecological economics incentive-based instruments predicated upon economic factors tended to be more successful in spurring eco-innovation as opposed to command and control instruments; conversely other literature (Hojnik & Ruzzier, 2016) supports the claim that regulations can invigorate more dramatic innovation rather than economic pressures. Particularly in the shipping industry, it has been revealed that both economic market pull and self-regulatory instruments provide a relationship stimulating eco-innovation but due to the current market circumstances challenges are encountered by ship-owners not being incentivized enough to install environmental technologies (Hermann, 2017). Although, when ship-owners participated in voluntary environmental programs through business to business information sharing, the incentives were enough to spur installations of eco-innovations (Horbach et al., 2012). It has also been shown that the eco-innovation drivers technological push and regulatory push are closely linked caused by lobbying from technological supplies to regulators, ensuring certain technologies maintain their inclusion in future regulatory measures (Hermann, 2017). Using the Delphi survey, I aim to explore which instruments can be most effective to incentivize WPT adoption. In accordance with this aim, the following propositions were concluded on through the input from a systematic review, content analysis, and subsequently validated with the Delphi survey. Fig 3 depicts this process.

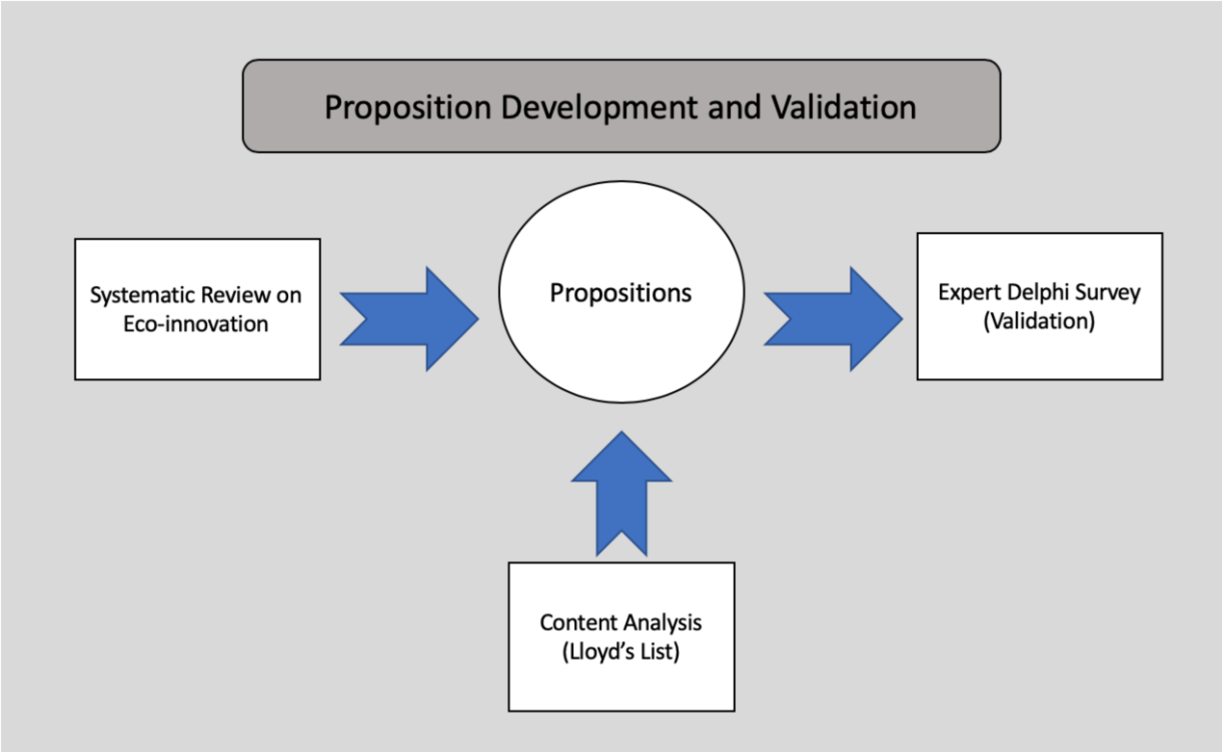

Figure 4: Proposition Development and Validation Model

Source: Independently designed by author

5.1. Propositions

1: Due to the dynamics of short sea shipping, regulatory measures will be most influential for adoption of WASP Technologies

When considering different routes within the shipping industry, The North Atlantic route presents itself with the most favorable conditions in order to recoup the most beneficial economic advantages if WASP technologies are installed on a gas turbine powered vessel opposed to on a diesel engine ship (Talluri et al., 2016). Although, during a model test, the most efficient configuration was found to be a gas turbine power plant without Flettner rotors; however, this could be accounted for due to the low propulsive power contribution of the Flettner rotors over the route (Talluri et al., 2018). Although it has been shown that regulation tends to be a low-level driver for eco-innovation due to its primarily reactive responses (Agan, Acar, & Borodin, 2013), in the shipping industry it may prove to act in a similar manner. Although a different study found that while regulation tends to function as a driver of process eco-innovation when compared to other driving forces, regulation has less influence (Hojnik & Ruzzier, 2016). It should be noted that an observation was made that if the taxation rate was increased the utilization of a diesel power plant in conjunction with Flettner rotors would provide an economic benefit; additionally in a tax scenario, where there is no CO2 taxation policy currently in place, the benefit of Flettner rotors on a ship for certain routes are unviable, as they provide little to no economic benefit (Talluri et al., 2018). In an earlier study (Talluri et al., 2016) opined that the installation of the vertical axis wind turbines such as Flettner rotors could work advantageously on ships traversing the Atlantic Ocean due to the fact that these routes are highlighted by high fuel consumption and more importantly particularly strong wind conditions, which support power propulsion by the wind turbines. With that knowledge, it shows the magnitude of the influence environmental policy has, and that the lack of effectiveness from tax subsidies or economic incentives is reason to push for a change in the current regulatory framework (Triguero et al., 2013).

Likewise, a more stringent regulatory framework is needed due to impose new standards and limit access to existing subsidies and fiscal incentives if enhancements in the eco-innovation process are desired; In this way, (Triguero et al., 2013) has recommended that the EU should promote certification programs regarding environmental management systems (EMS) as EMAS or ISO14001 as an alternative to offering subsidies or tax incentives. Outside of EMSs, other options include carbon taxing, which would directly impact the shipping sector. Additionally, after a period of carbon taxing and inclusive demonstration programs, a cost-effective policy could enhance the learning and diffusion rates of rotor technology and reducing the need for this carbon price support, would instead focus primarily on routes with favorable wind conditions (like Atlantic Routes, as have been previously mentioned) which then also form naturally protected innovation niches; It would then be even more beneficial to shipowners who operate on routes with less favorable wind conditions as it will lead to learning, reduced barriers and lower costs (Karslen et al., 2019) Within shipping this is seen more strictly due to pressure on CO2 and NOx levels of certain types of fuels. Several years ago an environmental charity was developed for fuel-saving systems; according to their hypothetical analysis model, the Greenwave team proposed that due to aerodynamics, wind-assisted applications would enable a supramax bulk carrier trading from China to Indonesia to save 31% on its fuel cost (Dearden & Conotopoulos, 2008). A factor further displaying the need for adequate regulations as this short sea trip from China to Indonesia has yet to see widespread adoption of wind assisted ships.

2: To stay competitive, once the first firm adopts, others will follow

There have has been several studies that show a link between eco-innovation and the positive correlation on a firm's economic performance (Cai & Li, 2018; Hojnik & Ruzzier, 2016). Firms that apply eco-innovation into the business models garner superior concentrations of revenue generated per employee as opposed to firms which do not implement eco-innovation (Doran & Ryan, 2012). These benefits may be seen directly when canvassing the operations side of the firm; specifically, through cost savings and higher levels of resource productivity along with more efficient logistics and the commercialization that follows (Sarkar, 2013). Furthermore, (Cheng & Shiu, 2012) found positive correlations between a firm's performance and the focus that firm directed towards eco-innovations in the eco-product, process, and organization aspects. Likewise, (Chen, Cheng, & Dai, 2017; Cruz-Cázares, Bayona-Sáez, & García-Marco, 2013) displayed how innovation focusing on technological efficiency was also positively linked to firm performance. Other studies have exemplified that environmental innovation, (meaning the optimization of firm natural resources and in terms of energy consumption per output unit) wield significant impacts on the competitiveness and business performances of firms (Bossle et al., 2016; Eiadat, Kelly, Roche, & Eyadat, 2008; Tseng, Wang, Chiu, Geng, & Lin, 2013).

Additionally, investment in eco-innovation spawned an iterative cycle where the more firms invested in eco-innovation led to a greater separation from their competitors on the market, which in turn provided a stronger advantage (Hojnik & Ruzzier, 2016). This also supports the notion that firms who seek opportunities while maintaining open collaboration with other players in the market tend to develop eco-innovations at a higher rate. Firms that excel at recognizing opportunities have a direct correlation to increased eco-innovation and these firms also tended to have customer and market orientations which enabled them to identify consumers preferences with the ultimate goal of evolving business models that further reinforce eco-innovation development (Sáez-Martínez et al., 2016). Other market based benefits of development and implementation of eco-innovations include enhancing the firms image, cost savings, local community outreach improvement, broadened access to green markets, and further competitive advantages (Shrivastava, 1995). Furthermore, (Sáez-Martínez et al., 2016) indicated that path dependency is highly prevalent in eco-innovation development and firms with high levels of innovation development capacity leads to supplementary green or eco-innovation in the future. So within the shipping industry it can be surmised that WPT technologies have the potential to provide this kind benefit and due to their expected cost savings of up to 20% (Talluri et al., 2018) make them extremely attractive. Even before this analysis, as far back as 2013, Scandlines has laid a long term vison to incorporate hydrogen, Flettner rotors, and other environmental tools into concept vessels so they can lure both potential buyers and customers who are angling for ways to cut their fuel consumption (Eason, 2013b).

3: Technological push will be the least important factor because ship owners purchase WASP technology and do not develop it themselves

The technological push firms experience are factors that sprout from the entanglement of endogenous innovative abilities and international technological spillover which tends to have deterministic influences on innovation performance; More specifically, when considering regional eco-innovation, the primary step should be for firms engaging in production supply to outfit themselves with capital (both knowledge-based, and physical) so new products and technologies will increase the investment in innovative solutions (Chen et al., 2017). It has also been shown that through the advancement of technology, the scope of technology based eco-innovation aspects become larger and more complicated, with intricate interactions throughout the dimensions; In this way, firms should aim to not only fulfill the dimensions form technology based demand, but also consider and quantify their performance from a triple bottom line framework (Kuo & Smith, 2018). Furthermore, (Del Río et al., 2016) displayed that the impacts from technological environments intensity resulted in a scenario where low-tech sectors (slow movers/adopters, mature industries, high polluters) have a higher proclivity to eco-innovate. This may be catalyzed by the necessity to stay within regulations, and so a low-tech firm would be forced to eco-innovation instead of choosing to do so out of their own volition. Although, (Sáez-Martínez et al., 2016) data suggested that eco-innovation displayed an inverted U-shaped relationship with industry technology intensity; this means that medium-tech firms are most likely to research and develop eco-innovations (compared with low-tech firms).

Relating to the shipping industry, if shipowners want to innovate, they send an order to shipyards to build or retrofit ships with the appropriate eco-innovation. Shipowners also have the option to invest in research and development so as to increase capacity. However, the improvements in emissions and energy efficiency delineating from the research and development are dependent on the type of technology to be utilized, as do the costs (both capital investment and operational). Thus, the fundamental role involved during the innovation phase within this industry is performed by shipbuilders (and suppliers), in direct reaction to the financial decisions felt throughout the shipping markets (Köhler & Senger, 2012).The impetus from shipowners to innovate tends to come from demonstration projects, showing the effectiveness of new technologies. With the underlying supposition that the results from demonstration projects both successes and failures should not reduce shipowner expectations but instead instill that learning accumulates during each period and thus expectations can increase over time (Karslen et al., 2019); It should therefore be understood that the market push from consumers and cooperation with authorities in demonstration project lead to higher levels of adoption and not from a technology push. Although in a recent shipping magazine (Osler & Farley, 2019) it was stressed that these WASP technologies, such as kite sails, Flettner rotors, require a cost benefit analysis predicated on a vigorous data set before ship owners are informed enough to make large commercial decisions on future adoption.

4: Upfront retrofitting costs will be biggest barrier to adoption

For shipowners, the installation of Flettner rotors is still not profitable enough on all routes at the current levels of fuel prices and regulatory policies; although the environmental gain is substantial, the economic realities have to be considered and at this point in time it doesn't make sense other than in situations where wind conditions are preferable (Talluri et al., 2016). The barriers within the shipping industry to be considered are imperfect information on technological performances and the split incentive structure set-up in the short-term time charter market (shipowners' investments in novel technologies are not rewarded with charter premiums), while other barriers relate to capital access (or lack thereof), incompatible infrastructure, technical risks, and geo-political risks such as oil price volatility or lower fleet utilization (Karslen et al., 2019; Rehmatulla, Parker, et al., 2017; Rojon & Dieperink, 2014). Oftentimes shipowners have underestimated the profits stemming from rotor technology, which has been caused by imperfect information, and split incentive set-up from the charter premiums when utilizing rotor technology. These limited charter premiums, and low fuel costs plus expectations, have led shipowners to view rotor technology as uneconomical which supports low adoption rates and limits learning while maintaining high capital costs; the imperfect information and split incentives barriers prevent knowledge diffusion by stalling positive feedback loops between experiments, learning, and expectations (Karslen et al., 2019). Due to the mobilization of functional resources being inadequately realized the financial support provided for technology development has primarily been funded through public innovation initiatives, while actors seeking to receive financial support have struggled to obtain it (Rojon & Dieperink, 2014).

From the standpoint of the shipping industry, many players struggle for commercial vitality and oftentimes lack the requisite financial means to invest, adopt, and subsequently install novel technologies. It goes without saying that within the current market climate, liquidity it more vital to firm survival than profitability, which rationalizes the non-investment in capital which would only pay for itself years after the initial purchase; thus any long term competitive advantage that would stem from wind propulsion technologies is overshadowed by the interim capital restrictions (Rojon & Dieperink, 2014). When dissecting network cooperation within shipping certain conflicts arose between partners whose interests diverged between economic value capture and environmental value capture. This occurs at the macro level because the firm see a direct benefit from research and development while simultaneously providing a benefit to the environment (double externality), however this disincentivizes firms to commit to eco-innovations because while they share in the value capture, they also assume all the costs (Garcia, Wigger, & Hermann, 2019). A recent case study highlighted how network participation from various actors can facilitate a nudge of eco-innovations while also increasing eco-efficiency; this eco-efficiency concept originated through an open network that offered shipping companies a "one-stop-shop" green retrofit location in a Danish harbor, providing each individual supplier one component that would improve the energy ratio usage per unit of fuel in older ships (Hermann & Wigger, 2017).

This type of set-up (one-stop retrofit harbor), may be a way to increase overall adoption rates of wind propulsion technologies by decreasing costs through centralization. When asked in a 2017 interview, Per Winther Christensen (Deputy Technical Director of Danish Shipowners' Association) was quoted as saying "I see an increasing interest for the Flettner rotor, and Maersk Tankers will install two rotors on a vessel this year. The expected savings on the rotor systems vary and are particularly dependent on the vessels' trade patterns and which wind systems they meet on the voyage. Savings could be up to 10%, which is significant. With few Flettner rotors installed and in operation today, I believe that the growth will be highest, so if 500 are installed in 2050 it will be a growth times 100 over 30 years." (Kinthaert, 2017). So, while retrofitting costs may be expensive, it may make more sense for newer ships to implement WASP technologies such as Flettner rotors over the course of several decades.

6.0. Survey Results

6.1 Technology Based Questions

Questions nine and ten were constructed to determine the technological driving factor. 17 of the 19 respondents completely agreed or somewhat agreed to the ninth question confirming if shipowners were more influenced by market demands or technological capabilities. What this could signify is that while the availability of technology is important, the market conditions and regulatory frameworks in place have a larger significance for decision makers within the firm. Following this point, as a way to limit research and development costs, participation in demonstration projects may be more attractable because the exploration costs are shared by numerous parties, as well as the potential benefits. Especially in a mature industry like the maritime industry, reluctance to change is prevalent, so as a mitigation solution, less resources are focused on new and upcoming technologies if it comes at the cost of further market concentration. Ships that need to be taken out of service for retrofitting or technological upgrades are then rendered idle and thus the firm loses out on contracts and service time. Question ten revealed that just under half of the respondents felt that WPT were not more suited for short sea routes as opposed to long hauls. While only five respondents somewhat agreed that they were, with another six not agreeing nor disagreeing. This does tend to contradict prior literature that, from the perspective of adoption, short sea route ships should adopt WPT before implementing them on longer routes. Due to the weather conditions in different locations around the world, certain routes are better suited for WPT. This was shown by (Rehmatulla, Parker, et al., 2017) that the Atlantic Ocean and North Sea offers some of the best conditions for WPT. While the survey results showed that some of the experts perceived longer routes as more conducive to WPT. It was my hypothesis that due to the weather patterns and wind velocity in the North Sea region, that short routes along these waters would make the most sense for initial testing. Although for cost saving technology, the larger data set that is used the more savings will accumulate. With this reasoning, it would then make sense that long routes implement WPT to reduce fuel costs, while decreasing its environmental externalities.

The technology-based questions of the survey showed that the capabilities of firms would not significantly impact the adoption rate of WPT. One of the reasons being is that certain barriers surrounding the implementation of WPT are predicated on a lack of knowledge of the technology itself in practical settings. This is why demonstrations and trials are so vital to the entire network of the maritime industry. While the innovation and technological developments play an important role in developed nations, the conscience that these innovations may present environmental and societal benefits is rapidly increasing. As such, the competitiveness between firms on “greening” their operations is contingent upon firms attempting to maintain a solid public reputation with stakeholders and also gaining an advantage on their competitors at both the regional and national level (Bossle et al., 2016). While the literature contends that technological capabilities have a significant impact on eco-innovative behavior, these results indicate a contradiction of the relationship between eco-innovation and technological push, at least in regard to the shipping industry. This can be a result of its maturity as an industry and or the fact that it was taken from the perspective of a shipowner, wherein these capabilities aren’t as necessary since they will be sourced to supply firms. However, this should not be taken as a sign that shipowner do not eco-innovate but instead be understood as a lesser driver than economic or regulatory factors. The reason being is that due to the split incentive problem, those that did not invest in the research and develop of certain technologies benefit more because they simply reap the end result. This can be exemplified through the interaction between the ship owner and the ship operator, which in many cases are not the same.

In this set-up, the ship owner is responsible for environmental upgrades and regulatory compliance, while the ship operators reap those energy efficiency benefits in the form of lowered fuel costs. Additionally, between ship owners, there is hesitance to be the first to undertake environmental upgrades, even if it creates a competitive advantage after the installation because the downside of such an investment could mean the demise of the firm. So herein lies the dilemma for shipowners, They don’t have complete information when it comes to WPT and its effectiveness without participating in trials; and because of this no shipowner wants to be first because it’s a safer play to let someone else go and mimicking if it proves successful, while standing on the sidelines if it doesn’t. However, the survey results show that shipowners are indeed inclined to eco-innovate for environmental as well as economic reasons, with or without regulatory pushes. Although, their drive to do so is not coming from their technological capabilities but rather from a competitive and market share perspective. Shipowners are open to utilizing technology available so long as it makes economic sense. It can be argued that this is why they participate in demonstration projects. Although they are not developing the technologies that can eventually be installed onto their ships, their participation can be seen as a form of research. This can be the money invested into the demonstration project, or the eventual results that arise from project. Coincidentally, shipping companies have been disincentivized in the past from making technological upgrades due to regulatory mandates that are subsequently eased. As such, investment into research and development has taken a more safeguarded approach which is seen through participation in demonstration projects that bring together regulators, rivals, and suppliers.

6.2 Market Based Questions

Questions six, seven, and eight were phrased in order to assess the market drivers from the perspective of shipowners. Question six posed the hypothetical scenario that if one shipowner were to retrofit their ship with WPT, then others in the industry would follow; the results showed that 14 respondents either completely or somewhat agreed, while four respondents saw no impact, and one somewhat disagreed. While this agrees with previous literature, it contradicts the 2013 scenario of Maersk retrofitting their line due to regulatory edicts only to have competitors sit on the sideline while the regulatory organization pushed back the deadline for compliance (Eason, 2013a). In this scenario, the rivals did not follow, and as such experienced an advantage due to foregoing capital investments. Although these investments will need to be made at some point, if compliance is to be adhered to, pushing the investment off gives the advantage to the late adopters. They receive an advantage because their ships will not sit idle during retrofitting and have more time to secure financing for these retrofits, or even receive subsidies if they were to become available. However, shipping company may want to push forward with the adoption regardless as a means to differentiate themselves from competitors while simultaneously benefiting from the public relations windfall of "greening" their operations.

Question seven asking if the upfront costs of retrofitting older ships with wind propulsion technologies outweighed their future environmental and financial cost savings revealed that 8 participants either completely agreed or somewhat agreed, while ten respondents were swayed either way, and one person completely disagreed. Due to the majority of respondents not agreeing nor disagreeing it is difficult to assess the implications from this question. In designing the question, I attempted to gain insight into the cost benefit analysis of retrofitting older ships or not. It was my hypothesis that depending on the market conditions, retrofitting would make more sense only if it was demonstrably beneficial. The reason being that if a firm had an opportunity to retrofit but was not required to under regulations, they would choose not to and instead divert those financial resources to other endeavors.

Question eight asked the participants if eco-innovations such as WPT give shipowners a competitive advantage over their rivals; 13 of them responded either completely agreeing or somewhat agreeing, while four did not agree nor disagree, and two somewhat disagreed. The responses from this question led to an indication that by outfitting a ship with WPT your competitiveness over rivals does indeed increase. This can take the form of more attractive stipulations when negotiating contracts with charters due to enhanced fuel efficiency. Furthermore, the public's perception of the shipping industry moving in a "greener" direction bodes well for future business and industry wellbeing. An added positive externality would be the environmental restoration through decreased fuel consumption and increased environmental sustainability. It should be pointed out that one potential issue with an increased adoption of WPT is the port infrastructure. Due to WPT construction, the way in which ports are designed may present problems for cargo handling which is primarily completed by crane and thus would be obstructed by a Flettner rotor, kite, or sail. From an industry wide perspective, the economic growth since the mid 2000's financial crisis has continued profitability seeking behavior, which at times comes at the cost of environmental sustainability.

While the shipping industry as a whole is a large polluter, the market has made strides in moving towards a climate conscious framework. Although, the competitive pressures of any industry make profitability necessary, there is a case to be made that firms providing eco-innovations, and in this case utilizing WPTs, can lead to an increase in competitiveness, while also actively bringing sustainable development throughout the sector. This last point may be the most important as the debate surrounding heavy industrial polluters takes the center stage in many nations around the world. Firms that take a proactive approach to environmental issues may be better suited to withstand the eventual uptick in regulations like carbon taxes, pollution limits, and other environmentally centered policies. A long-term strategic plan for ship owners may be the difference between survival and thriving in a future market running rampant with stringent environmental policies, and schemes. The fact remains that the market will continue to drive innovation because firms are always looking for any advantage over their rivals both in the interim and long run.

6.3 Environmental Questions

In order to ascertain the extent to which shipowners embrace environmental performance measures, questions one, two and five were deployed. Question one asked the participants if eco-innovations such as WPT were necessary to achieve high levels of environmental performance. A resounding 18 of the 19 individuals responded in complete agreement, while one neither agreed nor disagreed. This result is unsurprising since the essence of eco-innovations are to impact the environment in a positive way. However, it is interesting to note that this question was constructed in such a way as to imply the environment as a stakeholder as opposed to simply an externality. This concept is imbedded within sustainable development and facilities the transition from a utilitarian framework to an ecologically considerate one. Especially for an industry such as shipping, where GHG emissions are a major concern, a real transition is needed if the climate goals such as the Paris Climate Agreement are to be met. Eco-innovations, and in particular WPT will go a long way to reducing fuel consumption and ultimately the amount of pollution caused by this industry.

When looking at question two, 18 of the 19 respondents either agreed completely or somewhat that WPTs should be adopted by shipowners as a way to strengthen a firm's environmental management strategy while only one neither agreed nor disagreed. Following up on the analysis from the last question, now more than ever it is imperative for firms and particularly heavy polluting firms to develop and implement environmental management strategies. Not only from an environmental standpoint but also from an economic perspective, the more proactive firms are, decrease the amount of catch-up they will eventually have to play when more stringent regulations are implemented. In this regard, WPTs can provide an economic benefit but also signal to regulators and industry assessors that they are taking sustainable development seriously.

Of the 19 respondents for question five, roughly 79% of them either agreed or somewhat agreed that of the available solutions, WPT offers the greatest potential to provide most immediate environmental relief for the shipping industry. There are several options to shipowners that all provide various levels of environmental relief. However, the allure of WPT is the predicted amount of fuel savings, which acts as double incentive. First, by decreasing the amount of fuel that needs to be bought while also limiting the amount of pollution that is emitted as a result. In this way, WPT may seem more attractive than end-of-pipe technologies which only reduce the amount of pollution. However, the combination of different eco-innovations would be ideal, when considering the financial limitations of shipowners, WPT offer most immediate environmental relief. Furthermore, eco-innovative behavior has been shown to facilitate a positive, albeit indirect influence on the economic performance of firms. This is due to the fact that while firms need to adapt to environmental changes and regulations, the spillover from investments such as WPT have the potential to improve economic performance. Also, the collaboration within cluster networks will thus lead to more eco-innovations because firms that have a larger cache of environmental knowledge are better positioned to utilize that knowledge in the future through the development of new products and services.

Moreover, because shipowners need to adapt to maintain vitality in the industry while also complying with environmental regulations, they will continue to look for ways to improve the environmental capabilities by researching, and investing in green products, and processes. In the shipping industry this may include environmental monitoring systems for internal and external examination so as to create strategies for improved compliance and reducing pollution. Due to ships often navigating in waters of different nations, it is necessary for certain levels of "self-policing" in regard to environmental compliance. This self-monitoring may also improve economic performance in the future by giving shipowners larger data sets of shipping performance. Although, it will be necessary to have stern regulations collaboratively enforced by various regulatory institutions.

6.4 Regulatory Questions

Questions three and four centered on regulatory inquires to determine their potential influence on eco-innovation. Question three asked if governments should provide subsidies schemes to shipowners to increase the proliferation and adoption of WPT in the industry. Of the 19 respondents, 16 were either in complete agreement or somewhat agreement, while two neither agreed nor disagreed, and one participant somewhat disagreed. Governments around the world often provide subsidies for various industries both new and mature. However, higher environmental regulation will cause a larger proportion of environmental costs to operations in the shipping industry because shipowners and operators will need to implement environmental management systems, as well as invest in emissions reducing technologies. However, a market-based instrument instituted by a governing body may be useful in providing fiscal incentives in order to obtain the desired pollution reductions while also increasing the proliferation of eco-innovations to adhere to the new standards. If the lofty emissions goals of the Paris Agreement are to be reached, the decarbonization of the shipping industry must make greater strides in the coming decades. Due to the nature and magnitude of shipping the industry is a major emitter of GHG, although compared to other transportation options, it is one of the most environmentally friendly with global CO_2 emissions reaching 2.7% in 2007 (Buhaug, et al., 2009).

Even still, if options like WPT are to be implemented more broadly across the industry, governments may have to catalyze their adoption. If harsher regulations are implemented, shipowners may need financial assistance to incorporate newer technologies to reduce emissions into their fleet. This is where a subsidy could benefit the entire industry but specifically entice early adopters so as to disincentivize fence sitters. Continuing on this point, the fourth question postulated that if stricter environmental regulations were set in place within the shipping industry, this would lead to an increase in adoption. Roughly 90% of the respondents completely agreed or somewhat agreed with that supposition, while the other 10% did not agree nor disagree. Harsher and more stringent environmental regulations would force the hand of slow-moving shipowners into adopting emission reducing technologies like WPT. One option would be universal eco-rating schemes which can utilized as a benchmarking instrument for buyers, users, and regulators to make better informed decisions based on the performance of a given product or service. However, it has been shown that firms can use eco-rating schemes in complicated or obfuscating ways to deflect regulation and or provide irrelevant information to the marketplace (Poulsen, Hermann, & Smink, 2018).

Although a counter measure for this would be a universal rating scheme that is legislated and overseen by a consortium of national governments. Such a consortium could include the EU and IMO working collectively in the EU as a test region, which could then be extrapolated and implemented around the world with other nations joining. This scheme should allow for third party verified data to benchmark the environmental performance of ships to provide reliability. A novel implementation of this could take the form of a decentralized ledger or blockchain to ensure transparency. This further emphasizes the necessity for stern regulations. If regulations are definite, then first mover advantage is viable. However, if regulations aren't stiff or are unclear then first mover may be a disadvantage due to earlier than expected capital expenditure. This occurred in 2013 when head of regulatory affairs at AP Moller-Maersk Niels Bjørn Mortensen stated "early movers are getting penalized and all those laughing on the fence are getting rewarded" (Eason, 2013a). In this instance, legislation was implemented with a five year roll out window before being enforced, however, due to lobbying that deadline was pushed back thus rendering Maersk's retrofit unnecessarily early causing a disadvantage. If regulations are definite, they will also help to promote eco-innovations. This is supported by Porter's hypothesis that environmental regulations trigger the development and deployment of cleaner technologies for improved environmental performance. The spillover from stricter environmental regulations can have a positive impact reducing emissions in the shipping industry, while also proliferating the adoption of eco-innovations such as WPTs.

6.5 Survey Result Summary

This section dissected the results stemming from the Delphi method questionnaire. The four aspects the survey aimed to shed light on the technological, market based, environmental, and regulatory factors influencing eco-innovation adoption in the shipping industry. From a technological perspective, the maturity of the shipping industry leads it to be more conservative and slower to adapt new technologies as opposed to other more agile industries. Although wind propulsion isn't a new technology in the shipping industry, the renewed interest in and capabilities of current WPTs signify a willingness to adapt on the part of shipowners. However, due to the split incentive dilemma, shipowners may show trepidation to develop and implement WPT technologies, as they are concerned about burdening the costs while others reap the benefits. Furthermore, this supports the argument that the technological push, at least in the shipping industry is not as strong of drivers for eco-innovation as the regulatory pull or economic push.

The survey showed that the market demands of the maritime industry signal a strong influencing factor for the adoption of eco-innovations like WPT. Because shipowners are always looking for an advantage, if a rival implements WPTs into their fleet, others will tend to follow. With more attention being focused on firms' climate consciousness, especially in the shipping industry, shipowners will begin to incorporate WPTs into their fleet for the to gain an advantage on competitors, while also signaling to the market of their "green" direction. Furthermore, the IMO's goal of decarbonizing the shipping industry by at least 50% will be more easily achieved through the implementation WPTs. Shipowners will be enticed by WPTs ability to improve fuel efficiency which increases expected profitability of the asset and thus the ship, while also providing an operational hedge against volatile fuel costs for ship operators.

For these reasons, market-based influences remain a powerful influencing factor when examining eco-innovation in the shipping industry. The results illustrated that eco-innovations should play an important role in firms' environmental management strategies. Within the shipping industry, a cost-effective approach that also offers sizable emissions reductions are WPTs. While not the only option, WPTs can be utilized as part of a broader strategy that acts as a complimentary measure which incorporates various technologies to accelerate the decarbonization transition of the shipping industry. The benefits of eco-innovations such as these have been shown to provide indirect economic performance in the form of fuel efficiency and decreased fuel costs. Additional benefits include the spillover effects from collaborating within network clusters which lead to knowledge sharing and ultimately more eco-innovations. Furthermore, due to necessary environmental regulations, which only figures to become more stringent, shipowners will continue to look for various ways to improves their economic vitality while maintaining compliance.

There was near universal agreement from the respondents on the role of regulation and its influence in the dissemination of eco-innovation adoption. While regulation is necessary it is imperative that new regulations within the shipping industry are stringent and firm in their enforcement. This would expedite the adoption rate of eco-innovations like WPTs while also disincentivizing firms to lag behind or wait on the fence. An overarching governing body or collection of bodies should consider a universal plan such as eco-rating schemes that can broadly assess the various actors within the industry. The scheme should allow for verification from third parties to allow for the benchmarking of environmental compliance data. One consideration for this rollout could take the form of a decentralized ledger that can be kept up to date in real time while decreasing organizational bureaucracy. It is clear that regulatory pushes are a major driving force behind eco-innovation adoption. The figure below depicts a suitable path for WPT adoption in the shipping industry.

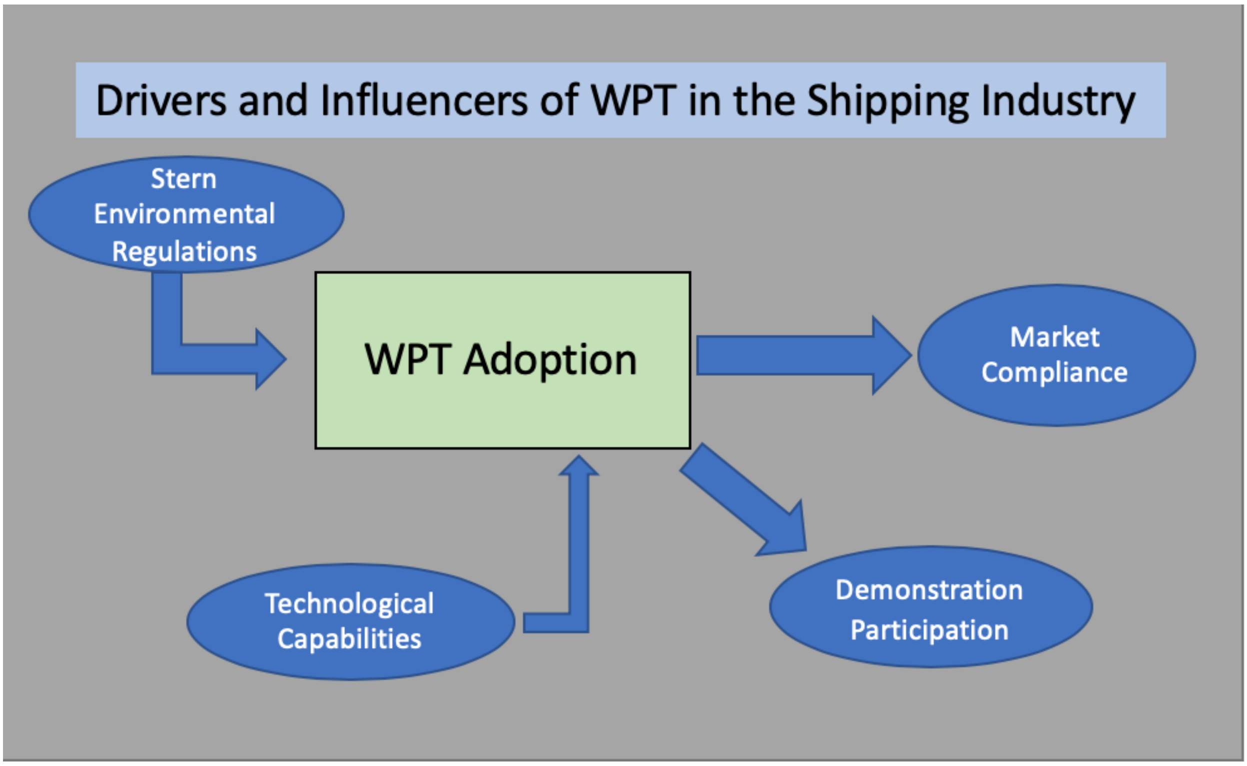

Figure 5: Drivers and Influencers of WPT in the Shipping Industry

Source: Adapted from Hermann, R.R. (2017)

6.6 Delphi Method Reflection

The Delphi method is a useful asset to determine goals, create logic models, facilitate in an empowerment evaluation, and also to determine relevant issues as an antecedent to the development of a survey. During the course of this research endeavor, I implemented the Delphi method to utilize the array of experts in the field of eco-innovation, education, research, and shipping to gain consensus on the propositions created from a systematic review and content analysis. In this format, the Delphi was administered online through the use of a survey to contact and receive feedback from participants in a less time-consuming method than in-person or virtual interviews. An added benefit of conducting this survey online is the elimination of influencing bias or pressure on the part of respondents from other respondents. Since all surveys are compiled by the researcher, respondents are free to change their answers at any point without judgement or reprisal from others. The information gathered from this survey was paramount for the completion of this thesis. The most useful outcome resulting from this survey was gaining an understanding of the participants views relating to eco-innovation within the shipping industry and how that consensus can be utilized in the creation of an ABM. This will be important information for future researchers as well as for the WASP project and its many partners.

It is valuable to dissect the response rates of the survey because the framework of the model is predicated on obtaining consensus while avoiding influence and bias. Of the 111 selected participants (11 of which were undeliverable due to old, expired, or malfunctioning email addresses), 19 respondents completed the survey, representing a response rate of 19%. Over 60% of the respondents were either researchers or working within an educational institution. The other respondents were comprised of 70% industry leaders, and 15% each of consultants and regulators. This response rate was lower than desired, and while suboptimal, was biased towards researchers. This certainly had an impact on the results of the survey since these researcher study eco-innovations, they would be more inclined to provide answers that display a bias towards the proliferation of eco-innovations.

From a validity perspective, it would have been desirable to see a response rate of at least 40%, with a fairly even split between researchers and industry players. It is also important to consider the individuals who were sent a survey but declined to respond. Their decision to decline participation can be understood for many different reasons with some of them being, they are not interested in eco-innovations, wind propulsion or other such emission reducing technologies, or did not view the survey to be a good use of the time. These "non-respondents" play critical role in understanding how surveys like this can be improved in the future as well as understanding the realities of results from these types of research methods. As such, the results from the survey must be analyzed objectively, and the lower than desired response rate in addition to the types of respondents and non-respondents could be the reason for what the data indicates.

By reflecting back on the shortcomings of the data received during this research endeavor a researcher can understand the limitations of the methodology and subsequent results while also utilizing it as a lesson on how to improve in the future. The data received was useful to evaluate general opinions and leanings, however it was difficult to ascertain the exact predilections of the experts as the questions were asked in a closed way only allowing for agreement or disagreement. It may have proved to be prudent to allow for open ended questions that needed detailed responses. By projecting forward into the future, an avenue to secure more stringent reliability for these findings would be to conduct more surveys in an iterative process. Over the course of several months to several years, this process can attempt to increase the participation and response rate while also incorporating a broader array of experts. This would not only bring reliability to the study but also provide a clearer depiction of the sentiments regarding eco-innovation generally, and WPT specifically within the shipping industry. Ideally, a response rate of over 50% with an equal distribution of participants from academia, industry, researchers, and regulatory institutions would ensure reliable and valid results. This is one of the drawbacks of a survey constructed within a Delphi method framework. Critics point to the limitations of this methodology due to the potential for sloppy execution, poorly designed surveys/questionnaires, inadequate choice of participants, unreliable data analysis, limited feedback, and inconsistency of responses (Geist, 2010). It should be noted however, that these limitations are not exclusive to the Delphi methodology but rather to all methodologies where a researcher is at risk of poorly designing, executing, and analyzing their given methods.

7.0. Discussion

The primary goal of this study was to examine the research question "*What mix of eco-innovation drivers will influence higher adoption rates of Wind Propulsion Technologies in the shipping industry"*. To accomplish this a systematic review, and a content analysis were carried out to create propositions that would feed into questions which comprised a survey within the framework of a Delphi method. The results of this process will be discussed to solidify a hypothesis for a future agent-based model predicated on the adoption of wind propulsion technology in the shipping industry.

During the systematic review, various eco-innovation drivers were found to influence the adoption rates of eco-innovations. However, depending on the industry, the importance of each driver varied. While it is difficult to isolate a specific driver and its influence on eco-innovation adoption, several studies (Aloise & Macke, 2017; Bossle et al., 2016; Hojnik & Ruzzier, 2016; Triguero et al., 2013) have shown that for agile, SME, and process driven innovative firms, the technological and market based drivers tends to be more influential than that of regulatory drivers. However, in mature industries such as construction, (Hazarika & Zhang, 2019) showed that regulatory drivers stimulate adoption of eco-innovations. This thesis confers with the later because as a mature and concentrated industry, shipping is a heavy environmental emitter, and slow mover which as a result requires a nudge from regulators to incentivize and or force eco-innovation adoption. As such, the data tends to indicate that the mix of drivers within the shipping industry that influences adoption of eco-innovations are regulatory and market based.

This is due to the fact that the fundamental role in innovation in this industry is played by the shipbuilders (and suppliers), while the markets respond to the investment decisions from these leaders. Ship construction and retrofitting operations are concentrated within the industry limiting the innovativeness, while professional societies such as RINA (Royal Institution of Naval Architects), and SNAME (Society of Naval Architects and Marine Engineers) function as key intermediaries for research and development along with setting standards and guiding engineering innovation. Furthermore, since ships must be insured for every voyage, the classification of construction and maintenance standards have had a significant historical influence on innovation within the industry. Additionally, the barriers within this industry consist of imperfect information regarding technological performances (such as WPTs), split incentives in the short-term time charter markets which can see shipowner eco-innovation investments go unrewarded through charter premium increase as well as from competitive spillover.

The other significant barriers to consider are availability of funding, technological risk, incompatible infrastructure, and also geo-political risks such as oil price fluctuation. However, multiple policies exist and have been recommended to surmount these obstacles: 1. carbon pricing, 2. demonstration projects of innovative technologies (such as the Interreg WASP initiative) which can be operated, funded, and or supported by public institutions such as the EU, IMO, and others to distribute performance data to increase awareness, and expectations of novel technologies, 3. Public capital funding and or subsidies provided to shipowners, and 4. Speed limit introductions (Karslen et al., 2019; Rehmatulla, Parker, et al., 2017; Rojon & Dieperink, 2014). The need to overcome these barriers is imperative if the diffusion of eco-innovations such as WPTs is to have a significant impact on the shipping industry's climate goals.

The agent-based model predicated around adoption of wind propulsion technology in the shipping industry should utilize shipbuilders/shipowners and their subsequent investment decisions as the primary agents. The hypothesis for this model would postulate that: *"if regulations are stern, then the adoption rate of eco-innovations like WPT will increase"*

Due to the considerable financial commitments, along with the market knowledge and judgement necessary, it is vital to understand how individual agents impact the collective decision-making operations of the market due to the concentration in the industry. The model should include interactions between agents on both the supply and demand side in order to develop appropriate curves by integrating an iterative mechanism for price determination between shipyards and shipowners. The model developed will predict and analyze different scenarios of investment and WPT adoption. The inputs for this model can be the demand for specific types of ship, and the parameters entrenched within the decision functions of the agents involved. These agents should consist of shipyards, shipowners, and the technology providers. The interactions would work as follows: Shipowners cooperate with technology providers on specific products to install on the ships, shipyards then receive orders from shipowners, and subsequently build the ships. Shipowners can also choose to invest in research and development or increase capacity. The cost of these ships both capitally and operationally, depend on the technology being implemented and installed. Shipbuilding and the shipping market work iteratively because the market demand for shipping is matched to a ship company's prices. This price is indicative of the operational costs for that ship, both fuel and emissions. The period that the model should run is roughly 30 years, as that would take us to the 2050 date prescribed by the Paris climate agreement.

8.0. Conclusion

The purpose of this thesis was to understand how the different eco-innovation drivers influence adoption of WPT in the shipping industry. The discourse on eco-innovation, while somewhat recent, has seen increased attention from the academic and researching realm on an international scale. This current study demonstrates that the intrigue is still emergent, with particular connection to the impacts of eco-innovation in the maritime industry. Upon completion of a systematic literature review, a preliminary list of quantifiable drivers was prepared. Furthermore, a content analysis of current trends in the shipping industry through the examination of industry specific magazines facilitated the overlaps, similarities, and oversights between the academic and industrial perspectives of determinates. The results have shown that several barriers or difficulties encumber the diffusion of innovations in the context of the shipping industry. In particular, due to its mature nature, the maritime industry is slower moving in terms of innovation adoption and implementation compared to other younger and spry industries or sectors. While the dominant characteristic of the existing economic framework is entrenched in the universally accepted notion of continual growth, the shift towards a green economy functions inside this paradigm by focusing on the reduction of negative environmental externalities but still maintaining growth and profitability (Jakobsen & Storsletten, 2018).

Although the transition to a greener industry is slow, there is still keen interest by shipowners, builders, port authorities, regulators, and researchers alike to further examine eco-innovation and its applications for the maritime industry.

This study adds important insight into the eco-innovation and shipping literature collectively, which has seen prominence individually while interest in both subjects collectively are emerging. First, it brings shipping within an eco-innovative framework. The dissemination of novel technologies used to mitigate climate emissions such as WPTs will play an integral role in shaping industry for the coming decades. Secondly, availability – as defined by the ability to procure climate mitigating technologies – will not guarantee the adoption nor predicted environmental improvements, until further information is available relating to their effectiveness. The environmental outcomes desired by climate alarmists will only be possible through the close cooperation of all relevant stakeholders. This means, shipowners, builders, technology providers, and regulators will all need to be involved and fully aligned for the industry wide climate goals to be met.

By filling this research gap, the practical aim of this research is to generate a greater understanding of eco-innovation factors influencing the adoption and implementation of eco-innovations within the shipping industry. Additionally, the conclusions drawn from this survey and thesis can assist in the development of a hypothesis for a future ABM relating to the proliferation of WPT technologies. As a result, this study contributes to the academic research examining a specific context of how certain eco-innovative drivers impact the shipping industry differently than in other sectors. Furthermore, academics and other professionals from various spheres may also use these results to obtain research and practical oriented insights for the further propagation of eco-innovation in their respective fields.

The results from this thesis should consider the limitations of the research design; the Delphi method as implemented in this context has certain drawbacks as does other survey reliant data canvassing. This paper aimed to determine the mix of eco-innovation drivers within the shipping industry and to do so utilized the available experts to ascertain the research question. However, one limitation of this methodology was the participation rate and potential bias towards WPT of selected respondents. This may have portrayed the survey results in a skewed manner which would ultimately affect the analysis and results.

Future research interest can use the identification of potential prospects and themes from this thesis which can be applied to different contexts and industries. One of these avenues is the development of similar frameworks of analyzing popular industry specific content to then create ABMs for the shipping industry and other industries. While eco-innovation drivers are similar across different sectors, the application and weight of each factor will vary. This practice will further the field of eco-innovation by proliferating the proposition of frameworks, models, and methods to facilitate eco-innovation investment and adoption across economies. These models should consider the various elements working within the eco-innovation eco-systems such as intuitions, both private and public organizations, government and non-government organizations, educational institutions, and national/international infrastructures.

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11.0. Appendix

Online Survey
a. Your name? (First and Surname)
b. What is your email address?
c. Country
d. Type of organization
e. Position or title within organization *(optional)
On a scale of 1-5, to what extent do you agree with the following statements
1. Eco-innovations in the shipping industry such as wind propulsion technologies are necessary to achieve high levels of environmental mitigation performance
2. Wind propulsion technologies should be adopted by shipowners to strengthen a firm's environmental management strategy
3. The government should provide subsidies schemes to shipowners to increase the adoption of wind propulsion technology
4. Stricter environmental regulations within the shipping industry would lead to an increase in wind propulsion technology adoption by shipowners
5. Of the solutions available, wind propulsion technologies have the potential to provide the most immediate environmental relief for the shipping industry
6. If one ship owner retrofits with wind propulsion technology, others within the industry will follow
7. In regard to retrofitting older ships with wind propulsion technologies, upfront costs outweigh future environmental and financial cost savings
8. Eco-innovations like wind propulsion technologies improve shipowners' competitive position in the market over rivals
9. Shipowners are more influenced by market demands than the technological capabilities of the firm
10. Wind propulsion technologies are more suited for short sea routes than long hauls