Environmental and Social Issues in Global Supply Chains

Emission Reduction in the Maritime Transport Industry and Maritime Search and Rescue Operational Response to Migration

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Document Version
Final published version

Publication date:
2020

License
Unspecified

Citation for published version (APA):
Kosmas, V. (2020). *Environmental and Social Issues in Global Supply Chains: Emission Reduction in the Maritime Transport Industry and Maritime Search and Rescue Operational Response to Migration*. Copenhagen Business School [Phd]. PhD Series No. 02.2020

COPENHAGEN BUSINESS SCHOOL
SOLBJERG PLADS 3
DK-2000 FREDERIKSBERG
DANMARK

WWW.CBS.DK

ISSN 0906-6934

Print ISBN: **978-87-93956-14-8**
Online ISBN: **978-87-93956-15-5**

ENVIRONMENTAL AND SOCIAL ISSUES IN GLOBAL SUPPLY CHAINS: EMISSION REDUCTION IN THE MARITIME TRANSPORT INDUSTRY AND MARITIME SEARCH AND RESCUE OPERATIONAL RESPONSE TO MIGRATION

PhD Series 2.2020

Vasileios Kosmas

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Doctoral School of Business and Management | **PhD Series 2.2020**

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HANDELSHØJSKOLEN

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Emission reduction in the maritime transport industry and maritime search and rescue operational response to migration

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1st edition 2020
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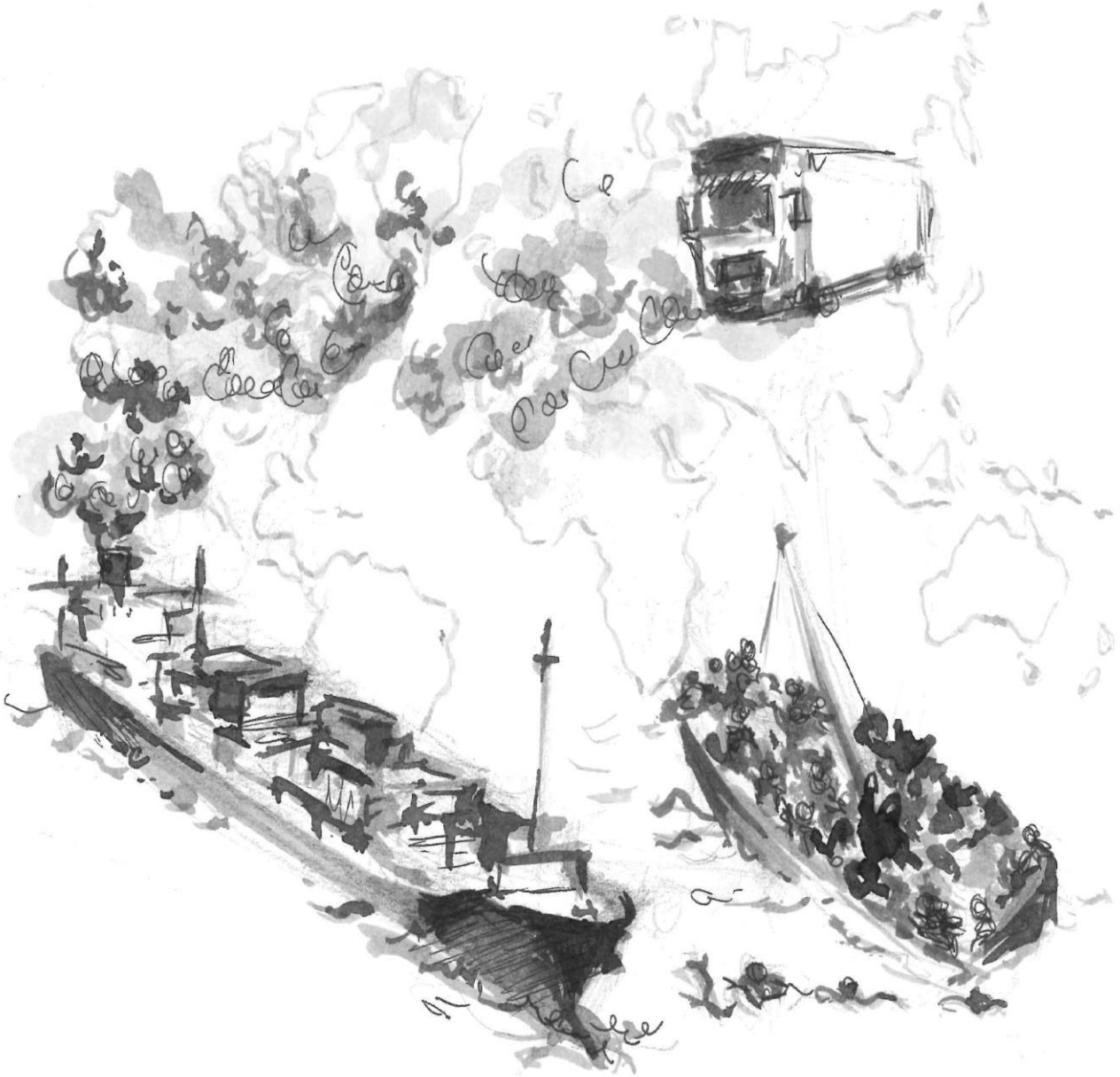

Ε. Τριανταφυλλου

Acknowledgments

I have been visualizing this moment since I began this project. Now that I have finally reached the end of this exciting but also demanding Ph.D. process—which, to be honest, was more challenging than I expected—only one thing remains: to thank all the people that have helped me throughout this research period. I will try to be brief. Before I begin, I first owe a thank you to both institutions, i.e., the Copenhagen Business School (CBS) and Kühne Logistics University (KLU), which gave me the chance to pursue a Ph.D. degree.

Next, a big thank you—from the bottom of my heart—goes to my supervisors. Michele (Prof. Acciaro), words cannot describe how much I appreciate your help throughout these years. You gave me this opportunity and I will always remember your assistance. I believe that we made a pretty good team, as I have told you from the beginning. Thank you for adopting me as your Ph.D. student. Carsten (Prof. Hansen) and Liping (Prof. Jang), thank you both very much for the guidance and help throughout this period. I still remember the time when I was looking for supervisors at CBS and, despite the fact that both of you were busy, you accepted me as your student. It was a pleasure working you.

I would also like to thank other faculty and staff members at both institutions. Maria (Prof. Besiou), it was a great experience working with you on the search and rescue article. You showed me a different perspective on how to conduct research. Henrik (Prof. Friese), thank you for making this Ph.D. a cooperative program, allowing me to work together with Michele; I also really appreciate the discussions we had, especially during the WIP seminars. The same appreciation also applies to René (Prof. Poulsen) and Leonardo (Prof Santiago) for their help during these seminars as well as during my time at CBS. Furthermore, Alan (Prof. McKinnon) and Jan (Prof. Becker), I am grateful for your contributions during my interim examination at KLU. Moving on, I want express my gratitude to Blazenka, Birgit, Melanie, and Yanina, who were always there to help address all administrative issues over the years. At this point, I would like to thank my fellow Ph.D. students and friends (you know who you are)—thanks go to my office mate Yasmine—for the interesting moments that we experienced together during this period.

Last but not least, I want to express my gratitude and love to certain people in my life who have always been there for me. I am referring to my parents Nikos and Eleftheria, to my sister Augusta-Maria, and to my partner Hannah. Words on a piece of paper (or in an electronic document) cannot express my feelings for you and for everything that you have done for me.

Executive summary

This Ph.D. project focuses on complex environmental and social global supply issues in line with the United Nations' 2030 Agenda for Sustainable Development. One of the possible key contributors to this Agenda is the maritime transport industry, which could drive sustainable development from various perspectives, such as tackling climate change, reducing societal inequalities, economic growth, etc. Derived from a broad range of potential shipping industry's contributions to the Agenda, this project dwells on two specific areas on the basis of their urgency to respond at an international level, their global impact, as well as the importance of their adverse effects and their individual characteristics, which add more complexity to their addressment. The first area under study refers to the enhancement of the industry's operational performance, aiming at the reduction of greenhouse gases through regulatory enforcement and, particularly, of a bunker levy scheme. The second area under investigation relates to the societal contribution of the sector by means of improving the maritime search and rescue operational effectiveness in the context of migration by sea emergencies. Despite the sector's contribution toward this direction, through collaboration with coastal states and its significantly high involvement in conducting such activities, migration by sea crises are defined by the engagement of various other stakeholders, such as humanitarian organizations, coast guards, etc., adding more complexity to how such emergencies are addressed. This Ph.D. project produces three research articles that have, as their main objectives, the structuring of the status quo of the issues under study and the provision of guidance to the international community for addressing them. This section summarizes the main findings of the project and highlights its contribution to the global debate for achieving sustainable development targets.

As far as the environmental performance of the maritime transport sector is concerned, the latest predictions of a future escalation of the industry's CO_2 produced emissions are disquieting. One of the emission reduction policies currently under consideration by the International Maritime Organization is the enforcement of market-based measures and, specifically, of a bunker levy scheme—i.e., a global fuel tax. Chapter 2 analyzes the latter's economic and environmental implications on international shipping. The study develops a first-of-its-kind bunker levy market equilibrium model on the basis of the cobweb theorem for benchmarking two differentiated schemes; in particular, a unit tax per ton of fuel and an *ad valorem* as percentage of bunker prices. In both

cases, a speed optimization by means of its reduction is expected as an initial response by the shipowners. The reduction in the unit tax scenario depends on both the levy amount and the fuel prices, while in the *ad valorem* scheme only on the enforced tax percentage. Nonetheless, *slow steaming* (i.e., speed reduction) cannot last indefinitely and shipowners would be pushed to find new ways of coping with the levy costs through investing in environmentally friendly technologies. Moreover, the enforcement of this market-based measure would lead to a profit decline in the industry, dependent on the scheme's structure and market conditions. The latter, in addition to alterations in the demand and supply of the market, also determines the allocation of the levy costs along the supply chain, specifically, from the shipowners to the shippers.

Notwithstanding the intuitive appeal of bunker levy scheme enforcement, possible adverse effects on the industry should not be neglected. Such negative implications imply the modal shift to other transport modes. Chapter 3 concentrates on this concern and examines what factors policy-makers should take into account when designing a bunker levy policy in the context of its implications on the competitiveness of short sea shipping (SSS) vis-à-vis road transportation. A freight modal split model, which incorporates a unity-tax variable, is constructed following a Bayesian network approach on the basis of the generalized transport costs theory. The chapter conducts a sensitivity analysis and investigates 16 indicative scenarios in order to identify the influence of the model's factors and of the policy's implications on the short sea shipping industry's competitiveness. The findings suggest that high bunker and tax prices would lead to a decline of high competitiveness probability. However, increasing this probability could be achieved in the case of low freight rate values, shipment's opportunity costs, cargo value, and distance. As far as the latter is concerned, it refers to the distance within the transport network of shipping companies. A rationalization of their network and a consequent distance reduction could increase the probability that short sea shipping competitiveness is high. Last but not least, the policy's implications depend, to a high degree, on the generalized road transportation costs and the enforced levy amount.

Moving on, Chapter 4 deals with the search and rescue operations of migration by sea emergencies. Migration by sea constitutes a substantial part of the global displacement crisis and requires an urgent response by the international community due to its associated negative effects, e.g., death of migrants. While provision of assistance to people in distress at sea is dictated by international maritime law, it

is also recognized as a moral duty by shipping companies, governmental agencies, and humanitarian organizations. Chapter 4 is the first scientific contribution that dwells on the enhancement of the search and rescue (SAR) effectiveness in the migration by sea context. An explorative inductive case study methodology is applied that is based on the Mediterranean Sea crisis due to its high number of reported tragedies and the involvement of multiple stakeholders. The main unit of analysis is SAR operational effectiveness. At first, the authors develop a preliminary theoretical framework, based on existing literature and their participation in conferences, forums, and academic programs, which enabled them to stay informed about the continuous altering operational response to the analyzed case. The framework is updated and finalized through an analysis of 25 interviews with the stakeholders involved in the crisis and is complemented with data from verifiable reports. The final framework comprises of external and internal factors and identifies their dynamics as well as the interactions that determine SAR operational effectiveness.

The external factors that influence the number of attempted sea crossings refer to the problematic context, the refugee and migration regulatory framework, and border control ineffectiveness. The research shows that long-term development is essential for tackling the root causes of migration; that an enhanced refugee and migration regulatory framework can decrease the number of migrants who are in genuine need of international protection; and that, while the application of stricter border control regimes can reduce the migration flow, it could also open alternative and more dangerous migratory routes. The analysis recognizes the migrants, the illegal networks, the humanitarian organizations, the security forces, the shipping companies, the general public, the media, the unknown actors, and the lobby groups opposing migration as the main stakeholders. Their goals, operational resources, and expertise, as well as the cooperation and coordination among them, constitute the internal factors of the framework.

Policy-makers hold a critical role within crises because they can influence external factors and the operations conducted by security forces and humanitarian organizations. The activities of the latter depend heavily on donations, which are directly influenced by the general public and indirectly by the media. Furthermore, the maritime transport sector cannot act as a long-term solution to migration by sea emergencies because the maritime legal obligations are not designed for such crises. Additionally, the study identifies the operational challenges that range from assets' availability and

competence to crew expertise and funding limitations. In order to enhance operational effectiveness, the cooperation and coordination among the stakeholders is imperative but is often hindered by the divergence between their missions' characters. The research calls for a complete disruption of the illegal networks that exploit an enhanced SAR effectiveness through resource reduction provided to the migrants. In conclusion, as this framework is the first of its kind—capturing SAR operational complexity—the basis of its application can serve for the examination of other migration by sea emergencies.

In conclusion, this Ph.D. project dwells on two issues that have held a high position on the agenda of the international community for several years. The project is the first of its kind, providing clear insights on the above outlined topics and enriching the global dialogue in order to address them. Beside the scientific contribution, which ranges from covering existing research gaps and introducing novel conceptual economic models to theory development, the three produced research papers also create new research directions and opportunities. It is the hope of the author to foster further research with this project in order to, ultimately, meet the sustainable development targets that have been set.

Dansk resumé

Dette Ph.d. projekt fokuserer på de komplekse miljømæssige og sociale globale forsynings problememer som adresseres i FN's 2030 bæredygtige udviklingsdagsagenda.. En af de potentelle centrale aktører i denne agenda den maritime transport sekor, der kan drive en bæredygtig udvikling ud fra flere forskellige perspektiver som f.eks. bekæmpelse af klimaændringer, mindskelse af samfundsmæssige uligheder, skabe økonomisk vækst m.v. Afledt af den brede vifte af potentielle bidrag fra den martitime transport sektors bidrag til denne dagsorden, vil dette projekt sætte fokus på to specifikke områder på baggrund af deres aktualitet og behovet for hurtig respons på internationalt plan; deres globale indvirkning og betydningen af deres bivirkninger og deres individuelle karakteristika, der tilføjer mere kompleksitet til deres hvordan de bør adresseres.. Det første område, der undersøgelse, refererer til forbedringen af industriens operationelle ydeevne, der sigter mod reduktion af drivhusgasser gennem reguleringshåndhævelse og især ved hjælp af en bunkerafgiftsordning. Det andet område, der undersøges, vedrører sektorens samfundsmæssige bidrag ved at forbedre sørednings aktiviteten og redningens operationelle effektivitet i forbindelse med migration af nødsituationer til søs. På trods af sektorens bidrag til denne udvikling gennem samarbejde med kyststater og dens betydeligt store engagement i ledelsen af sådanne aktiviteter, er migration af havskriser defineret af engagement fra forskellige andre interessenter som humanitær organisation, kystvagt mv., der giver mere kompleksitet til håndtering af sådanne nødsituationer. Dette ph.d. projektet har lavet tre forskningsartikler, som har som hovedformål at strukturere status quo af de undersøgte spørgsmål og at give vejledning til det internationale samfund til hvordan problemstilllingerne kan adresseres. Dette afsnit opsummerer projektets hovedresultater og fremhæver dets bidrag inden for den globale debat for at nå målene for bæredygtig udvikling.

Hvad angår søtransportsektorens miljømæssige præstationer, er de seneste forudsigelser om en fremtidig eskalering af industriens CO_2-producerede emissioner urolige. En af de emissionsreduktionspolitikker, der for øjeblikket er overvejet afIMO, er håndhævelsen af markedsbaserede foranstaltninger og specifikt en bunkerafgiftsordning, dvs. en global brændstofskat. Kapitel 2 analyserer de økonomiske og miljømæssige konsekvenser for international skibsfart heraf. Undersøgelsen udvikler, som den første af slagsen, en bunkerafgiftsmarkedsligevægtsmodel, på basis af Cobweb theoremets benchmarking af to differentierede ordninger, især en enhedsskat pr. ton

brændstof og *en advalorem* i procent af bunkerpriserne. I begge tilfælde forventes en hastighedsoptimering ved hjælp af fart reduktion som et første svar fra rederne. Reduktionen i enhedsskat scenariet afhænger både af afgiftsbeløbet og brændstofpriserne, mens det kun er i værdivurderingsordningen på den håndhævede skatteprocent. Ikke desto mindre vil kann mulighederne ved `slow steaming` (dvs. hastighedsreduktion) ikke være uendelige, og rederne vil blive presset til at finde nye måder til at klare afgiftsomkostningerne ved at investere i miljøvenlige teknologier til yderligere omkostningsminimeringer. Hertil kommer, at håndhævelsen af denne markedsbaserede foranstaltning, afhængig af ordningens struktur og markedsforhold, vil medføre en industris fortjenestenedgang. Sidstnævnte bestemmer også fordelingen af afgiften langs forsyningskæden, specifikt fra rederne til kunderne, der afsender varerne.

Uanset den intuitive fordel ved håndhævelsen af af en bunkerafgiftsordningen, bør eventuelle negative virkninger for industrien ikke overses. Sådanne negative konsekvenser henviser til konkurrence med alternative transportformer, også kaldet modalskift. Kapitel 3 koncentrerer sig om denne problemstilling og undersøger, hvilke faktorer politiske beslutningstagere bør tage hensyn til ved udformningen af bunkerafgiftspolitikken i forbindelse med konsekvenserne for nærskibsfartens konkurrenceevne i forhold til vejtransport. En ``fragtmodal split model“, der inkorporerer en enhedsskatte variabel, er opbygget efter en Bayesian netværk tilgang på basis af den generelle transport omkostninger teori. Kapitlet foretager en følsomhedsanalyse og undersøger 16 vejledende scenarier for at identificere indflydelsen af modelens faktorer og politikens konsekvenser for short sea shippingens konkurrenceevne. Resultaterne tyder på, at høje bunker- og skatteomkostninger vil medføre en nedgang i sandsynligheden for, at konkurrenceevnen er høj. En stigning i denne sandsynlighed kunne imidlertid opnås ved lave værdier af fragtrater, forsendelsens mulighedsomkostning, fragnsværdi og afstand. For så vidt angår sidstnævnte vedrører det afstanden inden for rederiernes transportnet. En rationalisering af deres netværk og en tilsvarende afstandsreduktion kunne føre til en øget sandsynlighed for, at short sea shipping konkurrenceevne er høj. Sidst men ikke mindst, afhænger politikens konsekvenser i høj grad af de generelle transportomkostninger på vejtransport og det håndhævede afgiftsbeløb.

Videre i afhandlingens kapitel 4, analyseres sø søredningsoperationerne for migration. Migration ad søvejen udgør en væsentlig del af den globale forskydningskrise og kræver et øget reaktionshastighed

det internationale samfund på grund af dets tilknyttede negative virkninger, f.eks. livstab af indvandrere. Selv om bistanden til folk i nød på havet er dikteret af international søfartslov, anerkendes den også som en moralsk forpligtelse fra rederier, statslige organer og humanitære organisationer. Kapitel 4 er det første videnskabelige bidrag, der fokusere på at forbedre SAR-effektiviteten i forbindelse med migration over havet. En eksplorativ induktiv casemetode anvendes til analyse af Middelhavnskrisen og det store antal rapporterede tragedier samt involveringen af af flere interessenter. Analysenheden er den operationelle effektivitet i SAR. For det første udvikler forfatterne en foreløbig teoretisk ramme baseret på eksisterende litteratur og deres deltagelse i konferencer, fora og akademiske programmer, som gjorde det muligt for dem at holde sig orienteret om det løbende ændrede operative svar på sagen. Rammerne opdateres og færdiggøres ud fra analyse af 25 interviews med interessenter involveret i krisen og suppleret med data fra verificerbare rapporter. Den endelige ramme omfatter eksterne og interne faktorer og identificerer deres dynamik og interaktioner, der bestemmer SAR's operationelle effektivitet.

De eksterne faktorer har indflydelse på antallet af forsøg på at krydse havet og henviser til den problematiske kontekst, flygtninge- og migrationslovgivningen samt grænsekontrollens ineffektivitet. Undersøgelsen viser, at langsigtet udvikling er afgørende for at tackle de grundlæggende årsager til migrationen; En styrket flygtninge- og migrationslovgivning kan reducere antallet af indvandrere med et reelt behov for international beskyttelse men samtidig med anvendelsen af strengere grænsekontrolordninger som reducere flygtninge strømmen, kan selvsamme tiltag føre til åbning af alternative og farligere migrations ruter. Analysen anerkender migranterne, de ulovlige netværk, de humanitære organisationer, sikkerhedsstyrkerne, rederierne, offentligheden, medierne, ukendte aktører og lobbygrupperne imod migration som de vigtigste interessenter og deres mål, driftsressourcer og ekspertise. , og samarbejdet og koordinationen mellem dem udgør rammens interne faktorer.

De politiske beslutningstagere indtager en afgørende rolle i krisen, da de kan påvirke de eksterne faktorer såvel som operationen udført af sikkerhedsstyrkerne og de humanitære organisationer. De sidstnævnte aktiviteter afhænger i høj grad af donationer, der direkte påvirkes af offentligheden og indirekte af medierne. Desuden kan søtransportsektoren ikke fungere som en langsigtet løsning på migration af søfartssituationer, da de maritime juridiske forpligtelser ikke er beregnet til sådanne

kriser. Desuden identificerer undersøgelsen de operationelle udfordringer, der spænder fra aktivernes tilgængelighed, besætningernes kompetencer og finansieringsbegrænsninger. For at forbedre den operationelle effektivitet er samarbejde og koordinering blandt de berørte parter afgørende, men er ofte hindret af divergensen mellem deres missioners karakter. Forskningen opfordrer til en fuldstændig forstyrrelse af de ulovlige netværk, der udnytter en forbedret SAR-effektivitet ved hjælp af reduktion af ressourcer, der ydes til indvandrerne. Konklusionen er, at rammen er den første af sin art, der fanger SAR's operationelle kompleksitet og kan fungere som grundlag for dets anvendelse til undersøgelse af anden migration af ulykker til søs.

Afslutningsvis konkluderes at dette ph.d. projekt er baseret på to spørgsmål, der i høj grad på dagsordenen for det internationale samfund i flere år. Projektet er det første af sin art, der giver klar indsigt i disse emner og beriger den globale dialog for hvordan emnerne kann adresseres. .Udover det videnskabelige bidrag, der spænder fra at dække eksisterende forskningsgab og indførelsen af nye konceptuelle økonomiske modeller til teoriudvikling, åbner de tre producerede forskningsdokumenter nye forskningsvejledninger og -muligheder. Det er forfatterens håb at afhandlingen ligeledes vil fremme yderligere forskning i området, og sammen med dette ph.d. projekt stykre den vidensbase, der ksal gøre det muligt i sidste ende at opfylde de mål for bæredygtig udvikling, der er fastsat.

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AIS	Automatic Identification System
BCI	Border Control Ineffectiveness
BN	Bayesian Network
CBO	Congressional Budget Office
CO_2	Carbon dioxide
CoC	Code of Conduct
CSCs	Commercial shipping companies
DNV GL	Det Norske Veritas Germanischer Lloyd
ECAs	Emission Control Areas
EEDI	Energy Environmental Design Index
ETS	Emission Trading Scheme
EU	European Union
EUNAFOR MED	European Naval Force in the Mediterranean
FEMA	Federal Emergency Management Agency
FOE	Friends of the Earth
GDP	Gross Domestic Product
GHG	Greenhouse gas
GT	Gross-Tonnage
HFO	Heavy fuel oil
HOs	Humanitarian Organizations
IAME	International Association of Maritime Economists
ICS	International Chamber of Shipping
IMO	International Maritime Organization
INs	Illegal networks
IOM	International Organization for Migration
ISO	International Organization for Standardization
ISM	International Safety Management

MARPOL	International Convention for the Prevention of Marine Pollution from Ships
MBM	Market-based measure
MBS	Migration by sea
MEPC	Maritime Environmental Protection Committee
MOAS	Migrant Offshore Aid Station
MRCC	Maritime Rescue Coordination Center
Ms	Migrants
MSc	Master of Science
MSF	Doctors without Borders
NATO	North Atlantic Treaty Organization
NGO	Non-governmental organization
NO_x	Nitrogen oxides
NPT	Node Probability Table
OM	Operations Management
PC	Problematic context
PMs	Policy-makers
POM	Production and Operation Management
P&I	Protecting and Indemnity
R&D	Research and development
RMRF	Refugee and migratory regulatory framework
RoRo	Roll on/Roll off
SAR	Search and Rescue
SDGs	Sustainable Development Goals
SEEMP	Ship Energy Efficiency Management Plan
SFs	Security forces
SHADE MED	SHAred Awareness and DE-confliction in the MEDiterranean Sea
SOLAS	International Convention for the Safety of Life at Sea
SO_x	Sulphur oxides
SSS	Short sea shipping

STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarer
TEN-T	Trans-European Transport Network
TNormal	Truncated Normal
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNDESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNODC	United Nations Office on Drugs and Crime
VLCC	Very large crude carriers
wmean	Weighted mean
WSC	World Shipping Council

Chapter 1

Introduction to the Ph.D. project

1.1. Sustainable development and the maritime sector

The concept of sustainable development appeared in its complete form in the Brudtland report in 1987—prior to this, only partial versions of it (e.g., eco-development) had been developed (Hoyos et al., 2010)—which defined it as "*the development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (World Commission on Environment and Development, 1987). The concept is built upon three pillars, particularly those of economy, environment and society (Muralikrishna and Manickam, 2017) and has held a high position at the international policy-making agenda ever since its appearance.

The latest efforts of the global community toward the promotion of sustainable development are reflected in United Nation (UN)'s 2030 Agenda for Sustainable Development. The Agenda includes the 17 renowned Sustainable Development Goals (SDGs), illustrated in Table 1, which consist of 169 targets that apply to all participant countries. The SDGs—which are implicitly interrelated among each other (Nilsson et al., 2016)—address multifold environmental, economic, and societal issues across all development sectors and have as their ultimate goal the present and future establishment of peace, prosperity, and respect for both humanity and planet earth (United Nations Department of Economic and Social Affairs [UNDESA], 2017).

The maritime transport industry, with its international character and an undeniably important role for both global supply chains and economic growth (Stopford, 2009), could act as a major contributor to the Agenda across the three pillars of sustainable development. Both the recent Det Norske Veritas Germanischer Lloyd (DNV GL) report (2017), which was commissioned by the Norwegian Shipowners' Association, and the declaration of the International Maritime Organization (IMO)—the UN's international shipping security, safety, and environmental performance regulatory agency—acknowledge the industry's potentials toward meeting the SDGs (IMO, 2019). The sector's possible contribution covers a broad range of areas that, among others, refer to environmental preservation,

public health, cost-efficient provision of products to markets at a global level, facilitation of economic development, sustainable working environment throughout the industry's value chain, and safety of life at sea.

Table 1: UN's Sustainable Development Goals

	Goals
1	No Poverty
2	Zero Hunger
3	Good Health and Well-Being
4	Quality Education
5	Gender Equality
6	Clean Water and Sanitation
7	Affordable and Clean Energy
8	Decent Work and Economic Growth
9	Industry, Innovation, and Infrastructure
10	Reduced Inequalities
11	Sustainable Cities and Communities
12	Responsible Production and Consumption
13	Climate Action
14	Life Below Water
15	Life On Land
16	Peace, Justice, and Strong Institutions
17	Partnerships for the Goals

Source: United Nations Sustainable Development (2019)

The industry's environmental and social contribution is the foundation of the present Ph.D. project. As the introductory section progresses, the project's specific research focuses will unfold. As far as the environmental focus is concerned, it is driven by the sector's accountability for a significant portion of globally produced exhaust gases (i.e., 2.5%), about which significant concerns for their future escalation have been expressed. Particularly, carbon dioxide (CO_2) emissions could rise up to 250% by 2050 from those of the 2012 baseline year (IMO, 2014). Aligned to this disquieting

projection, the IMO—focusing on air pollution and greenhouse gas (GHG) emissions issues through the revised International Convention for the Prevention of Marine Pollution from Ships (MARPOL) Annex VI and its later amendments (regulation 20, 21, 22)—reached a milestone agreement[1] for the enhancement of the environmental performance of the shipping[2] industry in April 2018. In this first ever IMO strategy, specific targets were set that require an initial 40% reduction of ship's carbon intensity by 2030, as well as an increase of efforts toward a 70% decrease of GHG emissions produced by the sector by 2050, in comparison to the 2008 baseline year (DNV GL, 2018).

On the other hand, the societal emphasis of the project relates to the safety of life at sea aspect, which holds a distinct position within the wide range of the sector's possible contributions (e.g., reduction of inequalities along the industry's supply chain, mitigation of poverty through cost effective cargo transport, etc.) (DNV GL, 2017). The IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarer (STCW), with its provision and establishment of the required safety-related competencies for seafarers and companies, contributes toward this direction (IMO, n.d.). The importance of an enhanced safety culture at sea is also evident in the provision of search and rescue (SAR) operations in situations of distress that, besides constituting a long-lasting maritime tradition and moral obligation, is dictated by the international maritime law—i.e., by the International Convention for the Safety of Life at Sea (SOLAS) 1974 (IMO, 2014) and the 1979 SAR Convention (IMO, 2006). Within the context of SAR operations, the fact that they are conducted as a response to migration by sea emergencies—the incidents of distress that are the result of migrants boarding unseaworthy and overcrowded dinghies in order to cross the sea—is arguably a potential area through which the shipping sector could eventually contribute to the UN's Agenda. DNV GL (2017) highlights that this could be achieved by enhancing the effectiveness of such activities through close collaboration between the sector and the coastal states (DNV GL, 2017).

Despite the opportunity for the maritime sector to contribute to the UN's sustainable development Agenda by reducing its produced emissions and enhancing the SAR operational response to migration

[1] The industry was one of the few that was not included in the COP 21 Paris agreement. In this agreement, the parties of the United Nations Framework Convention on Climate Change (UNFCCC) decided that, for this century, while having as baseline the pre-industrial levels, the global temperature should not increase more than two degrees Celsius (UNFCCC, 2019).

[2] In the present project, the term *shipping* refers to maritime transport.

by sea emergencies, it can also be argued that these potential contribution areas could create economic and operational pressure on the sector itself at the same time. At this point, further elaboration is needed regarding this closed-looped relationship. As far as the emission reduction is concerned, the measures to be followed to achieve the desired goals, which have been set by policy-makers, could translate to an increase in costs for shipowners and companies as well as to other possible operational challenges. With respect to SAR, regardless of the moral and legal character of such activities being conducted, they could also result in operational challenges and extra costs for the shipping companies and these issues would have to be addressed within the sector. Given this closed-looped relationship, the international character of the two focal areas discussed above, and their importance for both humanity and the environment, the present Ph.D. project focus is defined. Subsequently, the research gaps are identified in sections 1.2. and 1.3., the project's objectives and methodology are introduced in section 1.4., and a comprehensive description of its structure is provided in section 1.5.

1.2. Emission reduction in the maritime transport sector

Technological advancements and the improvement of operational efficiency represent two paths toward tackling the emissions produced by the maritime transport industry's operations (World Shipping Council [WSC], 2009). The shipping companies' underlying drivers for operational efficiency enhancement include competitiveness, corporate social responsibility, and regulations (Starcrest Consulting Group, LLC, et al., 2015). The current regulations and policies enforced by the IMO are the Emission Control Areas (ECAs), the Energy Environmental Design Index (EEDI), and the Ship Energy Efficiency Management Plan (SEEMP). The ECAs refer to specific sea areas, with stringent control limits related mainly to Sulphur oxides (SO_x) and Nitrogen oxides (NO_x) emissions, while the EEDI and the SEEMP are mandatory operational and technical measures. The EEDI applies to ships built after 2013 and sets limits associated with their energy performance—per capacity mile a minimum efficiency level is mandatory (IMO, 2015b). Moving on, the SEEMP is an operational measure that provides "guidance" to companies by promoting best green practices and aiming at the energy efficiency performance enhancement of vessels over time (Johnson et al., 2013).

The associated downsides of these regulations cannot be neglected, albeit their noble intentions and positive effects. For instance, the ECAs, despite the reduction of NO_x and SO_x emissions, can also result in an increase of CO_2 gases (Fagerholt et al., 2015; Dudnikoff and Lacoste, 2014; Gilbert,

2014), while the EEDI is argued to be insufficient for tackling emissions at necessary target levels (Anderson and Bows, 2012). Additionally, this regulation would have resulted in better outcomes if older ships were also encompassed by it (Miola et al., 2011). On the other hand, the SEEMP lacks clarity in its formulation in comparison with other certifications, such as the ISO 50001, and consequently may not add value to the energy management systems of companies (Johnson et al., 2013). The inadequacy of existing regulations, aligned with the disquieting GHG escalation projections, increases the urgency for additional actions to be taken toward enhancing the environmental performance of the shipping industry. This urgency is reflected in the recently launched IMO emission reduction strategy, which contains a broad spectrum of possible short-, medium-, and long-term measures, in order to meet the targets that have been set. Its potential measures range from improving the EEDI and SEEMP to developing zero-emission fuels and enforcing market-based measures (MBMs). The latter refer to the provision of economic incentives to companies to promote investments in green technologies, increase operational efficiency, and offset emissions by the shipping industry (IMO, 2015a).

According to BIMCO (2018), the MBMs that may be imposed should be controlled by the IMO, promote research and development (R&D) toward energy-efficient technological advancements. The MBMs proposed by the Member States, Associate Members, and observer organizations of the Maritime Environmental Protection Committee (MEPC) relate, without loss of generality, either to an Emission Trading Scheme (ETS) or bunker levy scheme enforcement. Under an ETS, the shipping industry would have to meet an emission reduction cap that would be set in advance. This MBM would have a binding character that would legally oblige vessels to operate within allocated emissions. The main debate around the enforcement of an ETS is whether it should be an open or a specific maritime scheme. Existing research varies on their associated implications. For instance, Luo (2013), on the basis of a literature review, argues that the bulk sector could witness a supply reduction higher than the liner sector in case the shipping industry is included in an open ETS. On the other hand, a METS is claimed to be an effective measure with no significant administrative efforts required for its establishment (Koesler et al., 2015).

The other proposed MBM under consideration is a bunker levy scheme, which actually constitutes a monetary amount raised on a vessel's fuel consumption. All ships over 400 Gross-Tonnage (GT)

would be subject to the *tax/levy* which would vary depending on the fuel type and the ship's fuel consumption. An International Greenhouse Gas Contribution Fund would be established for collecting the amount owed by shipowners and operators. In the submitted proposal, the term *contribution* is used instead of *levy* or *tax* due to IMO's mandate that does not have a tax-raising character. Despite the scheme's arguably better results in achieving CO_2 emission reduction than the ETS (Congressional Budget Office [CBO], 2008), its better performance in terms of resource allocation in comparison to other proposed measures, such as a European speed-limit (Cariou and Cheaitau, 2012), and its characteristics related to price certainty (as the costs would be known in advance), the existing scientific literature on its implications and feasibility for achieving an operational efficiency enhancement remains scarce.

As far as the scheme's environmental implications are concerned, Devanney (2010) and Kapetanis et al. (2014) are two studies that focus on very large crude carriers (VLCC) and Handymax bulk carriers, respectively, showing that a CO_2 emission reduction is achievable. Moving on to the economic implications of this MBM, the article by Lee et al. (2013) points out that the competition among liner shipping companies that operate on long-haul routes is expected to increase. Another study that deals with such implications is by Vivid Economics (2010), prepared for the IMO's Expert Group on MBMs, and it examines a generic 10% fuel price increase for specific routes and products. Within the aforementioned studies, suggestions are provided by their authors regarding the scheme's possible structures. Indicatively, Kapetanis et al. (2014) call for a flexible levy amount, depending on the market conditions, while Lee et al. (2013) recommend that the levy should vary according to different trade routes.

It is disquieting that both researchers and policy-makers have not concentrated on further investigating the bunker levy scheme implementation in the shipping sector, despite the measure's far-reaching industrial and societal implications, in addition to the concerns expressed by the Global Shippers' Forum (2012) regarding the measure's inability to achieve operational efficiency enhancement within the industry due to the possibility of taxation cost transfer along the supply chain. The uncertainty associated with the levy scheme's enforcement makes its exploration particularly timely and urgent in order to eventually meet the emission reduction goals set by the IMO.

1.3. Maritime SAR operations in the context of migration

In comparison to the figure of 172.6 million people in the year 2000, the global migration phenomenon has now reached record-breaking numbers—approximately 257.7 million people (UNDESA, 2017)—a migration figure that has even surpassed the records of the World War II aftermath. Around 65.3 million forcibly displaced people (United Nations High Commissioner for Refugees [UNHCR], 2016) are included within this figure, primarily constituting of refugees, asylum seekers, and internally displaced people. The UN Refugee Agency, commonly known as the UNHCR, has reported that those movements are driven by various factors such as persecution, wars, persecution, and other human rights violation causes (UNHCR, 2016). The former UN Secretary General, Ban Ki Moon (UN, 2016), highlights the critical state of the situation, emphasizing that *"Above all, this is not just a crisis of numbers; it is also a crisis of solidarity."*

An extremely risky form of the global displacement crisis is migration by sea, where people deploy unseaworthy and overcrowded dinghies and rubber boats to make their sea crossing in the attempt to reach their intended destination. Migration by sea is a long-lasting global phenomenon, including indicative cases such as: the 1994 Balseros crisis in Cuba with over 35,000 people trying to reach the United States (Greenhill, 2002); the Southeast Asia to Australia sea crossings (Kneebone, 2010) that resulted in the adoption of the so-called Pacific Solution by the Australian authorities, which is a policy that enables those people trying to reach Australia by boat to be transferred to Nauru or other countries (Larking, 2017); the sea crossings of Bangladeshi and Rohingya migrants across the Bay of Bengal; and the Mediterranean Sea case in which more than one million people crossed the sea to come to Europe in 2015 alone (IOM, 2016).

Migration by sea has attracted the attention of the international community primarily as a result of its consistency and the high number of migrants as well as the associated negative effects of the phenomenon, which primarily relate to the loss of life of migrants. Numerous shipwreck incidents have been witnessed for both the Rohingya (Catrambone, R., 2017) and Mediterranean Sea cases. The latter, with around 5,096 recorded deaths (UNHCR, 2016), could definitely also be formally characterized, falling within the definition of the Federal Emergency Management Agency (FEMA), as *"an event that causes 100 deaths or 100 human injuries or damage worth at least US$ one million"* (Apte, 2010).

The conditions under which the migrants try to cross the sea triggers the appearance of distress situations that require the provision of SAR assistance. The international community has called upon the conduction of such operations in order to mitigate the occurrence of life loss tragedies. Indicatively, in the Rohingya case, both humanitarian organizations (Catrambone, R., 2017) and the countries involved in the crisis in the Bay of Bengal (e.g., India, Bangladesh) have highlighted the need for cooperation among the involved stakeholders and in conducting SAR operations (Ministry of Foreign Affairs of the Kingdom of Thailand, 2015). In the Mediterranean Sea case, the provision of SAR assistance from a broad range of stakeholders (i.e., humanitarian organizations, commercial vessels, coast guards, European border agency FRONTEX, etc.) has also been witnessed, resulting from either their operational mandates or legal obligations under international maritime law.

The role of the maritime sector is undeniably important in migration by sea emergencies, as can be seen in the Mediterranean Sea case and, particularly, in the Central Mediterranean area, where commercial shipping companies accounted for around 25% of the conducted SAR activities in 2014 (Guerdia Costiera, 2018). After 2015, with the beginning of involvement of humanitarian organizations and security forces, this percentage has declined. Nevertheless, despite the engagement of various stakeholders in this particular crisis, life loss incidents still remain at a high level and the proportion of deaths with respect to crossings has increased (UNHCR, 2018). Given the high number of tragedies and the persistency of the phenomenon, it is disquieting that the enhancement of maritime SAR operations in the context of migration by sea emergencies has not received the appropriate attention from the research community. Particularly, the existing SAR-related literature, which could contribute to the examination of the topic under study, follows mainly an asset allocation approach.

Afshartous et al. (2009) deal with the location of the U.S. Coast Guard air stations, pointing out the significance of modeling uncertainty regarding this decision. Another study, by Pelot et al. (2015), focuses on the allocation of the Canadian coast guard vessels and takes into consideration the ships' capabilities and the severity of SAR incidents. Basdemir (2000) looks into the allocation of SAR helicopters when demand is predefined, while a geographic decision support model for SAR activities is developed by Abi-Zeid and Frost (2005). The minimization of response time to emergencies that require assistance holds the main focus in the study by Razi and Karatas (2016), who create an allocation model for SAR boats. The only studies that can relate to the focus of this Ph.D. project are

those by Cusumano (2017, 2018), which highlight the impact of political involvement in the operations and principles of humanitarian organizations. On the basis of the existing literature, it is noted that the enhancement of SAR operational effectiveness, in the context of migration by sea emergencies, does not constitute an area of study by the academic community. Therefore, this project aims to fill this literature gap, given the topic's significance.

1.4. Objectives of the Ph.D. project

In terms of meeting the SDGs by tackling their associated challenges, the policy-makers, business corporations, and governmental and other beneficiary organizations stand at a critical historical point. The two areas under study in the present Ph.D. project are, on the one hand, the emission reduction in the maritime sector through the regulatory MBM of a bunker levy scheme and, on the other hand, the maritime SAR operational enhancement linked to migration. Given the far-reaching implications and the international character of these two topics, their examination becomes urgent. This Ph.D. project has, as its main objectives, the structuring of the status quo of these complex, environmental and social, global supply chain issues and the provision of guidance to the international community for addressing these issues by answering the following research question:

- How do the maritime actors and the international community interact for the resolution of complex global supply chain environmental and social issues?

To begin with, the concept of bunker levy scheme enforcement as a possible measure for emission reduction in the shipping sector, despite its intuitive appeal for policy-makers, needs further exploration to clarify the additional uncertainty that exists regarding its feasibility for the enhancement of the operational performance of shipping companies. Additionally, the concern that the levy cost would not be covered by beneficiaries but would be transferred along the supply chain needs to be examined. This Ph.D. project addresses these disputes. Following the investigation of the policy's feasibility and associated implications for international shipping, the project concentrates on the policy from the perspective of short sea shipping. Since the sector is argued to be an environmentally better alternative to road transportation (European Commission, 2015), the enforcement of this MBM could be a significant barrier for its exploitation, as it would lead to an operational cost increase for short sea shipping companies. Such implications have drawn the

attention of the academic community for other regulatory pieces, such as the introduction of the ECAs in Northern Europe (Odgaard et al., 2013). Consequently, this project examines what factors—with a possible influence on the competitiveness of the short sea shipping sector vi-a-vis road—policy-makers should take into account with respect to bunker levy scheme enforcement.

The examination of bunker levy scheme enforcement constitutes the first research area of this project. The second deals with the SAR operational response to migration by sea emergencies and has as its main objective to investigate how the effectiveness of such activities can be enhanced in order to tackle the adverse effects associated with the distress at sea situations. Migration by sea emergencies constitute a constant and persistent phenomenon. Despite the fact that the shipping sector promotes a safety culture at sea and is present either through collaboration with coastal states or in conducting such response operations, the effectiveness of these activities is influenced by the involvement of various other actors. This project delves into the migration by sea emergencies phenomenon, examines the operational challenges associated with the conduction of SAR activities, and aims toward their improvement.

1.4.1. Methodological research approach

The project follows a mixed method research design that assimilates elements of both quantitative and qualitative designs (Creswell and Plano Clark, 2007). The methods selected to find the answer to the research question(s) depend on the fundamental philosophical paradigm of how the researcher perceives the world (Patton, 2002). Over the years, a debate has been taking place between the qualitative and quantitative methodologists and their respective paradigms. In particular, the *positivism* and *constructivist* philosophies support the usage of quantitative and qualitative methods, respectively (Tashakkori and Teddlie, 1998). The debate has resulted in what is commonly known as the *incompatibility thesis*, which argues for the inappropriateness of combining the qualitative and quantitative methods.

The research design of this Ph.D. project rejects this debate and is grounded in the paradigm of *pragmatism*, which argues that a researcher chooses a philosophical and methodological research approach on the basis of the research question (Tashakkori and Teddlie, 1998). The paradigm of pragmatism—it has gained more attention after the *incompatibility war*—does not require any

research justification in terms of ontology, epistemology and methodology. This paradigm does not consider the other approaches of being in the wrong. Particularly, it perceives them as beliefs and actions—pragmatism refers to the acquirement of knowledge as a process of inquiry through constant interactions between the beliefs and actions of the researcher—for specific circumstances (Morgan, 2014).

Pragmatism relates to the application of mixed methods research, which is a creative and pluralistic approach that does not constrain a researcher (Johnson and Onwuegbuzie, 2004). Existing studies of supply chain management have received criticism for the absence of and reluctance toward methodological adversity adaptation (Naslund, 2002) and, therefore, the integration of a mixed method approach could positively contribute to the discipline's advancement (Golicic and Davis, 2012).

The differing topics of this Ph.D. project cannot be addressed using the same research design or methodology. The fundamental reason for following a mixed methods approach lies in the existence of a theory that is related to the topics under investigation. As far as bunker levy scheme enforcement in the maritime transport industry is concerned, current theory enables the application of a quantitative research methodology. Extensive literature exists for both the relations among the economic variables within the maritime industry and the competitiveness between freight transport modes, and it can be used to follow a modeling approach in the analysis of the topics under study. Although a quantitative approach is feasible for the bunker levy scheme topic, it would not be appropriate to apply it to the research dealing with SAR operational effectiveness in the context of migration by sea emergencies. The scarcity of existing literature and theory related to the topic under study, which is discussed extensively in Chapter 4, requires for a qualitative approach to be applied. This is necessary in order to explore the phenomenon and, consequently, to construct its theoretical framework, which could then be used as a pillar for future quantitative studies.

1.5. Ph.D. project outline

This cumulative (i.e., compilation of articles) Ph.D. project consists of five chapters. Chapter 1 introduces the concept of sustainable development convergence in global supply chains, identifies and justifies the need for additional policy actions in this direction, and presents the main objectives

of the overall Ph.D. project. Furthermore, Chapter 1 provides an outline of the project and an overview of the research articles that constitute its research core. The three distinct articles are found in Chapters 2, 3, and 4, respectively. Last but not least, the conclusion of the project is found in Chapter 5. Here, the main findings, policy, and theoretical contributions, as well as suggestions for further (inter)-disciplinary research areas with the aim of ultimately tackling the environmental and social challenges in global supply chains, are presented.

Table 2: Overview of the research papers

Research papers	Authors	Research outputs
Bunker levy schemes for greenhouse gas (GHG) emission reduction in international shipping	Vasileios Kosmas and Michele Acciaro	Economic and environmental implications of bunker levy scheme enforcement. Allocation of levy costs along the supply chain.
Short sea shipping and bunker levy scheme enforcement: A Bayesian Network approach	Vasileios Kosmas	Conceptual Bayesian network modal split model. Implications on the competitiveness of short sea shipping vis-à-vis road transportation.
Maritime search and rescue operational response to migration	Vasileios Kosmas, Michele Acciaro, and Maria Besiou	Theoretical framework of SAR operational effectiveness in the context of migration by sea. Propositions for SAR operational effectiveness enhancement.

As far as the three research papers illustrated in Table 2 are concerned, they can stand as distinct articles (i.e., can also be read outside the context of this project). Resulting from the cumulative format of the project, a marginal overlap occurs between Chapter 1 and some of the literature used in Chapters 2, 3, and 4. The first research paper has been published in a peer-reviewed journal, while

the third is currently undergoing the review process in another peer-reviewed journal. The second is intended for submission and publication subsequent to the completion of this Ph.D. project. All three articles have been presented at several academic conferences, where their earlier versions have passed a peer-review process and were afterward published in the conference proceedings in most cases. Furthermore, Chapters 1 and 3 have also been presented, upon invitation, at other academic institutions and forums. Subsections 1.5.1., 1.5.2., and 1.5.3. provide a brief but comprehensive overview of these research papers.

1.5.1. Overview of the first research paper

The first research paper, provided in Chapter 2, deals with the enforcement of a bunker levy scheme as a possible MBM for emission reduction in international shipping. Two differentiated schemes that are directly enforced on bunker costs are examined. The first is in the form of a unit tax (i.e., the levy is a fixed amount), while the second is an *ad valorem* (i.e., imposed as a percentage on fuel costs). The paper sheds light on two research questions:

- What are the economic and environmental implications of a bunker levy scheme on the maritime transport industry?
- How are the levy costs allocated along the supply chain?

A dynamic economic model on the basis of the cobweb theorem, which encompasses a tax parameter, is constructed. The model enables the benchmarking of two alternative forms of levy with respect to the economic and environmental implications of both schemes. Speed optimization through the application of *slow steaming* (i.e., speed reduction), which differs according to the structure of a scheme, is presented as an initial expected response strategy by shipowners. In addition, the profit decline of the sector is analyzed for both scenarios. Moving on to the second question, the paper explains how the supply and demand alterations and market conditions of the sector determine the allocation of the levy costs along the supply chain, particularly going from shipowners and operators to shippers. Chapter 2 shows that the enforcement of a bunker levy scheme can act as an incentive toward investments in environmentally friendly technologies. Nonetheless, suggestions are also provided (e.g., creation of a levy redistribution fund) in order for the wellbeing of the sector not to be jeopardized while climate target goals are being met.

This research paper is already published in the peer-reviewed journal *Transportation Research Part D: Transport and Environment, Volume 57, December 2017, pp. 195–206* under the title "*Bunker levy schemes for greenhouse gas (GHG) emission reduction in international shipping*" by Vasileios Kosmas and Michele Acciaro. Earlier versions of the paper had been presented at the 2015 Shipping in Changing Climates Conference and, upon invitation, to the Master of Science (MSc) class of Marine Transport with Management program at Newcastle University in 2015.

1.5.2. Overview of the second research paper

The second research paper, found in Chapter 3, also concentrates on bunker levy scheme enforcement. As appealing as this MBM may seem, the possibility of adverse effects in the sector should not be neglected. Therefore, the paper addresses the following main research questions:

- What are the implications of a bunker levy scheme on the competitiveness of the short sea shipping sector vis-à-vis other freight transportation modes and, particularly, road transport?
- What other factors play an important role in the competitiveness of the sector within the context of this MBM implementation?

The article focuses on short sea shipping because of the sector's competition for cargo against other modes of transport and of the policy-makers' intentions to promote it to relieve road congestion. The examined competitiveness implications indicate the possibility of a modal shift toward the road sector. In order to answer the research questions, a conceptual modal split model that is grounded on a Bayesian network approach is constructed, encompassing a levy parameter in the form of a unit tax. Thus constructed Bayesian network model is used to examine different transportation scenarios. This is followed with an identification of the effects of various factors and, especially, of the fuel and levy prices on the modal split between the two transport modes. The analysis shows that the influence of the others factors (e.g. distance, freight rates) can enhance the short sea shipping sector's competitiveness.

Earlier versions of the paper—in which an extension of the model constructed in Chapter 2 was represented and a Bayesian network approach was not followed—were presented at the 2016 Shipping in Changing Climates Conference, the 2017 International Association of Maritime

Economists (IAME) conference, and, upon invitation, to the Master of Science (MSc) class of Marine Transport with Management program at Newcastle University in 2016. The article is intended for submission subsequent to the completion of this Ph.D. project. A part of section 3.3.1., found in the previous work, and used in this version has also been the author's own contribution. The current version has been accepted for the 2019 IAME conference, after undergoing a peer-review process.

1.5.3. Overview of the third research paper

Chapter 4 presents the third research paper of this project. It focuses on the maritime search and rescue operations linked to the migration by sea flows and answers the following research questions:

- What stakeholders are involved in the maritime SAR operations, in the migration by sea context, in terms of disaster management?
- How do the actions of the stakeholders involved impact SAR operational effectiveness?
- What additional factors need to be taken into account for enhancing SAR operational effectiveness in the migration by sea context?

Due to the scarcity literature related to this topic, the paper follows an exploratory research approach. SAR operational effectiveness is the unit under analysis. The study focuses on the Mediterranean Sea crisis because of the high number of recorded life losses and the complexity of the operational responses by the numerous stakeholders involved, who act under differing mandates. Initially, the paper builds a preliminary theoretical framework on the basis of existing SAR and disaster literature, as well as its authors' participation at conferences, forums, and in academic programs that are related to human rights, emergencies at sea, and maritime operational response to migration. Consequently, the framework is updated following the collection of primary and secondary data. The former are derived from semi-structured interviews with the stakeholders and experts involved in the crisis, such as commercial shipping associations, humanitarian organizations conducting SAR activities, national coast guards, and security experts. The secondary data are collected from various verified reports.

The study provides a taxonomy of all engaged stakeholders and presents their dynamic interactions, which influence SAR operational effectiveness. Furthermore, the operational challenges, the importance of coordination and cooperation among the stakeholders, as well as the critical role of

their mandates are identified. The analysis ultimately shows that external factors can contribute to determining the examined SAR operational effectiveness. Last but not least, the study originates some propositions to be tested in further research.

A new version of the third research paper has been submitted to a peer reviewed journal. Earlier versions of the paper have been presented at academic conferences, such as the 2018 Production and Operation Management (POM) conference and the 2018 IAME conference—where it has also been published in the 2018 IAME conference proceedings following a peer review process, under the title "*Migration by sea: The operational response of search and rescue*" by Vasileios Kosmas, Michele Acciaro, and Maria Besiou.

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Chapter 2

Bunker levy schemes for greenhouse gas (GHG) emission reduction in international shipping

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Abstract

A fuel levy is one of the market-based measures (MBMs) currently under consideration by the International Maritime Organization (IMO). MBMs were proposed to improve the energy efficiency of the shipping sector and reduce its emissions. This paper analyses the economic and environmental implications of two types of levy on shipping bunker fuels through an analytical model built on the cobweb theorem. A unit-tax per ton of fuel and an *ad valorem* tax, enforced as a percentage of fuel prices, are examined. In both cases, speed and fuel-consumption reduction that is equivalent to an improvement in the energy efficiency of the sector would be expected as a result of regulation enforcement. The speed reduction in the unit-tax case depends on fuel prices and the tax amount, whereas in the *ad valorem* case it relies upon the enforced tax percentage.

Both schemes lead to industry profit decline, the extent of which depends on the structure of the levy and market conditions. Since there is a concern that the costs resulting from this policy would be passed from shipping companies to their customers along the supply chain, this paper dwells on how the costs arising from the enforcement of the levy would actually be allocated between shipowners and operators, and cargo owners. This allocation depends on the alterations in supply and demand and the market conditions as well.

Keywords: *Market-based measures (MBM), green shipping, greenhouse gas (GHG) emissions, international tax, bunker levy.*

2.1. Introduction

Emissions produced by the maritime transport industry are rapidly increasing (IMO, 2014), despite recently introduced environmental regulation—i.e., the enforcement of the Emission Control Areas (ECAs), the Energy Environmental Design Index (EEDI), and the Ship Energy Efficiency Management Plan (SEEMP). Those initiatives are proven to have significant unexpected consequences. The ECAs, for example, in addition to tackling NO_x and SO_x, may lead to an increase in CO_2-emissions (Fagerholt et al., 2015; Doudnikoff and Lacoste, 2014; Gilbert, 2014). Anderson and Bows (2012) argue that the EEDI is not far-reaching enough to reduce shipping emissions at the levels necessary to meet climate-change targets. Besides, the index could be more effective in reducing emissions if only it was also applicable to older ships (Miola et al., 2011). As far as the SEEMP is concerned, crucial gaps have been identified in the formulation of this regulation in comparison with other best-practice certifications (i.e., International Organization for Standardization [ISO] 50001 and International Safety Management [ISM] Code), regarding how companies should interpret and implement its provisions; hence, this measure may not contribute to the enhancement of shipping companies' energy management systems (Johnson et al., 2013). Although it is clear that additional policy interventions, aiming to influence and improve the industry environmental performance, are necessary, it is, however, imperative that their environmental and economic consequences are well-understood beforehand. This should happen soon if the industry is to make a fair contribution to tackling climate change.

The international character of maritime transport and its primarily business-to-business nature are some of the obstacles for the development of effective environmental regulation in the shipping industry. In comparison with other transportation sectors, emission abatement policies are already in place in various countries under different forms, i.e., fuel or engine taxation. Environmental taxes, indeed, have resulted in the mitigation of exhaust gases in the car sector (e.g., Rogan et al., 2011; Hennessy and Tol, 2011) and in the aviation industry (e.g., Swedavia AB, 2015; Flughafen Zürich AG, 2010).

Only in July 2009 did the Marine Environment Protection Committee (MEPC) 59 ask its Member States, Associate Members, and observer organizations to submit their MBM proposals for further

consideration. MBMs are considered an effective GHG emission mitigation solution by the IMO. Their aim is primarily twofold, namely:

- to provide economic incentives to shipping companies for investing in more environmentally friendly technologies and to increase operational efficiency, and
- to offer mechanisms to offset emissions out of the shipping industry (IMO, 2016).

Most proposals can be related to the two schemes that are currently still under examination: an Emission Trading Scheme (ETS) and a bunker levy scheme. An ETS requires the shipping sector to satisfy a GHG emission reduction cap that has been set *a priori*, making it illegal for ships to operate beyond the allocated emissions and without offsetting (Psaraftis, 2012). The scheme would favor more energy efficient operators and progressively penalize those who are less environmentally friendly. Notwithstanding the intuitive appeal of the scheme and the undeniable advantages of extending to shipping an already existing framework, the actual implementation of an ETS encompassing the shipping sector remains controversial. A critical issue is whether an open ETS or a maritime specific ETS (METS), with the advantage of better control over financial transactions within the maritime sector, should be developed. The consequences of these schemes are also controversial. Wang et al. (2015) expect a speed, workload, and fuel consumption decrease in both cases. As far as the inclusion of the shipping industry in an open ETS is concerned, it may lead to a higher supply reduction in the bulk sector than in the liner shipping industry (Luo, 2013). The economic impact of an ETS on the World Gross Domestic Product (GDP) would likely be small, with the exception of developing countries in which it would depend on a country's trade balance and the relative importance of the shipping industry (Anger et al., 2013). Regarding the introduction of a METS, Koesler et al. (2015) argue that it would have the capability to operate as an effective measure, having as a major advantage the low administrative effort additionally required.

One of the measures proposed at MEPC 59 by the Member States, Associate Members, and observer organizations is the enforcement of a bunker levy scheme—in other words, a tax raised on fuel consumption onboard vessels. The bunker levy proposal is linked to the establishment of an International Greenhouse Gas Contribution Fund that would collect a so-called *contribution* on all ships over 400 Gross-Tonnage (GT), differentiating according to the type of fuel used in proportion

to the fuel consumed. It is worth mentioning that, in the proposal, the term *contribution* is consistently used to refer to the amounts due by owners and operators, instead of the terms *tax* or *levy*, as IMO's responsibility is limited to the prevention of marine pollution from vessels and does not include tax-raising. The essential meaning of the term *contribution*, semantics aside, is the same.

The enforcement of a tax in shipping on a global scale—there is nothing like it at the moment in any other industry—raises questions about effectiveness and is controversial in terms of the actual arrangements necessary for the tax collection (IMO, 2007; Psaraftis, 2012). Notwithstanding the intuitive appeal of such a measure for policy-makers, its application is based on assumptions about the costs for the industry and society at large, which are highly uncertain. Given the far-reaching implications of such policy, it is disquieting that, to date, the efforts among researchers and policy-makers to clarify some of the uncertainty associated with a bunker levy scheme have been rather limited.

Academic literature on the bunker levy thus far is scant. Psaraftis (2012) argued that a levy would provide price certainty, as the extra costs resulting from the scheme would be known beforehand, thus enabling shipowners to act proactively by investing in new technologies. Additionally, Kapetanis et al. (2014) claim that a levy is the easiest measure to be enforced and the one most suitable for the maritime industry but also highlight that some degree of flexibility regarding the payment amount is needed. Amounts should depend on market conditions, as deviations from optimal outcomes are possible as a result of a modal shift toward less environmentally friendly transport modes. Another study (Lee et al. 2013) explored the global economic impact of a bunker levy in the liner shipping industry in terms of profitability, sector competitiveness, and GDP implications. The study observes an increase in competition among liner companies that operate on long-haul routes, attraction of more demand for short distance routes, and 0.02% GDP loss for China. As a result, it is suggested that the levy scheme should be differentiated in line with the shipping costs on every trade route.

One area of study focuses on a comparison of the levy's environmental effectiveness with other forms of regulation aimed at GHG emission reduction. Cariou and Cheaitau (2012) argued that, when it comes to resource allocations, a globally enforced bunker levy is the preferable option in comparison to a Europe-wide speed limit. Despite the positive attitude of the research community toward a levy-

scheme, the industry's opinion is more divided, with some stakeholders expressing outright concerns toward such a measure (Giziakis and Christodoulou, 2012). The costs of the levy would eventually not be absorbed by the shipping sector but only passed along the supply chain (Global Shippers' Forum, 2012), with virtually no impact on the energy efficiency profile of the industry and with higher transportation costs. Should this be the case, a levy scheme would be an inadequate MBM for fostering energy efficiency improvements in the industry. This debate makes the exploration of the economic implications of a bunker levy particularly timely. A rigorous investigation of the significance of the claim that the levy would be passed along the supply chain requires the use of tax incidence and cost pass-through theory, which are interconnected and important areas of research in economics. A first economic analysis pointing in this direction can be found in the report of Vivid Economics (2010), prepared for the MBM Expert Group of the IMO. It focuses on the economic impact of a generic MBM through a 10% bunker price increase on specific shipping routes and product markets in terms of price, market share, and demand changes, as well as cost pass-through rate derivation. The present manuscript differs from this report in the methods used, as its focus is on determining a general economic explanation for the consequences of alternative taxation schemes.

Literature on tax incidence has focused on how tax policies affect the distribution of economic welfare (Kotlikoff and Summers, 1987). Given the possibility of passing the taxes through, from those targeted by them to other segments of society, the tax incidence theory has attracted considerable attention and has been applied in different industries at the macroeconomic level (e.g., Tockarick, 2006; Besley and Rosen, 1999), to specific industries (e.g., soft drinks in Bonnet and Réquillart, 2013; tobacco, Hanson and Sullivan, 2009; and Harding et al., 2012), and in transport (e.g., gasoline tax in Agostini and Jiménez, 2015; Doyle and Samphantharak, 2006).

Cost pass-through refers to the price change of a product offered in a business industry that results from its cost change. A thorough description of this theory framework is presented in the RBB Economics report (2014), prepared for the United Kingdom's Office of Fair Trading. The report describes the cost pass-through theory for an industry-wide or idiosyncratic cost change, for differentiated supply and demand conditions being applied, and for cases of alternative competition forms. In economics, tax incidence and cost pass-through are closely linked through the supply and

demand equilibrium concept and aim at identifying, in a tax change case, how the levy is going to be allocated between consumers and producers.

This paper is one of the first contributions to focus on the economic and environmental effects of a bunker levy scheme in an international context; it also applies a cost pass-through theory via a dynamic economic model that captures the market interactions of the industry. The paper examines and benchmarks two different forms of levy that are studied with specific reference to the international shipping industry: a unit tax per ton of fuel and an *ad valorem* tax, enforced as a percentage on fuel prices. These two forms of the scheme were included in the discussion at the MEPC level at IMO—either as a fixed cost on the fuel costs, found in the feasibility study and impact assessment report of the expert group appointed by the agency (IMO, 2010) or as a percentage increase of bunker expenses found in the previously mentioned report of Vivid Economics (2010). Nevertheless, since the discussions came to a halt at the MEPC 65 in 2013, no significant progress has been made. The objective of this study is twofold. First, the outcome of a bunker levy in terms of costs and environmental effects is investigated, with particular focus on speed optimization and energy efficiency improvements at the industry level. Second, the study also investigates what portion of the levy would be passed from shipowners along the supply chain, as this is perceived to be one of the critical issues in the debate on the implementation of this MBM (Global Shippers' Forum, 2012), given the importance that the potential cost transfer has on the effectiveness of the policy for improving environmental efficiency.

One of the reasons, in fact, why these forms of indirect taxation are preferred to tax as a percentage, of either freight rates or profit, is that a levy affects a shipping company's fuel costs and, as such, should provide an incentive for increasing energy efficiency. Hence, these schemes are aligned with the "polluter pays" principle also endorsed by the IMO. The impact of a levy on technical or operational efficiency, however, depends on whether these costs are transparent and can be easily forecast by owners or operators. With respect to a unit tax, the costs are fixed and can be estimated on the basis of fuel consumption in previous years, while the costs associated with an *ad valorem* tax are more uncertain because the excised amount varies depending on bunker prices.

This issue is relevant from a policy-making perspective in particular. The general framework provided in the study on how a bunker levy is potentially transferred from the shipping industry to cargo owners, taking into consideration the price elasticities of supply and demand, offers a tool to assess the effectiveness of the scheme. The prevailing market conditions in the shipping industry turn out to be a determinant factor. From an industry perspective, the study offers useful insights for owners in terms of what operational and technical measures are best suited for minimizing the negative effects of the scheme. Particular attention in this paper is devoted to the optimal speed for both scheme types, whose levels depend, among other factors, on the levy scheme structure that is implemented.

The study provides a significant academic contribution to the current knowledge on transport policy in multiple ways. First, notwithstanding the importance of maritime transport for the global economy and the significance of any form of regulation that could potentially increase the costs of moving cargo by ship, the studies on MBMs in shipping have been few and far between. Second, the existing quantitative studies concerning MBMs in shipping focus primarily on the Emission Trading Schemes (ETS) (e.g., Wang et al., 2015), while levy schemes are examined using qualitative methods mainly. Third, the paper provides an important contribution to identifying the issues that need to be further investigated so that the impacts of MBMs can be adequately assessed. Finally, the contents of the paper are also useful for shipowners, operators and the industry in general.

The paper is structured in four sections. This introduction outlines the main problems associated with the inadequacy of the existing emission mitigation measures and policies, mentioning the need for supplementary actions. The section also discusses the concept of market-based measures, its application in other transport industries, and the existing literature that proposes its use in international shipping. In section 2.2., an economic model encompassing the main characteristics of international deep sea maritime transport and different forms of levy schemes is constructed. In section 2.3., the economic and environmental implications of the policy are presented. Finally, section 2.4. concludes the study by providing a summary of the main findings, its limitations, and recommendations for further research topics to be addressed.

2.2. A bunker levy market equilibrium model

2.2.1. A shipping market equilibrium model

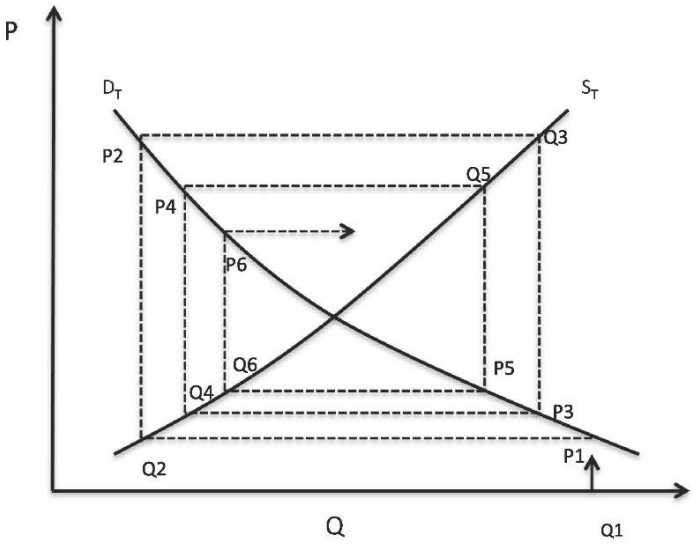
In order to investigate the impact of a bunker levy on the shipping sector, a theoretical equilibrium model of supply and demand is proposed. The model is based on the cobweb theorem proposed by Nicholas Kaldor (1934) and uses a different approach from the majority of supply and demand models used in shipping, which are typically empirical (e.g., Tinbergen, 1959; Beenstock and Vergottis, 1993; Lewis and Koopmans, 1939; Strandeness, 1984; and Tsolakis, 2005). These studies, beyond their empirical value, are useful for understanding the relations among economic variables in shipping. Additional literature reviews that are valuable for understanding the maritime industry can be found in Haralambides et al. (2004), where a model of new building and secondhand markets behavior is provided, and in Alizadeh and Talley (2010), where the authors present the microeconomic determinants of freight rates and contract times of the bulk shipping sector with the use of a simultaneous equations method.

A recent study by Luo et al. (2009), which presents an empirical econometric model of the container shipping demand and fleet capacity for a freight rates' analysis, is particularly relevant for this paper because it also applies the cobweb theorem. This is one of the most recent studies and the only one that makes use of this theorem in the shipping sector. The cobweb theorem explains the prices and the supply and demand fluctuations in an industry in which a time-lag between the supply and demand is critical. Three conditions need to be satisfied for the application of the cobweb theorem (Ezekiel, 1938). The first condition is that production is based on a producer's response to prices in perfect competition and that production decisions made by a producer individually do not affect the market. The second condition refers to the fact that the available supply is fixed when prices are determined. The last condition is that, in order for the scale of production to be changed, a full period is required.

Before introducing the model developed in this paper, a description of how the cobweb model and the shipping markets function is expedient (Kaldor, 1934). In the first period, a greater supply, Q1, is available, intersecting the demand curve at its responding price, P1. In the second period, a reduced supply, Q2, is identified as a result of the previously observed price value that consequently intersects the demand curve at a higher value, P2. The higher price leads to an increase in the supply at Q3, which then intersects the demand curve at a lower price value, P3, in the third period. This decreased

price results in a decrease in the supply value during the fourth period, Q4, which then drives the price up to P4. The same procedure continues for the subsequent phases. The price sensitivity of the supply and demand is the determining factor for the behavior of the industry's models. When distortions in the supply and demand appear, the industry enters a new cobweb model.

Figure 1: Cobweb model



Source: Ezekiel (1938)

The cobweb model, presented in Figure 1 above, needs to be adapted to the shipping industry, which consists of four interacting markets: the freight market, the shipbuilding market, the sale and purchase market, and the demolition market. The freight market, the main source of revenue, plays the most important role in the shipowners' decision-making process. The demolition market also acts as a source of revenue during economically tough times when shipowners may decide to demolish inefficient and older vessels. Sometimes, it can act as a relief instrument against the industry's overcapacity. However, in real life, industry specific cases can be found when shipowners hold on to older vessels in hope of an economic upturn of the market. In the sales and purchase market, the monetary transactions neither change fleet capacity nor the industry owned cash amount. Money is spent by shipowners to purchase new vessels in the new building market. In case of the demand exceeding the industry's supply, needing to be covered, a freight rate rise is observed, consequently leading to a revenue increase. Subsequently, shipowners are willing to pay higher prices for

secondhand vessels. However, when prices are extremely high, new buildings are preferred. When new ships are delivered, capacity is added to the sector, driving freight rates to decline. In case that shipowners cannot remain active due to the financial downturn, they can either sell or demolish ships in their search for revenue sources in order to remain in business (Grammenos, 2010; Stopford, 2009).

In the model proposed in this paper, the interactions in the sale and purchase market are ignored because they do not affect the capacity of the world fleet. Likewise, the new building market is also not modelled because it does not have a direct impact on the determination of freight rates. On the contrary, new building prices are dependent on freight rates, following a pattern similar to that of how secondhand vessel prices are determined (Stopford, 2009). In the model, demand (X) is considered exogenous, similarly to other studies—e.g., Luo et al. (2009) and Taylor (1976). Moreover, since the time factor is of vital importance for the application of the cobweb theorem, it is appropriate to take into account the ship delivery time, θ, of a new order. Usually, θ ranges between one to two years, however, in some situations—i.e., during the last economic boom in 2007—delivery time may increase significantly. The market equilibrium is expressed by the equation: $Q_S^{FR} = Q_D^{FR}$, where Q_S^{FR} stands for the quantity that is being supplied and Q_D^{FR} for the quantity that is being demanded.

Furthermore, the model assumes that the shipping supply is influenced by the following factors:

- World fleet capacity *Z* (dwt),
- New orders delivery *N* (dwt), and
- Industrial Profit = *Π* (US$).

The bunker levy is included in the model as *T* (US$) and it affects the supply of shipping services through the freight rates, indicated with *P*. Thus, the freight rates can be expressed as a function:

$$P = g\,(\Pi,\ T \mid Z, N, X).$$

We follow the assumption made by Luo et al. (2009), which is based on the idea that high freight rates imply a high turnover for a business, and the total new order for ships for a period *t* (a year) is stated as:

(1) $$N_t = n \times \Pi_t,$$

where *n* is the average profit proportion that accounts for new vessel purchases. Profit is calculated as:

(2) $$\Pi_t = P_t X_t - TC_t,$$

where P_t are the freight rates at a time, *t* (expressed in US$ per ton), and X_t is the demand at a time, *t* (expressed in tons of cargo carried). TC stands for total costs and can be expressed by:

(3) $$TC_t = (OC_t + F_t)\Psi_t.$$

Total costs consist of two parts. The first is OC_t, which accounts for the vessel operating costs— such as crew costs and repairs, which are fixed—at a time, *t*, expressed in US$. This element is considered, in the model, to be exogenous as in other studies—i.e., Hsu and Hsieh (2007). The second element is voyage costs, which following Wang et al. (2015), and can be expressed as:

(4) $$F_t = \rho_t f_t \lambda_t S_t^3.$$

Without loss of generality, equation (4) does not include all voyage costs but only fuel costs,[3] because they account for the highest percentage of voyage costs (Psaraftis and Kontovas, 2013).

[3] It should be mentioned here that, in practice, the party who bears the fuel expenses is not always the shipowner; often, this is the operator or the charterer who is contractually obliged to cover bunker costs, as in the case of the so-called *time charter* or *bareboat charter*. The case in which the shipowner bears the costs of fuel is referred to as *voyage charter*. In this paper, we assume, without loss of generality, that the economic agent is the one responsible for operational decisions—and this could be the shipowner, the operator, or the charterer. We refer to the shipowner in general, unless it is critical for the discussion to distinguish between the various roles, for example, when analysing the longer-term consequences of a levy scheme.

ρ_t accounts for the operating time at sea (hours), f_t represents fuel price (US $/ton)—taken as exogenous because freight rates and/or fleet capacity do not have an influence on their price—λ_t is the coefficient of the energy efficiency of a ship, and S_t (knots) stands for the average speed, all at a time, *t*.

The total costs per ship are multiplied by Ψ_t, following Wang et al. (2015), which refers to the number of ships required to satisfy the demand and can be defined as:

(5) $$\Psi_t = \frac{X_t * d_t}{H_t * S_t * \rho_t},$$

where d_t is the route distance (nautical miles) and H_t is a ship's average capacity (tons).

The change in the industrial fleet capacity is defined as:

(6) $$\Delta Z_t = Z_t - Z_{t-1} = N_{t-\theta}.$$

Hence, combining the equations (1) to (6), the world fleet dynamic can be expressed as:

(7) $$\Delta Z_t = n(P_{t-\theta} X_{t-\theta} - (OC_{t-\theta} - F_{t-\theta}) \Psi_{t-\theta}).$$

Following Luo et al. (2009) and applying the cobweb theorem, the freight rate change in international shipping can be expressed as:

(8) $$\Delta P_t = \delta * (\Delta X_t - \varphi * \Delta Z_t),$$

where $\Delta P_t = P_t - P_{t-1}$, ΔX_t is the change in cargo transported at an industrial level, ΔZ is the change in fleet capacity, $\delta > 0$ refers to the freight rate adjustment factor on the basis of the supply and demand alterations, and $\varphi > 0$ (constant) is the average fleet capacity utilization rate.

2.2.2. The unit tax scenario

The cobweb model is modified to include a bunker levy parameter. The first levy that is introduced is in the form of a unit tax. With the introduction of a tax, the equations for profit, fleet, and freight rates need to be modified. In order to distinguish the unit tax from the *ad valorem* tax, they are indicated as *TP* and *VP*, respectively, and as *T*, collectively.

The profit equation is modified to include the unit tax as:

(9) $$\Pi_t^u = P_t X_t - (OC_t + \rho_t(f_t + TP)\lambda S_t^3) * \Psi_t.$$

Equation (7), after inclusion of the unit tax, becomes:

(10) $$\Delta Z_t = n(P_{t-\theta} X_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta}(f_{t-\theta} + TP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}).$$

By substitution of ΔZ_t into equation (8), the change in freight rates is then:

(11) $$\Delta P_t = \delta(\Delta X_t - \varphi \Delta Z_t) =$$

$$= \delta \Delta X_t - \delta\varphi n(P_{t-\theta} X_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta}(f_{t-\theta} + TP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}).$$

2.2.3. The *ad valorem* scenario

In an *ad valorem* tax scenario, where VP stands for a percentage on fuel prices, equations (2), (7), (8), much like in the unit tax scenario, become:

(12) $$\Pi_t^v = P_t X_t - (OC_t + \rho_t(f_t(1 + VP))\lambda S_t^3) * \Psi_t,$$

(13) $$\Delta Z_t = n(P_{t-\theta} X_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta} f_{t-\theta}(1 + VP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}),$$ and

(14) $$\Delta P_t = \delta(\Delta X_t - \varphi \Delta Z_t) =$$

$$= \delta \Delta X_t - \delta\varphi n(P_{t-\theta} X_{t-\theta} - (OC_{t-\theta} + \rho_{t-\theta} f_{t-\theta}(1 + VP)\lambda S_{t-\theta}^3)\Psi_{t-\theta}).$$

2.3. Economic implications

2.3.1. Speed optimization and the industry's energy efficiency

The objective of a shipowner is to maximize profits.[4] Under this assumption, it is possible to determine the values of freight rates, *P*, and the capacity, *Z*, at the time, *t*. Through the cobweb theorem and the model developed in the previous section, it can be shown that these variables are dependent on their values at periods $t - 1$ and $t - \theta$. Since the proposed levy schemes are imposed in

[4] This research paper does not include the asset play case, which can occasionally result in high financial gains for shipowners, but focuses only on the revenues gained from trade activity. The logic behind this assumption is that the industry's fleet capacity during an asset play situation does not experience any change, consequently remaining constant.

period *t*, the values for P_{t-1}, Z_{t-1}, $P_{t-\theta}$, and $Z_{t-\theta}$ are already known in the model because they account for the previously observed years and can be assumed exogenous in the model. Until the time *t*, no tax was included. However, the tax would influence the level of the freight rates and the capacity from period $t + 1$ onwards.

The sector's profit with the inclusion of a bunker levy can be calculated following equation (2), for every levy scheme, as:

$$\Pi_t^u = P_t * X_t - \left(OC_t + \rho_t * (f_t + TP) * \lambda_t * S_t^3\right) * \frac{X_t * d_t}{H_t * S_t * \rho_t} \tag{15}$$

for the unit tax scenario, and as:

$$\Pi_t^v = P_t * X_t - \left(OC_t + \rho_t * (f_t * (1 + VP) * \lambda_t * S_t^3\right) * \frac{X_t * d_t}{H_t * S_t * \rho_t} \tag{16}$$

for the *ad valorem* scenario.

Applying first order conditions to the profit maximization equations,[5] the w.r.t. speed for the first and second levy schemes, respectively, results in:

$$\frac{d\Pi_t^u}{dS} = -\frac{X_t * d_t}{H_t * \rho_t} * \left(2 * \rho_t (f_t + TP) * \lambda_t * S_t - \frac{OC_t}{S_t^2}\right) \text{ and} \tag{17}$$

$$\frac{d\Pi_t^v}{dS} = -\frac{X_t * d_t}{H_t * \rho_t} * \left(2 * \rho_t * f_t (1 + VP) * \lambda_t * S_t - \frac{OC_t}{S_t^2}\right). \tag{18}$$

Since traffic volume, quantity transported (demand), fuel prices, operating costs, freight rates, fuel consumption, and speed have non-negative values, then, based on equations (17) and (18), the optimal speed $\left(\tilde{S}\right)$ and optimal fuel consumption of international shipping after a levy enforcement can be calculated as:

[5] In the simplified industry organisation assumed in this paper, if companies maximise their profits, then the industry profit would be also maximized. The industrial profit cannot be maximized if any company does not maximize its profits. For each individual maximum profit, there is a corresponding optimal speed; hence, the summation of the maximum profits corresponds to the average of individual optimal speeds.

(19.1) $$\tilde{S} = \sqrt[3]{\frac{OC_t}{2*\rho_t*\lambda_t*(\mathrm{f+TP})}},$$

(19.2) $$\widetilde{S} = \sqrt[3]{\frac{OC}{2*\rho_t*\lambda_t*f_t(1+VP)}},$$

(20.1) $$\widetilde{FC_t} = \rho_t * \lambda_t * \tilde{S}_t^3 \frac{\mathrm{X*d}}{\mathrm{H}*\tilde{S}*\rho} = \frac{\sqrt[3]{\left(\frac{OC_t}{2*\rho_t*\lambda_t*(\mathrm{f+TP})}\right)^2}}{H_t} * \lambda_t * X_t * d_t, \text{ and}$$

(20.2) $$\widetilde{FC_t} = \frac{\sqrt[3]{\left(\frac{OC_t}{2*\rho_t*\lambda_t*f_t(1+\mathrm{TP})}\right)^2}}{H_t} * \lambda_t * X_t * d_t.$$

It can be seen that the extra costs from the levies are imposed and added to the total fuel costs. It is expedient to calculate the derivatives of speed and fuel consumption, with respect to fuel costs, and the industry energy efficiency for both cases, respectively.

(19.3) $$\frac{d\tilde{S}}{d(f+TP)} = -\frac{1}{3}\sqrt[3]{\frac{OC_t}{2*\rho_t*\lambda_t*(f_t+\mathrm{TP})^4}},$$

(20.3) $$\frac{d\tilde{S}}{d(f+f*VP)} = -\frac{1}{3}\sqrt[3]{\frac{OC_t}{2*\rho_t*\lambda_t*(f_t+f_t*\mathrm{VP}))^4}},$$

(19.4) $$\frac{d\tilde{S}}{d\lambda} = -\frac{1}{3}\sqrt[3]{\frac{OC_t}{2*\rho_t(f_t+TP)*\lambda_t^4}}, \text{ and}$$

(20.4) $$\frac{d\tilde{S}}{d\lambda} = -\frac{1}{3}\sqrt[3]{\frac{OC_t}{2*\rho_t(f_t+f_t*VP)*\lambda_t^4}}.$$

The meaning of the above derivatives can be easily interpreted. Because of the negative sign in equations (19.3) and (20.3) and of the non-negativity of the parameters, when the fuel prices rise as a result of the enforcement of a levy scheme or the industry vessel efficiency decreases, ship operators consequently sail at a lower speed in order to minimize additional costs. This speed reduction effects fuel consumption, which consequently declines. By taking the ratios of fuel consumption with the inclusion of the levy $\widetilde{(FC_t)}$ to fuel consumption without the levy imposition (FC_t), which are

presented in equations (21.1) and (21.2), a levy results in a new (lower) optimal speed and fuel consumption declines.

(21.1) $$\frac{\widetilde{FC}}{FC} = \frac{\lambda_t * X_t * d_t * \sqrt[3]{\left(\frac{OC_t}{2*\rho_t*\lambda_t*(f_t+\mathrm{TP}))}\right)^2}}{\frac{\rho_t*\lambda_t*S_t^3*X_t*d_t}{H_t*\rho_t*S_t}} = \sqrt[3]{\left(\frac{f_t}{f_t+TP}\right)^2} < 1$$, for the unit tax, and

(21.2) $$\frac{\widetilde{FC}}{FC} = \sqrt[3]{\left(\frac{1}{1+VP}\right)^2} < 1$$, for the *ad valorem* tax.

Another noteworthy aspect relates to the role that energy efficiency is bound to play within the shipping industry, as alternative fuels and forms of propulsion become more common. Should fuel consumption decrease because of improved energy efficiency, the impact of the levy would not need to be accommodated by speed reduction to maintain profit levels. This is an important issue because the model does not account for technology change, which is one of the main policy drivers behind the introduction of a levy. It should also be noted that the effectiveness of speed reduction as a response to a levy is limited, especially in view of the slow steaming observed in the last decade, resulting from poor market conditions. Hence, it is critical for policies to complement the introduction of a levy in order to overcome barriers to the uptake of environmentally friendly novel technologies (Acciaro et al., 2013).

A possible solution is to link the deployment of a bunker levy scheme to financial aid for shipping companies in order to incentivize investing into new technologies. A successful example of this is the Norwegian *NO_x Fund (*Høibye, 2011). The *NO_x Fund* was established after a national *NO_x* tax was enforced in Norway. The structure of the tax allows shipping firms to be exempt, under an agreement with the Ministry of the Environment, but to contribute an equivalent fee—proportional to their emissions—to a fund. The collected amounts are then redistributed to shipping companies in the form of financial support for the deployment of environmental friendly technologies (up to 80% of the total investment). This approach contributed to the 12% reduction of Norway's total NO_x emissions between 2008 and 2011, and it has fostered a rapid uptake of new environmentally friendly ships (Høibye, 2011).

In the same context of eco-friendliness enhancement through policy implementation, the different levels of levy impact on the shipping industry's agents should be addressed. Voyage charters are expected to have a higher level of incentive in comparison to time charters, where the costs have to be borne by the shipowner (IMO, 2010). The expectation of an energy efficiency premium in time charter rates is complex due to the existence of market failure; empirical evidence of the bulk sector shows that during normal market conditions only 14–27% of bunker savings are revealed in the increased rates, while greener ships are penalized during market booms (Adland et al., 2017). In order to overcome this market failure, Adland et al. (2017) suggest the implementation of obligatory and standardized systems, aiming at the collection and distribution of ships' energy efficiency-related data as a potential policy solution.

As far as the decrease in optimal speed is concerned, it is useful to discuss the factors that affect speed change and how profits in the sector are affected. The latter is discussed in section 2.3.2. As far as the former is concerned, if we indicate the percentage change in speed with *M*, then we have:

(22.1) $$M = \frac{\tilde{S}-S}{S} = \sqrt[3]{\frac{f_t}{f_t+TP}} - 1$$ for the unit tax scheme, and

(22.2) $$M' = \frac{\tilde{S}-S}{S} = \sqrt[3]{\frac{1}{1+VP}} - 1$$ for the *ad valorem* scheme.

Speed reduction that results from a tax would be inversely related to the size of the tax, independently from the type of tax. However, the speed change necessary to compensate the tax would depend, in case of a unit tax per ton of bunker, on the fuel prices also. This is one of the main differences between the two schemes and the implications of such a difference can be observed in Figure 2. Assuming bunker prices of $234 per ton (the level of bunker prices observed in October 2015) and $400 per ton, different tax rates are applied and examined. For the unit tax scenario, charges of $10, $30, $60, $90, $120, $150, $180, $200, $220, $250, $280, and $300 per ton of bunker fuel are imposed. As far as the *ad valorem* scenario is concerned, charges of 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80% per ton of bunker are chosen as presented in Table 3.

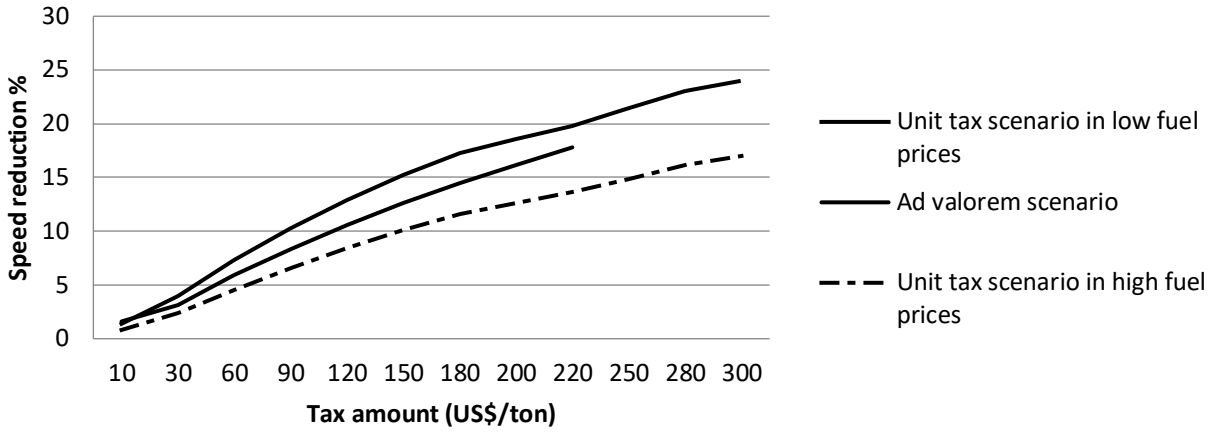
With respect to a low fuel price value, a unit tax scheme would elicit a higher speed reduction than the *ad valorem* one. Inversely, when fuel prices are at a high level, then the *ad valorem* tax would

prompt a higher speed decrease. It should be noted that this is counterintuitive, as it would be expected that higher speed reductions would be associated with higher fuel prices. This is not always the case and it can be shown that, with realistic fuel prices and other things being equal, a unit tax scenario with low value fuel prices can result in a higher speed reduction than a unit tax with high value fuel prices.

Table 3: Speed reduction (from left to right); unit tax scheme with low fuel prices, unit tax scheme with high fuel prices; *ad valorem* scheme

TP ($/ton)	M	TP ($/ton)	M	VP (%)	M
10	1.39%	10	0.82%	5	1.61%
30	3.94%	30	2.38%	10	3.13%
60	7.33%	60	4.55%	20	5.9%
90	10.28%	90	6.54%	30	8.37%
120	12.9%	120	8.4%	40	10.6%
150	15.2%	150	10.1%	50	12.6%
180	17.3%	180	11.6%	60	14.5%
200	18.6%	200	12.6%	70	16.2%
220	19.8%	220	13.6%	80	17.8%
250	21.5%	250	14.9%		
280	23%	280	16.2%		
300	24%	300	17%		

Figure 2: Speed reduction with differentiated imposed tax values



2.3.2. Profit differentiation

Having found the optimal speed and fuel consumption for both cases respectively, it is feasible to examine the influence of the proposed levy schemes on industry profit. The profit-maximizing values of $\widetilde{S_t}$ and $\widetilde{FC_t}$ are substituted into the previously obtained profit function. The derivatives, in relation to the tax for both levy scenarios, are:

(23.1) $$\frac{d\widetilde{\Pi_t}}{dTP} = -\left[\frac{X_t * d_t * \sqrt[3]{OC_t^2} * \sqrt[3]{2*\rho_t*\lambda_t}}{3*H_t*\rho_t*\sqrt[3]{(f_t+TP)^2}} + \frac{2*\rho_t*\lambda_t*X_t*d_t*\sqrt[3]{OC_t}}{3*H_t*\rho_t*\sqrt[3]{2*\rho_t*\lambda_t}*\sqrt[3]{f_t+TP}}\right]$$ for the unit tax and

(23.2) $$\frac{d\widetilde{\Pi'}_t}{dVP} = -\left[\frac{X_t*d_t*\sqrt[3]{OC^2}*\sqrt[3]{2*\rho_t*\lambda_t*f_t}}{3*H_t*\rho_t*\sqrt[3]{(1+VP)^2}} + \frac{f_t*\rho_t*\lambda_t*\sqrt[3]{OC_t^2}*X_t*d_t}{3*H_t*\rho_t*\sqrt[3]{(2*\rho_t*\lambda_t*f_t)^2}*\sqrt[3]{(1+VP)^2}}\right]$$ for the *ad-valorem*.

As expected, both derivatives are negative. This can be interpreted as a levy market effect, where a tax would result in the reduction of profits. It is useful to examine how industry profits decrease for both levy scheme scenarios.

The change in profit can be indicated with *N* as:

(24.1) $$N = \frac{\widetilde{\Pi_t} - \Pi_t}{\Pi_t} = \frac{OC_t * d_t * (S^{-1} - \tilde{S}^{-1}) + d_t * \lambda_t * \rho_t * (f_t * S_t^2 - (f_t + TP) * \widetilde{S_t^2})}{H_t * \rho_t * P_t - OC_t * d_t * S^{-1} - f_t * \rho_t * \lambda_t * S_t^2 * d_t} =$$

$$= \frac{A + d_t * \lambda_t * \rho_t * (f_t * S_t^2 - (f_t + TP) * \widetilde{S_t^2})}{B}$$ for the unit tax scenario and

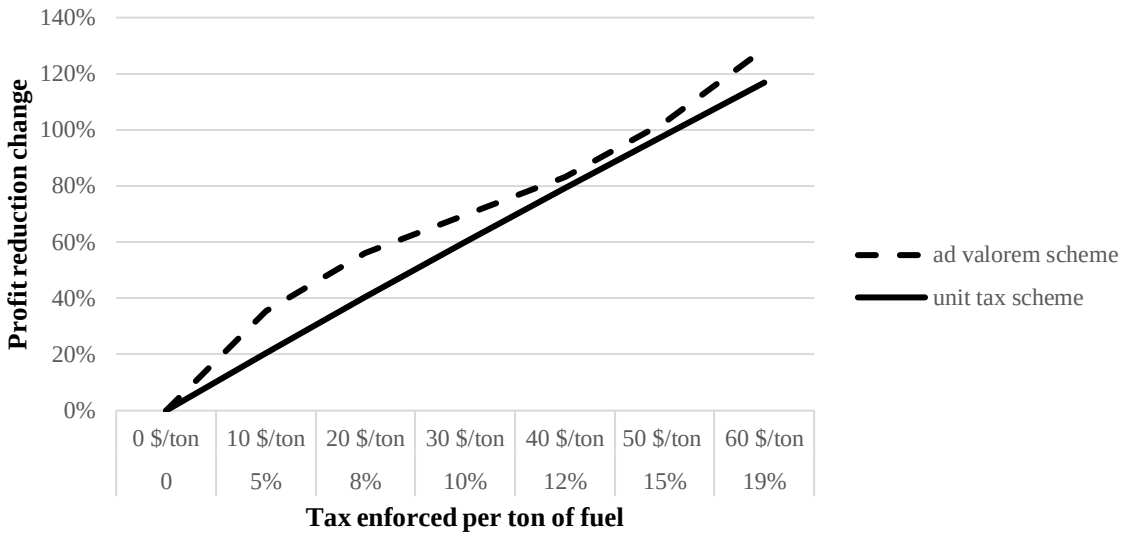
(24.2) $$N' = \frac{\widetilde{\Pi_t'} - \Pi_t}{\Pi_t} = \frac{OC_t * d_t * (S^{-1} - \tilde{\tilde{S}}^{-1}) + d_t * \lambda_t * \rho_t * f_t * (S_t^2 - (1 + VP) * \widetilde{S_t^2})}{H_t * \rho_t * P_t - OC_t * d_t * S^{-1} - f_t * \rho_t * \lambda_t * S_t^2 * d_t} =$$

$$= \frac{A + d_t * \lambda_t * \rho_t * f_t * (S_t^2 - (1 + VP) * \widetilde{S_t^2})}{B}$$ for the *ad valorem* scenario.

Figure 3 illustrates the changes in profit for the two scenarios. The data used are, for the dry bulk sector, for the year 2007, as presented in Wang et al. (2015):

- Sailing speed prior to the tax S = 14 kts,
- ship size used H = 49,000 tons,
- ρ = 6,480 hours,
- demand of the industry X = 4,100 million tons,
- average voyage distance d = 9,036 nms,
- f = 350 $/ton,
- ship´s efficiency λ = 0.0012,
- P = 48 $/ton, and
- annual operation costs of ship OC = $1.51 x 10^7.

Figure 3: Profit reduction for both levy schemes



For this example, an *ad valorem* scheme would lead to a higher profit loss in the shipping industry.

2.3.3. Levy cost allocation

One of the main purposes of this analysis is to investigate how costs are allocated among shipowners, operators, and cargo owners—i.e., those who actually bear the burden of the tax. To this end, the cost pass-through theory is useful but the estimation of the allocation share requires a set of assumptions about the price elasticity of the supply[6] and demand. The price elasticity of the supply and demand can be expressed as:

$$E_s = \frac{\%\Delta Z}{\%\Delta P} = \frac{\%\ change\ in\ quantity\ supplied}{\%\ change\ in\ price} \qquad \text{and} \qquad E_d = \frac{\%\Delta X}{\%\Delta P} = \frac{\%change\ in\ quantity\ demanded}{\%change\ in\ price}\ .$$

It can be assumed, without loss of generality, that the levy schemes are in place at the periods t – 1 and t – θ. Thus, to illustrate the consequences of equations (25) and (26) on the amount of tax—we follow the RBB Economics (2014) report for the cost-pass through theory—that would be borne by

[6] The supply is assumed to be the product of the fleet's capacity and φ (the capacity utilization rate; positive constant). The latter is dropped while the equations are constructed.

the shipper, shipowner, or ship operator at period *t*, the fraction of the levy costs, ξ, covered by the shipowner, can be expressed as:

$$\xi = \mathrm{E}_d/(\mathrm{E}_d + \mathrm{E}_s) = (\Delta \mathrm{X}_t * \mathrm{Z}_{t-1})/(\Delta \mathrm{Z}_t * \mathrm{X}_{t-1} + \Delta \mathrm{X}_t * \mathrm{Z}_{t-1}). \quad (25)$$

Similarly, the fraction of the levy costs borne by the consumer, ζ, in our case the shipper, is presented as:

$$\zeta = \mathrm{E}_s/(\mathrm{E}_d + \mathrm{E}_s) = (\Delta \mathrm{Z}_t * \mathrm{X}_{t-1})/(\Delta \mathrm{Z}_t * \mathrm{X}_{t-1} + \Delta \mathrm{X}_t * \mathrm{Z}_{t-1}). \quad (26)$$

The enforcement of a levy scheme in the shipping industry is similar to the case of industry-wide cost pass-through, because the change in the costs associated with a tax has an effect on all firms involved (i.e., shipping companies). It is important to highlight that the extent of the cost change passed to consumers (i.e., shippers) by firms does not need to be uniform but can differ from consumer to consumer and depends on the price elasticity of the demand. The market conditions and the alterations in the supply and demand determinate the levy allocation. Particularly, when the demand to supply ratio—it represents how fast supply and demand change—has increased, then this article assumes that market conditions have improved.

At this point it is interesting to observe how ξ and ζ vary depending on the market conditions. Therefore, an example is provided for illustration purposes, only in order to assess the potential impact of market conditions on the values of ξ and ζ. If the levy schemes had been enforced in those periods the values of the fleet capacity and freight rates would have been different. The example—the approximate numerical data were retrieved from Clarksons Research (Clarksons.net., 2019) and refer to the crude oil market—assumes for the first case Z_{2006} = 269.70 million deadweight tonnes, Z_{2005} = 253.57 million deadweight tonnes, X_{2005} = 1,880.30 million tonnes and X_{2006} = 1,894.08 million tonnes. Inserting this data into equations (25) and (26), it can be calculated that ζ_{2006} = 90%. The extra costs from a theoretical tax had to be absorbed mainly by the shippers. The second case assumes, X_{2016} = 1,938.45 million tonnes, X_{2015} = 1,861.55 million tonnes, Z_{2016} = 380.10 million deadweight tons, and Z_{2015} = 371.42 million deadweight tons. The results show that ζ_{2016} = 36 %, so that the lowest portion of the tax would be borne by the shippers. In both cases the demand and the

capacity of the industry have increased. The market conditions (i.e. demand to supply ratio) have deteriorated for the first case while they have improved for the second example.

The international maritime transport industry has been experiencing—apart from exceptionally rare cases (e.g. the world economic crash)—a continuous growth in both its associated supply and demand throughout the years. Hence, it can be argued that in the case when the market conditions are favourable for the international shipping sector, with buoyant demand and high freight rates, a higher percentage of the tax costs is absorbed by the shipowners. In the other case, where market conditions have deteriorated, a higher cost proportion can be transferred to the shippers. This has also been shown in the numerical examples.

2.4. Conclusion

This research paper focused on the economic implications of introducing a bunker levy scheme in international shipping. Two alternative forms of tax, a unit and an *ad valorem*, were examined and benchmarked. A dynamic economic model was used for the analysis, which differs from previous ones because it accounts for the inclusion of a tax parameter. The model was constructed making use of the cobweb theorem that has been previously applied in shipping for forecasting purposes only.

The model provides the basis for benchmarking the two levy schemes. In both cases, the levy results in additional costs that compound with fuel expenses. Speed optimization results in a speed reduction and can compensate partial profit losses. The benefits of such strategy, however, are limited, as speed cannot be reduced indefinitely. In the medium-term, this would require finding other ways to improve the energy efficiency profile of the sector by investing in new environmentally friendly technologies, which is one of the stated aims of the MBM. The analysis presented in this paper contributes to the identification of the factors that determine speed change. In the unit tax scenario, the change varies depending on the values of fuel price and the fixed tax amount. In the *ad valorem* case, on the other hand, it relies upon the percentage set up as the tax scheme and fuel prices have no influence on the cost increase that results from the introduction of the tax. The analysis proves a profit decline associated to levy scheme enforcement in both cases. As far as the question whether the enforced tax costs would simply be passed along the supply chain is concerned, the research provides a framework

for how the tax amount would be allocated in the industry. Alterations in supply and demand and market conditions are the key determinants factors of how the levy cost are allocated.

This paper is one of the first attempts to illustrate the implications of introducing a levy scheme into the shipping sector. Given the importance of the shipping sector for the global economy and the urgency for climate action, the analysis of the impacts of this MBM is particularly pressing. A bunker levy scheme can act as an incentive for investments into environmentally friendly technologies. Nevertheless, in order to mitigate the negative impacts on shipowners, the MBM should be linked to a reimbursement scheme through the provision of financial aid in order to increase the adoption of new technologies. This is particularly urgent because the saving opportunities obtainable through speed reduction are quickly exhausted. The existing Norwegian *NOx Fund*, described in section 2.3.1, appears as a useful and viable proposition, for example. The IMO should take into consideration that a part of the resources collected though MBMs should be destined to foster future research and ease the financial burden of those shipping companies that proactively invest in green technologies. Associating the enhancement of the shipping industry's eco-friendliness and the reduction of GHG emissions to the provision of (financial) support to companies for purposes of obtaining greener technologies is vital for achieving a policy outcome that does not jeopardize the wellbeing of the international shipping sector.

Despite the study's contributions, several limitations can be identified. The first limitation is that demand is considered to be exogenous and inelastic. This assumption mainly holds for deep sea shipping and not for short sea shipping (SSS), where competition with other transport modes exists. Given that this manuscript is one of the first efforts to analyze a bunker levy scheme, topics for further examination still remain open and need to be addressed. The economic effects on SSS and the possibility of a modal shift to alternative competing transportation modes should also be explored; an issue as challenging as a bunker levy scheme may hinder its promotion and exploitation. The implications of the MBM on world trade (Luo, 2013), the risk of a modal shift (Psaraftis and Kontovas, 2010), and the impact on the profitability of the maritime industry, as illustrated in this paper, are reasons motivating enough to inspire further research. The enforcement of a bunker levy scheme would lead to dissimilar effects on shipping networks and industry segments, as the supply and demand interactions are dependent on trade routes. The possible solution for the industry—

decreasing further sailing speed in order to cope with the extra costs—may challenge the operational and logistics activities, especially in the container shipping sector. Hence, further areas for research could include: a) implications in global supply chains—i.e., just-in-time delivery problems, alterations in shipping networks, changes in trade patterns, b) economic implications in other maritime sectors, and c) examination of other forms of environmental tax schemes. These and other areas need to be looked at now if academic research is to provide guidance for an informed policy debate—in the absence of which, inertia and political interests are bound to prevail to the detriment of the planet, the shipping industry, and society by and large.

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Chapter 3

Short sea shipping and bunker levy scheme enforcement: A Bayesian network approach

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Abstract

One of the possible measures for achieving emission reduction targets that have been set by the International Maritime Organization (IMO) in the shipping industry is the enforcement of a bunker levy scheme—i.e., fuel tax. Despite the appealing character of the levy, caution is required because its associated costs could negatively impact the competitiveness of short sea shipping (SSS) vis-à-vis other modes of transport. This study dwells on this issue by examining the factors, including the levy scheme that can influence the competitiveness of the sector vis-à-vis road transportation. The article develops a conceptual modal split model, which incorporates the tax variable on the basis of a Bayesian network approach. A sensitivity analysis is conducted and 16 scenarios are examined. The analysis indicates that high bunker prices and a high tax price would reduce the probability of high short sea shipping competitiveness. The latter is also influenced accordingly by cargo value, shipment's opportunity costs, freight rates, and distance. Moreover, shipping companies could increase the probability of competitiveness being high by rationalizing their transport network. Last but not least, the generalized road transport costs play an eminent role in the final implications that a bunker levy would have on the competitiveness of short sea shipping.

Keywords: *Market-based measures (MBM), short sea shipping (SSS), modal shift, bunker levy*.

3.1. Introduction

The importance of the maritime transport industry in supply chains is undeniable as it accounts for around 10.3 billion tons of world trade (United Nations Conference on Trade and Development [UNCTAD], 2017). Nevertheless, additional to the sector's energy efficiency gap (Eide et al., 2011; Acciaro et al., 2012), concerns have been expressed about the greenhouse gas (GHG) emissions produced by its operations. Specifically, international shipping's CO_2 emissions could escalate up to 250% by the year 2050 from its recorded values for the year 2012 (International Maritime Organization [IMO], 2014). This is the worst possible scenario that was presented in the latest IMO's GHG study (2014).

In alignment with this exhaust gas increase, the Marine Environment Protection Committee (MEPC) of the IMO reached an agreement in April 2018 and established the first ever strategy for tackling GHG emissions in the maritime sector. This agreement represents a milestone for enhancing the industry's environmental performance because it sets specific reduction targets. Explicitly, carbon intensity must be reduced by at least 40% by 2030 and efforts should be made toward a 50% GHG emissions decrease by 2050 in comparison to the 2008 base-level year (Det Norske Veritas Germanischer Lloyd [DNV GL], 2018). The initial strategy includes possible short-, medium-, and long-term emission abatement actions that range from improving already established measures—i.e., the Energy Environmental Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP)—to enforcing market-based measures (MBMs) and research for establishing zero-carbon fossil fuels. Notwithstanding the fact that the EEDI and the SEEMP have been in place for the past few years, the emission strategy brings to the discussion of MBMs to the forefront, which are, in fact, economic incentives that would be provided to shipping companies with the aim to improve their operational efficiency (IMO, 2016).

It has been argued that the enforcement of MBMs in the shipping sector is a necessity in terms of the efforts to tackle the industry's produced emissions (Shi, 2016). Nevertheless, possible implementation of such measures requires caution when considering that the already imposed regulations either had unanticipated side-effects—i.e., Emission Control Areas (ECAs) could increase CO_2 emissions (Fagerholt et al., 2015)—or were not adequate—i.e., the EEDI (Miola et al., 2011). A possible consequence of an MBM enforcement, arguably, relates to the appearance of a

modal shift—i.e., cargo switching from sea- to land-based transportation modes. A modal shift from short sea shipping (SSS) has already been under investigation among practitioners and academics after the introduction of the ECAs in Northern Europe (Odgaard et al., 2013; Zis and Psaraftis, 2018) due to the increase of the companies' operating costs (Bengtsson et al., 2014). Thus, an additional rise in expenses resulting from an MBM introduction could constitute a threat to the competitiveness of short sea shipping (SSS) companies vis-à-vis other transportation modes. The assessment of this risk is both timely and important because policy-makers argue about SSS's role in tackling road congestion. The present article sheds light on this concern after the enforcement of a bunker levy scheme. This MBM is, without loss of generality, a tax imposed on fuel that can lead, under certain circumstances, to investments in green technologies (Kosmas and Acciaro, 2017a). Modal shift or modal split analyses have been conducted in previous literature—e.g., Zis and Psaraftis (2017)—assessing the effects after the enforcement of environmental regulations on the shipping industry.

This article is centered on the SSS sector's competitiveness vis-à-vis road freight transport and examines what factors the policy-makers should take into account when designing the implementation of a bunker levy scheme and what the implications of this policy are on the competitiveness of the sector. The levy scheme under consideration here is in the form of unit tax—i.e., fixed amount of levy imposed on bunker price. The unit tax scheme is chosen for two reasons. First, a levy based on an *ad valorem* structure (i.e., a tax percentage levied on fuel prices) would add more uncertainty within an already volatile market. Second, the expected speed reduction after this policy enforcement would depend both on fuel prices and on levy costs for the unit tax scheme, while it would be based only on the levy percentage for the *ad valorem* one (Kosmas and Acciaro, 2017a). Nevertheless, the examination of an *ad valorem* levy scheme could constitute a future research opportunity. This study differs from existing studies by developing a conceptual modal split model—that includes a levy parameter—based on a Bayesian network approach and examines the importance of the additional factors that could have an impact on the competitiveness of the sector. A Bayesian network (BN) approach enables a graphical knowledge representation of the uncertainty related to the fuel taxation concept prior to its implementation.

The SSS industry can also compete with the rail transportation sector or be part of a multimodal transport system. Nevertheless, the present article builds the model within the context of the SSS

sector's competition vis-à-vis the road sector. The reason for this binary focus is the aim and contribution of the article. Primarily, it relates to the identification of the importance of, and the extent to which, influential factors may have on the determination of the SSS' competitiveness. Consequently, these will affect the extent of the policy's implications on the sector. Hence, given the fact that the article's main objective does not concentrate, explicitly, on the modal split among the various transport modes in regarding the MBM's enforcement, the article follows a binary approach. Due to the fact that policy-maker's concern concentrate heavily on the decongestion of road transport, the binary focus of the article is between SSS and road. The identification of the importance of, and the extent to which influential factors affect the competitiveness of the SSS sector is also enabled by the application of the BN methodology. In the case of discrete econometric choice modal split models, large datasets would be required to determine the extent to which the factors under analysis have on the competitiveness of the sector. Yet, the BN approach can deal with this issue in the absence of data, hence, being an appropriate methodology to shed light on this research topic.

The contribution of the study is threefold and embraces aspects of interest for a broader spectrum of stakeholders. First, by designing a modal split model that takes a levy parameter into consideration, it provides a supportive analysis tool for policy-makers that could be used in the MBM enforcement debate for greening the shipping industry. Second, shippers and shipping companies would benefit because the designed model can mitigate the uncertainty associated with the results of a fuel cost increase. Last but not least, this study expands the academic literature related to MBMs and modal shift models as it follows the differentiated approach of BNs, which has mainly been used for collision risk analysis (e.g., Hänninen and Kujala, 2012) in the sector.

The article is structured in five sections. The first introduces the aim of the research. The second section presents the bunker levy scheme context in the maritime industry and the importance of examining the implications of bunker levy scheme enforcement on SSS. Moving on, the third section introduces the BN methodology, while the fourth section constructs a conceptual dynamic modal split model. The fifth section presents main findings of the paper. Initially, a sensitivity analysis is conducted for investigating the impact of the various components of the model on SSS's competitiveness. Consequently, 16 scenarios are analyzed. Finally, the sixth section concludes the manuscript, highlights its limitations, and suggests further research directions.

3.2. Literature review

This section is composed of two parts. The first introduces the concept of a bunker levy scheme, presents the limited existing literature that focuses on its possible environmental and economic implications, and highlights the need for investigating potential adverse effects. The second part describes SSS as an alternative mode for freight transportation and justifies the aim of this research.

3.2.1. Concept of bunker levy scheme enforcement

The debate of introducing market-based measures as an emission reduction solution in the maritime transport industry was officially begun within the IMO when, in July 2009, Member States, Associate Members, and observer organizations were asked by the MEPC 59 to submit possible schemes for future consideration. In August of 2010, an impact assessment report and a feasibility study related to the proposals were submitted at the MEPC 61 (IMO, 2010). For a preliminary assessment of possible MBMs, Psaraftis (2012) reviews them according to specific criteria, such as environmental and cost effectiveness, risk of fraud, and practical feasibility. Without loss of generality, the MBMs proposals can be grouped to two different schemes that have drawn the attention of both industry and academia: an Emission Trading Scheme (ETS) and a bunker levy scheme.

An ETS relies on the principle of cap and trade[7] and would decree ship operations within a specific allocated emission limit (Psaraftis, 2012). As the present manuscript does not focus on ETS, this section does not go into detail about related existing studies. On the other hand, a bunker levy scheme—the term tax is not used by the IMO due to the agency's character—is argued to have the easiness of enforcement and industry suitability as an advantage (Kapetanis et al., 2014). In addition, one of its pros is that the enforced costs would be known in advance, which would provide price certainty for shipping companies and enable them to invest proactively in new technologies (Psaraftis, 2012).

Notwithstanding the fact that literature on the environmental and economic implications of bunker levy scheme enforcement on the shipping industry is scarce, existing studies point toward its positive outcomes for enhancing the green performance of the sector. As far as the environmental implications are concerned, research articles present that CO_2 emission reduction that can be achieved varies for

[7] A GHG reduction cap would be set as a *priori*.

different vessel types and levy scenarios. Indicative studies are those by Devanney (2010) and Kapetanis et al. (2014), focusing on very large crude carriers (VLCC) and Handymax bulk carriers, respectively. In terms of other pieces of regulation, a levy could result in a double-level CO_2 emission reduction and have the same environmental implications for at least half of the cost in comparison with an ETS (Congressional Budget Office [CBO], 2008). The latter is also argued to be ineffective in driving technological investments (Friends of the Earth [FOE], 2009).

From an economic perspective, besides the feasibility study prepared by the IMO's expert group (IMO, 2010) and the report by Vivid Economics (2010) conducted for the agency, to the author's knowledge at least, the recent study of Kosmas and Acciaro (2017a) examines such implications in the international shipping sector. Both differentiated schemes under investigation—i.e., a unit tax and in an *ad valorem*—could actually put pressure on shipowners for green investments. Furthermore, the article describes how the imposed levy fees would be allocated between shippers and shipowners, depending on the market situation of the industry. The intuitive appeal of such a policy toward success in the global effort for the industry's emissions reduction should not overlook possible negative implications—such as cargo shift to other transportation modes.

3.2.2. Promotion of short sea shipping

This modal shift concern stands, especially for SSS due to its competition with other modes—i.e., road and rail. SSS has been delineated as the "*shipping of cargo or goods for relatively 'short' distances or to nearby coastal ports*" (Henesey and Yonge, 2006) or as the freight and passenger transportation by sea without crossing an ocean (Johnson and Styhre, 2015) within various definitions it has received through the years (Trujillo et al., 2011). Nevertheless, a universally accepted definition is absent, even from policy-makers at the European level, which has resulted in a failure to promote this transportation mode (Douet and Cappuccilli, 2011). Its intended promotion in Europe—which is evident primarily through financial provision by its inclusion in the Trans-European Transport Network (TEN-T) projects—aims for improving its economic and environmental performances and developing it into a gear of the European transport system (Douet and Cappuccilli, 2011).

Within the discussion about the promotion of SSS, the study by Ng (2009) points out that policy-makers should concentrate on regions, where the positive promotion and usage of SSS may actually

be realized, and avoid strategies that are generic. The intention for advancing SSS's usage relies on its competitive advantage with respect to negative externalities when compared to other transportation modes. Nevertheless, this environmental competitive advantage—green performance can be further improved through reduced time in ports (Johnson and Styhre (2015)—is threatened by the enforcement of fuel quality restrictions in the road sector (Hjelle, 2010). Additional studies, e.g., Styhre (2009), have also presented that the latter can have a better eco-friendly performance in certain cases.

The existing literature associated with the competitiveness and usage of SSS as an alternative freight transportation mode often focuses on specific case regions. For instance, some of the representative studies are: Torbianelli (2000) for the Mediterranean Sea case; Sambracos and Maniati (2012) on the competition between SSS and road sectors in Greece, suggesting promotion of the first, improvements in ports' hinterland connectivity infrastructure, and exploitation of subsidies for vessel investments; Ng (2009) for the North Europe case; and Yang et al. (2013) on the influential power of the port pricing and customs procedure system in the usage of SSS in Taiwan. Additional literature on the mode's promotion expand to areas related to its integration into transportation chains. Other studies such as Paixao and Marlow (2009) and Ng (2009) highlight that the quality of hinterland accessibility are important toward this direction, whereas Paixao Casaca (2007) suggests specific logistics strategies for ports in order for them to become important nodes in the chain.

Overall, SSS companies operate in a competitive environment and are required to satisfy an inflexible and just-in-time sensitive demand (Tostmann, 2004), with costumers asking for a service of high quality (Paixa˜o Casaca and Marlow, 2005). It is undeniable that, besides the already existing ECAs and the upcoming future introduction of the Global Sulphur Cap—which requires the reduction of sulphur content emitted by shipping operations at 0.5 % outside of the ECAs that can be achieved either through cleaner fuels, which are more expensive than the typically used heavy fuel oil (HFO) or through the installation of costly special scrubbers technology—the enforcement of a bunker levy scheme would result to additional financial pressure on shipping companies and, consequently, to a threat to the competitiveness of SSS in relation to a modal shift, resulting from its competition with other transportation modes. Thus, research on the possibility of such adverse implications is imperative, timely, and required.

3.3. Modal shift models and Bayesian networks

The present section presents the methodological part of this article. At first, it provides a representative overview of the usage of modal shift models in freight transportation. Subsequently, a Bayesian network approach is introduced and described, followed by its main research application within the maritime transport industry. This section of the study shows the discrepancy of the commonly applied modal shift models with the newly introduced approach.

3.3.1. Discrete choice models

A behavioral econometric freight modeling technique represents a discrete choice analysis.[8] Under a discrete choice model framework, an individual (which, for the shipping industry's case, is a shipper or cargo owner) selects the transport mode, according to its achieved utility level (Ben-Akiva and Lerman, 1985). The determinant factors for the utility estimation vary, as has been shown in many studies—e.g., cost, time, and shipment frequency (García-Menénez et al., 2004); and cost, freight rates, and origin and destination (Cascetta, 2001; Domencich and McFadden, 1975). Discrete choice models have been explored from multifaceted aspects. The basic distinction among them depends on the data used for the studies—aggregate or disaggregate. The latter refers to data that include total freight volume flows for each mode in a regional or national context, whilst the latter consists of discrete consignments data (Zlatoper and Austrian, 1989).

A representative example of a discrete choice model that was constructed to capture the modal shift after bunker levy scheme implantation is found in a previous version of this paper by Kosmas and Acciaro (2017b), which was presented at the 2017 International Association of Maritime Economists (IAME) conference. The model focuses on the freight competition between SSS and truck transportation. Overall, following Ben-Akiva and Lerman (1985), this binary logit model—its components are illustrated in Table 4—can be formulated as follows:

(1) $P_{ij}=f\ (U_{ji})$, where (2) $U_{ji}= V_{ji}+ \varepsilon_{ji}$.

[8] In general, models that focus on the decisions made from among the different choices that consumers face are defined as behavioral. Discrete choice models are the behavioral models that represent the transport decisions among a discrete set of alternative modes (Ben-Akiva and Lerman, 1985).

Table 4: Components of binary logit models

j	*Two alternative transport modes (j = r or s, r = road, and s = short sea shipping)*
i	*Shipper-carrier*
U_{ji}	*Net utility function*
P_{ij}	*Probability that i chooses j*
e_{ji}	*Error term of the utility*
V_{ji}	*Portion of the utility of j that is observed by i*

Equation (1) can be further expanded as:

(3) $$P_j = \exp(V_j)/\sum_{j=r,s}\exp(V_j) = 1/(1+\exp(V_r - V_s)),$$

and

(4) $$\sum_{j=r,s} P_j = 1.$$

For simplification purposes, researchers may decide not to take into account the decision-making differences of shippers. Hence, it is possible to drop the *i* from the equations. By dropping the *i*, it is also assumed that "past experience" does not play a role in the decision-making process. Additionally, the coefficient θ can be assumed to be the same for both utilities, as in McCarthy (2001). The error term—i.e., the unobserved utility—can also be dropped from the final equation when only the observed utility is examined. Last but not least, the factors included in the equation are assumed to have a linear relationship and are stated as $x_{j1},\ldots,x_{jz}$. Thus, the utility for each transportation mode is stated as follows:

(5) $$U_r = \theta_{r1}x_{r1}+\theta_{r2}x_{r2}+\ldots.+\theta_{rz}x_{rz} \text{ and}$$

(6) $$U_s = \theta_{s1}x_{s1}+\theta_{s2}x_{s2}+\ldots.+\theta_{sz}x_{sz}.$$

A simplified binary logit model has been described. Nevertheless, when shippers have the capability of choosing between more than one alternative mode of transportation, then a nested logit model can be useful to investigate the modal split (Ortúzar and Willumsen, 2011). A recent study by Zis and Psaraftis (2017) develops such a model for the investigation of the Sulphur ECA limits' implications

on the European Roll on/Roll off (RoRo) maritime sector. The underlying idea of this methodology is that a shipper has to choose between the ship and road options in the first phase of the model and then between the alternatives (companies) available for each mode. In the nested logit option, the probabilities, which are dependent on the attributes that would be included in the functions, are calibrated at each stage. Nevertheless, as is discussed in section 3.1. the author constructs a binary model given the aim of the article.

3.3.2. A Bayesian network approach

Bayesian Belief networks or, simply put, BNs are a probabilistic modelling technique for the representation of a complex and possible conditionally interdependent set of selected variables (Pearl, 1988). These models can be applied for designing an expert system in case of uncertainty and are structured as a Directed Acyclic Graph. The variables are epitomized as the model's nodes, whereas the links refer to the dependencies among them. The graphical representation of a system's network is considered the qualitative aspect of the model. Its quantitative feature is provided by the assignment of probability parameters (Darwiche, 2009) (for a representative description of the probabilistic components of BNs, please refer to Pearl, 1988).

The results of BN models are depicted as probabilistic values. The models can contribute in risk analysis (Aalders, 2008). Specifically, they can act as a helping tool for decision-makers on the grounds that the models are capable of capturing and illustrating the complexities of a system and/or a problem by modelling existing knowledge and dependencies among the constituting factors. It can be time-intensive for a researcher to construct such models. Regardless, the application of BN models has been experiencing an exponential growth within the research community in the recent years (Marcot, 2017). Kraisangka and Druzdzel (2018) argue that such models have their intuitivism and solid structure, grounded on existing theory, as an advantage.

In order to understand the background of the joint probability distribution calculation—as a BN encompasses the prior and conditional probabilities of all variables—of a BN's set of discrete random variables, the article refers to the study by Friedman et al. (1997). The pair $B = \langle G, \Theta \rangle$ represents the BN for U, which is the set of random variables ($Y_1,\ldots,Y_n$). The letter G refers to the directed acyclic graph. The letter Θ is the second component that encompasses the set of parameters used for the

quantification of the network. Particularly, according to Friedman et al. (1997), those are $\theta_{Y_i|\Pi_{Y_i}} = P_B(Y_i|\Pi_{Y_i})$ for the possible values of each y_i of Y_i and Π_{y_i} of Π_{Y_i}. Π_{Y_i} refers to the parental set of Y_i in the directed acyclic graph G. The nodes have an underlying Node Probability Table (NPT), which represents their probability, given the probabilities of its parents and depending on the combinations of the node and the parents.

Indicatively, the joint probability distribution of a Bayesian network *A* is:

$$P_A(U) = P_A(Y_1, \dots, Y_n) = \prod_{i=1}^{n} P_A(Y_i|\Pi_{Y_i}) = \prod_{i=1}^{n} \theta_{Y_I|\Pi_{Y_i}}.$$

3.4. A bunker levy modal split model

This section constructs the BN model, which has as objective, (see Figure 4), to capture the mode's competitiveness through a prediction of the modal split between SSS and road transportation under certain assumptions. The modal split in the model is determined based on the generalized cost approach, which captures the shipper's decision and has previously been used in SSS literature (Chang and Thai, 2017). The *generalized costs* are composed of the *transportation costs*, which are the total price paid for the shipping services, and of the *value of time costs* related to the shipment (i.e., inventory costs of the shipment while being in transit). The model does not include external costs, which refer to the transportation mode's costs to society, following Zis and Psaraftis (2017).

Thus, the *generalized costs of short sea shipping* can be broken down into additional components, particularly, to the *transport costs* and the *value of time costs*. Given the fact that distance is important for the mode's selection, the present study assumes that the *transport costs* depend both on the *freight rates* (in price per ton per km) and the transportation *distance* (in km). Moving on, the *value of time costs* (US$ per ton) of the shipments is formed based on the *transit time* (hours) and the *monetary value of time* (US$ per ton per hour), following Zis and Psaraftis (2017). The *transit time* is subject to the *distance* required to be sailed for the transportation and the sailing *speed* of the vessel. As far as the monetary value of time is concerned, it is subject to the *opportunity cost of capital* (%) and the *value of the cargo* ($/ton). The sailing speed, as described by Kosmas and Acciaro (2017a), is a function of a ship's annual *operating costs* (in US$), *fuel costs* (US$/ton), *operating time* (ρ) *at sea*

(in hours), the *energy efficiency* of a ship *(*presented as λ, which is the associated coefficient), and the bunker levy (US$/ton of fuel). The node of *generalized costs of road transportation* are assumed to be exogenous in the model, which means that the author has no control over them.

The idea of the present model is to predict the implications of the levy policy on the competitiveness of SSS via the calculation of modal split on the grounds of prior assumptions, without performing any diagnostic reasoning. The model is constructed through the AgenaRisk software, which incorporates new developments of probabilistic reasoning and Bayesian artificial intelligence (AgenaRisk, 2018). At this point, the explanation of some terminology follows:

Ranked nodes: These are discrete variables and their states represent ranked ordinal states, (e.g. *high*, *medium*, and *low)*. Since they are assumed to be defined on a [0–1] scaled unit interval, their numerical scale is calculated by the divide of the [0–1] range to the number of intervals. Therefore, indicatively, the numerical equivalent for *low* would be [0–0.333), for *medium* [0.333–0.666) and for *high* [0.666–1]. For a specific explanation of the background of ranked nodes and how the BN approach solves all the related modelling challenges, the reader is referred to Fenton and Neil (2012).

Truncated Normal (TNormal) distribution: This is a statistical distribution defined on a numerical scale of the nodes. This distribution is especially recommended for ranked nodes with ranked parents due to its proven capability of producing NPTs for all BN fragments at a satisfactory level (Fenton and Neil, 2012).

Table 5: Consistent Ranked Scales

Modal share of short sea shipping	Generalized costs of short sea shipping	Generalized costs of road transportation
Low	High	Low
Average	Average	Average
High	Low	High

Source: Author's illustration based on Fenton and Neil (2012)

Table 6: Inconsistent Ranked Scales

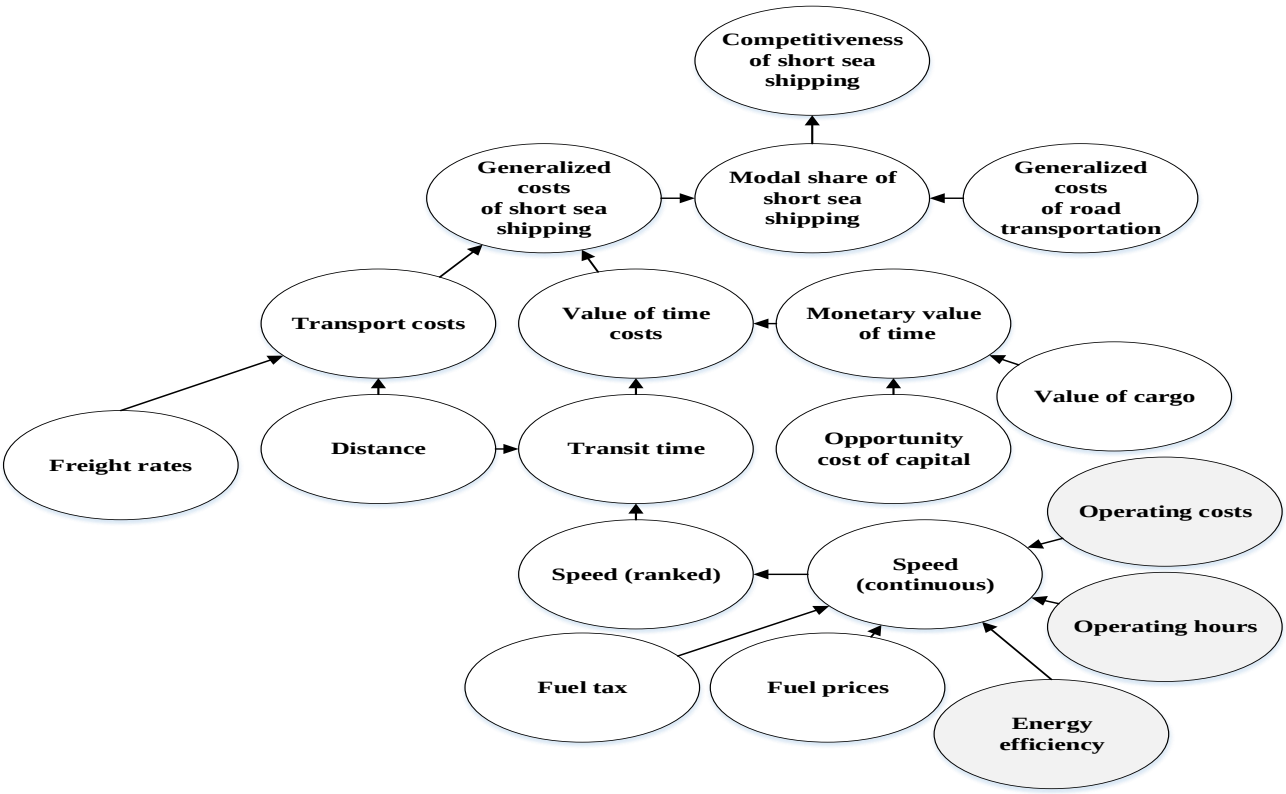
Modal share of short sea shipping	Generalized costs of short sea shipping	Generalized costs of road transportation
Low	Low	Low
Average	Average	Average
High	High	High

Source: Author's illustration based on Fenton and Neil (2012)

While defining the ranked nodes, it is important to ensure that there are no inconsistency issues regarding the scales. Tables 5 and 6 present this consistency requirement based on the ranked nodes used in the present BN model. For simplicity reasons, the SSS node is taken as ranked, which is formed by the ranked nodes of the *generalized costs of short sea shipping* and *road transportation*, respectively. Indicatively, with *low generalized costs for short sea shipping* and *high generalized costs for road transport*, there is *high share of short sea shipping*. It would be inconsistent to state that the *high* value of *short sea shipping share* is increased when using the *high* value of the generalized costs of both modes.

The inconsistency issues are addressed for all nodes of the BN model in the same way. Additionally, the nodes' *ship's annual operating costs*, *operating time at sea*, and *energy efficiency of a ship* are linked to constants. This approach means that these nodes do not require discretization. In this manner, significant efficiency savings are achieved when running the model (Fenton and Neil, 2012). These nodes are illustrated in grey color in Figure 4.

Figure 4: A Bayesian network model



The categories of modal share are assigned a certain probability value that depends on its parents. The model could have as its only output the modal share node. Nonetheless, for simplicity reasons, a new Boolean node—which exploits the underlying numerical scales of its parent node—is introduced that represents the competitiveness of SSS on the basis of the mode's modal share node. When the sum of the probability of the SSS's share values is smaller than 50%, then the competitiveness is defined as *low*. Thus, when the sum is equal to or exceeds 50%, the competitiveness is defined as *high*. As far as the NPTs are concerned, these are not defined manually but are based on expressions that are arithmetical or statistical. Table 7 presents the definition of the nodes that constitute the model.

Table 7: BN model node details

Node	Type	NPT and values
Freight rates	Ranked (high, medium, low)	Default (all value equal)
Distance	Ranked (high, medium, low)	Default (all value equal)
Transport costs	Ranked (high, medium, low)	*Weighted mean (wmean) (1.0 freight rates, 1.0 distance), variance: 5.0E-4*
Value of time costs	Ranked (high, medium, low)	*wmean (1.0 transit time, 1.0 monetary value of time), variance: 5.0E-4*
Transit time	Ranked (high, medium, low)	*wmean (1.0, Distance, 1.0 Speed (ranked)), variance: 5.0E-4*
Monetary value of time	Ranked (high, medium, low)	Default (all value equal)
Speed	Continuous (Simulation), range 6 to 30	Triangle (6 < optimal speed < 30)
Fuel prices	Continuous (Simulation), range 0–1000	Uniform
Fuel tax	Discrete real (0, 20, 40, 60, 80, 100, 200, 300, 400)	Default (all value equal)
Dummy variable for speed (invisible)	Continuous interval (6–15, 15–20, 20–30)	Arithmetic function equal to parent (speed)
Speed (ranked)	Ranked (low, medium, high)	One-to-one mapping of the interval states based on the dummy for speed
Generalized costs of short sea shipping	Ranked (high, medium, low)	*wmean (1.0 Transport costs, 1.0 Value of time), variance: 0.5*
Generalized costs of road transport	Ranked (low, medium, high)	Default (all value equal)

Table 7: BN model node details, Continued.

Modal share of short sea shipping	Ranked (lowest, very low, low, medium, high, very high, highest)	*wmean (1.0 Generalized costs of short sea shipping, 1.0 Generalized costs of road transport)*
Operating costs (OC)	Constant	Value of $\$1.51 \times 10^7$
Operating time	Constant	Value of 6,480 hours
Energy efficiency of ship	Constant	Value of 0.0012
Competitiveness of short sea shipping	Boolean	Comparative function (if<0.5, "Low competitiveness," "High competitiveness")

Source: Author's compilation based on Fenton and Neil (2012)

It needs to be pointed out that the dummy variable for speed is introduced in order to transform the continuous node into a ranked node. This approach benefits the analysis. In particular, Fenton et al. (2007) present that the approach of ranked nodes and its assignment of the NPTs produces acceptable results for practitioners. Thus, the usage of ranked nodes can benefit the construction of satisfactory models, especially for cases that require tailored approaches and/or large data sets. Moving on, the NPTs are defined through the application of a weighted mean function, following Fenton and Neil (2012) who highlight this function's sufficiency for generating an NPT for every ranked node that has ranked node parents. In the definition of NPTs, variance is important. In the present model, the assumption of a low variance is made for each weighted node (i.e., *5.0E-4*), except for the *generalized transport costs of short sea shipping*. As the construction of the model is based on existing literature, a high certainty is assumed. Nevertheless, since external costs are not included in the model, a variance of 0.5 is preferred for the weighted node of *generalized transport costs of SSS*.

Moving on to the explanation of the constant nodes, it is assumed that shipowners or shipping companies operate ships at their optimal speed in order to cope with associated costs. The optimal speed, which is used in the related node, is calculated following Kosmas and Acciaro (2017a), as:

$$\tilde{S}=\sqrt[3]{\frac{OC}{2*\rho*\lambda*(\mathrm{f}+\mathrm{TP})}},$$

and the values of the constants[9] are also taken from the same study, which followed Wang et al. (2015). The ranked node speed has three states, following the assumptions that speed in the 6–15 range is considered to be *low*, 15–20 is *medium*, and 20–30 is *high*. The nodes *speed* and *fuel prices* are defined as numerical simulation nodes in order to avoid static discretization issues. For the sake of this research, the author refers for the explanation of such issues to Fenton and Neil (2012). The *fuel prices* are assumed to be uniformly distributed and range from 0–1000 $/ton. The node of *generalized costs of road* is not expanded into its further components (i.e., value of time costs and transport costs). This approach is chosen for simplicity reasons first and due to the fact that the introduction of additional ranked nodes in the BN model can lead to a loss of accuracy (i.e., a wash out effect) second. However, further research can expand this node.

3.5. Main findings

3.5.1. Sensitivity analysis of the BN model

First, due to the absence of available datasets, this section looks into the influence of the model's nodes on the SSS's *competitiveness* on the basis of prior assumptions. Furthermore, 16 indicative scenarios are explored for illustration purposes. In order to investigate the level of SSS's competitiveness's change subject to each node of the model, a sensitivity analysis is performed through the AgenaRisk software. The analysis is conducted by following the principle of all things being equal. The nodes are assigned the prior probability values from Table 8 and, for each stage of the analysis, only a specific node is examined while the others are kept unchanged. The analysis is conducted for *opportunity cost of cargo*, *cargo value*, *freight rates*, *distance*, *levy costs*, and *fuel prices*. Figures 5 and 6 present the results. Figure 5 includes the results subject to *capital cost, cargo*

[9] A low energy efficiency is assumed as the age of the SSS's fleet is high. The operating costs assumed are toward the high end of the spectrum. Other, lower, values, found in Transport & Mobility Leuven and Nautical Enterprise (2010), have also been tested; no significant changes in the results of Figure 6 were witnessed.

value, *freight rates*, and *distance*, because these nodes are ranked. The horizontal axis moves from *high* to *low* values.

The results indicate that, when the values of *capital costs*, *cargo value*, *freight rates*, and *distance* change from *high* (base case for Figure 5) toward *low* while all other things remain equal, then the probability that SSS has a high competitiveness increases. Specifically, if the distance has a *low* value, then this probability increases by 5.2%. This finding needs further elaboration. The *distance* in the model does not refer to the actual distance between the origin and destination of a transportation case. It refers to the distance within the transport network of the shipping companies. Hence, shipping companies, if they rationalize their network by reducing their transportation distance, could benefit from the increase of the probability that SSS has a *high* competitiveness.

It is important to highlight that this result also relates to the assumption that the *generalized road transportation costs* are taken as exogenous. This means that *distance* does not enter into the discussion of the capability of the road sector to rationalize its transport network. Moving on, the results indicate that *capital costs* and *cargo value*, if their values move from *high* to *low*, would have the same high increase (1.7%) in the probability of the competitiveness. The results of the two nodes overlap, as illustrated in Figure 5. Last but not least, when the value of the *freight rates* change from *high* to *low*, a 3.4% increase of the probability that the SSS's competitiveness is *high* is expected.

Figure 5: Results of sensitivity analysis (1/2)

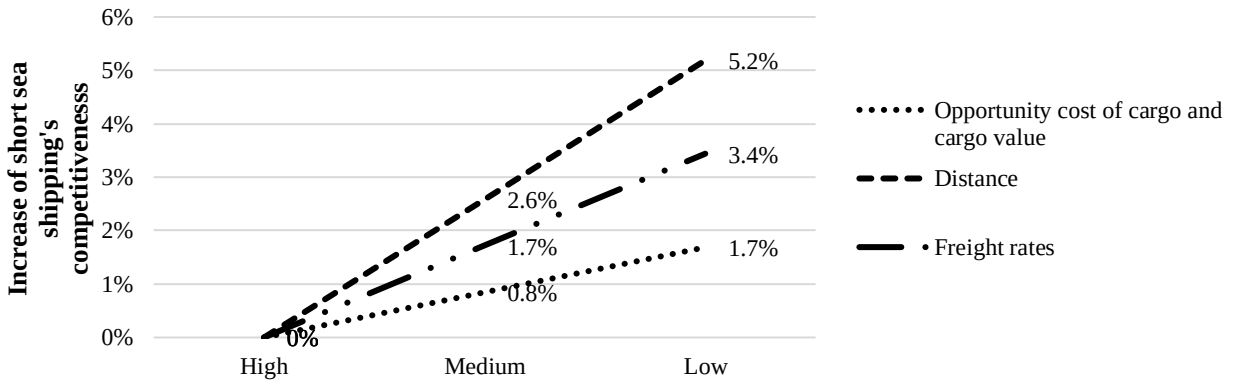
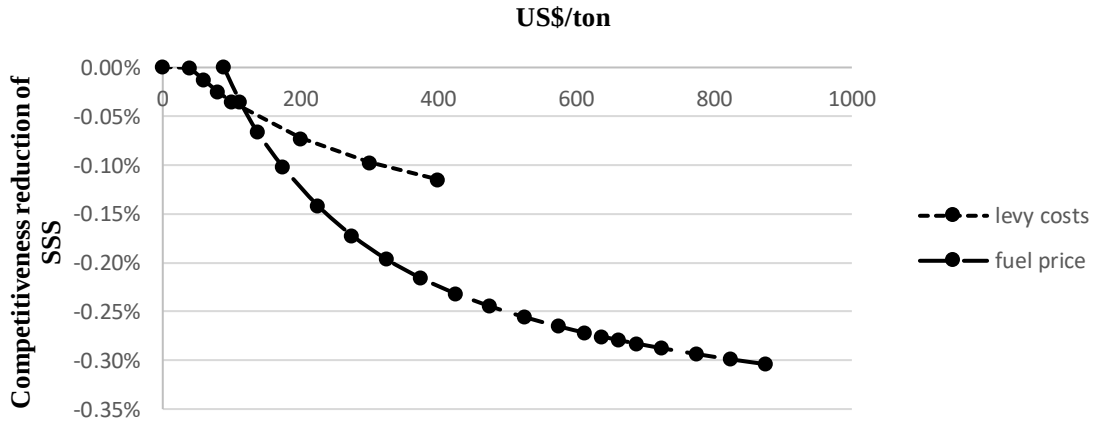


Figure 6 presents the results of the sensitivity analysis that was conducted to determine the impact of *fuel prices* and *fuel tax* on competitiveness. The absolute value of the impact on the probability of *SSS competitiveness* is significantly lower in comparison to the impact of *opportunity costs, cargo value, distance*, and *freight rates*. Moreover, an increase in *fuel prices* and the *fuel tax* amount leads to a decrease of a *high* SSS's *competitiveness* probability. Although both nodes have this negative influence, the *fuel prices* have a significantly higher impact than the *levy costs*. The findings present another two interesting facts. First, the reduction of the high competitiveness probability is not linear and, second—only for the present scenario and with all other things being equal—in order to experience a noticeable probability reduction of high competitiveness (i.e., 0.1%), the enforced tax amount should be high (i.e., 350 $/ton).

Figure 6: Results of sensitivity analysis (2/2)



3.5.2. Extreme values scenarios

The previous section examined the impact of certain nodes on the competitiveness of short sea shipping. The sensitivity analysis was conducted subject to initial assumptions and values that had been assigned while constructing the BN model. Therefore, this section now examines 16 scenarios to illustrate the implications of levy policy enforcement on the competitiveness of short sea shipping. The scenarios, which are described in Table 8, are used only for illustration purposes and focus on cases of extreme nodes' values. This means that the probability value of *high* is 100% and the probability value of *low* is 100%. Since the prior values of some nodes, which were used in section 3.5.1., had been assigned as 33.3%, this section looks into the implications of the policy in case of such extreme values.

Without loss of generality, in order to avoid examining a much greater number of scenarios due to the high number of possible combinations among all the nodes' values, the node *monetary value of time* is assigned directly the values of *high* or *low,* avoiding the examination of its parents. Another reason for following this approach is that the enforcement of a bunker levy scheme would not influence the monetary value of time. Nonetheless, future research could also examine scenarios by assigning values to the nodes of *opportunity cost of cargo* and *cargo value*.

Table 8: Scenarios for the Bayesian network model

Nr.	Freight rates	Distance	Monetary value of time	Generalized road transport costs
1	High	High	High	High
2	High	Low	High	High
3	High	Low	Low	High
4	High	High	Low	High
5	Low	High	High	High
6	Low	Low	High	High
7	Low	Low	Low	High
8	Low	High	Low	High
9	High	High	High	Low
10	High	Low	High	Low
11	High	Low	Low	Low
12	High	High	Low	Low
13	Low	High	High	Low
14	Low	Low	High	Low
15	Low	Low	Low	Low
16	Low	Low	High	Low

As far as *speed* and *fuel prices* are concerned, no values are assigned by the author. Their values, instead, follow the prior assumptions of the model. However, *speed* is influenced by the values of the levy when running the model. The first step in the analysis is to construct the possible combinations

of values. Consequently, a sensitivity analysis is performed for the *competitiveness of short sea shipping* with respect to the differentiated levy values for all scenarios. The sensitivity analysis is performed in order to obtain a prediction for the policy's implications and its results are illustrated in Figure 7. Since the illustration of the findings for all 16 scenarios and for all possible tax values would lack of clarity, only the results for tax prices of 100 US$/ton and 400 US$/ton are shown.

Figure 7: Reduction of short sea shipping's competitiveness for the scenarios (scenarios are presented from left to right)

As expected, a decline in the probability that SSS's competitiveness is "high" is observed for both levy values and for all scenarios. The numerical decline is aligned with the previous section's numerical results. In addition to confirming the expected decrease of the probability, two other noteworthy outcomes result. The first refers to the importance of the *generalized road transport costs of road* to the final impact of the levy enforcement. Particularly, as observed, if the *generalized road transport costs* are *high*, the probability of SSS's competitiveness being *high* decreases and is lower than when *generalized transport costs* are *low*. Furthermore, if the *generalized road transport costs* are *low* and the levy price is 100 US$/ton, then the probability decrease is closely similar to the case of a *high generalized road transport costs* with a levy amount of 400 US$/ton. The second interesting

outcome relates to scenario five, where the analysis indicates that there are no implications for the examined competitiveness independent of the levy prices for high *generalized transport costs*, low *freight rates* (for short sea shipping), high *distance*, and high *monetary value of time*.

3.5.3. Discussion and further research steps

The above analysis presented the impact of the influential factors on SSS's competitiveness. As could have been anticipated, the probability that SSS has a *high* competitiveness would decrease when fuel prices were high and the price of a levy was high. This decrease is more substantial for the bunker costs than the levy costs. A critical factor within the discussion of the policy's implications is the value of the generalized costs of road transportation as an SSS competitor and the level of levy price as well. Particularly, it is shown (Figure 7) that when the road costs are low and a low levy price is enforced, the SSS competitiveness could eventually experience a similar reduction to the high road costs and high levy price scenario. Thus, the level of the enforced tax could add significant pressure to short sea shipping companies even when they have the competitive cost advantage prior to the policy's implementation. Furthermore, depending on the level of various factors, there could also be cases in which a levy scheme would not lead to a decline of examined competitiveness.

In addition to the above, the results in Figure 7 deserve specific attention because they show the importance and level of influence of *freight rates*, *capital costs*, *cargo value*, and *distance* in determining short sea shipping's competitiveness. A noteworthy finding relates to distance reduction and its impact on the mode's competitiveness. SSS companies, by rationalizing their transport network and, hence, by reducing their distances, could eventually benefit and increase the probability of SSS's competitiveness being high. Moreover, the analysis presents the substantial importance of *freight rates*, a shipment's *capital costs*, and *cargo value*. In case of all other things being equal, *freight rates* have a higher impact on the probability of SSS competitiveness being high. Nevertheless, the impacts of *capital costs* and *cargo value* should not be neglected. These two factors play a critical role in SSS competitiveness because they influence the monetary value of time. The latter has always been a determinant element in the shipper's modal choice decision (NorthSEE, 2019). The importance of *capital costs* and *cargo value* gains even more weight as SSS has to cope with just-in-time delivery issues.

Overall, the enforcement of a bunker levy scheme would put financial pressure on the SSS sector. The author supports the suggestion by Kosmas and Acciaro (2017a) regarding the linkage of the bunker levy policy with a redistribution scheme, which would provide financial support to companies that seek the uptake of eco-friendly technologies. Financial support (i.e., subsidies) has often been provided to SSS companies by policy-makers, aiming to promote the mode's competitiveness in order to relieve road congestion. Subsidy programs are often critical for the mode's operations and their absence or finalization could even lead to the cancelation of shipping services, as was the case with the FRESMOS (2014–2019) program (CENIT, VITO, COWI, 2015). It is the author's opinion that policy-makers, when applying subsidy programs, should look into specific regions in which SSS could have a better environmental performance than its competitors. On the same note, the author also suggests that the establishment of subsidy programs is linked to the environmental performance of SSS companies. This means that, with respect to bunker levy scheme enforcement, policy-makers should provide additional financial support to companies that show an improvement in their environmental performance. Existing literature has argued about the significant improvement in the environmental performance of other transportation modes. For example, the road transportation mode can be a more sustainable option compared to SSS for the carriage of goods in certain cases. Nevertheless, in case SSS outperforms its competitor, policy-makers should not jeopardize its competitive advantage since the cargo shift to a less environmental friendly mode would lead to adverse effects (e.g. increase of CO_2, SO_X emissions). Therefore, policy-makers should also provide economic incentives—under the conditions that SSS increase their environmental performance—for promoting this mode of transport in regions where it would be feasible and environmentally beneficial for society.

Despite the interesting results of the analysis and the fact that the constructed BN model is the first of its kind in presenting the freight modal choice between short sea shipping and road transportation, it is still in its conceptual phase even though its approach is based on existing literature. Future research should try to validate the model either through data usage or on the basis of expert opinions. Using the latter is one of the main advantages of BN models in comparison to traditional statistical models. Similarly, such opinions can be incorporated to examine the policy's implications for real-life situations in specific trading regions. Moreover, the ranked nodes that are used in the present model could be transformed into continuous nodes. Future research should also aim at expanding the

model through the incorporation of other influential variables and the exploration of other possible linkages among the existing variables.

Another idea for future research is the possibility of expanding the model and, particularly, its development from static to dynamic. Briefly, an explanation of how this development could take place is given as follows: *Freight rates* are formed, without loss of generality, on the basis of the interaction between a *demand* for shipping services and a ships' *hauling capacity*. The *hauling capacity* would be chosen because it is determined by both the *supply* of shipping services (in metrics of ship's capacity) and the *sailing speed* that varies depending on *fuel prices*. Then, the calculated *modal share of short sea shipping* in the static model would be considered as the *demand* in the dynamic model. This link would allow for examination of the policy's impacts in future stages.

3.6. Conclusion

The IMO has only very recently reached an agreement for the decarbonization of the shipping industry. The enforcement of a bunker levy scheme, as a potential emission abatement measure, is currently debated at the policy-making level. Despite the appealing character of this MBM and the arguments that could push shipowners and companies toward investing in environmentally friendly technologies, the possible negative implications of this policy are still underexplored. Moreover, the international community needs to take also into account the influence of other factors (e.g. freight rates, cargo value) that could determine the policy's implications and their extent on the competitiveness of the SSS sector. Therefore, this article had as aim to shed light into these issues.

The article followed the generalized cost approach and constructed a Bayesian Network model, thus differentiating itself from existing transportation modelling studies that measure the modal split and compare the SSS and road transport modes. Had a traditional discrete econometric choice approach been followed, this would require large datasets for measuring the implications of the other factors that could have an impact on SSS sector's competitiveness. Therefore, a conceptual modal split model by means of the Bayesian Network methodology was developed. The BN model was used to analyze different scenarios. A sensitivity analysis was additionally carried out in order to identify the effects of various factors, including fuel volatility and levy costs, in the underlying examined modal split, and the competitiveness of short sea shipping. As expected, bunker levy scheme enforcement and

high bunker prices would result in a decline of the probability that the competitiveness of short sea shipping is high. An important finding of the study relates to the importance of generalized costs of road transportation in determining the competitiveness under study. Furthermore, the enforcement of a high bunker levy could eventually result in the decrease of short sea shipping's competitiveness even in cases when this mode has a prior competitive cost advantage over the road one. The possibility that the policy may not have an impact cannot be excluded for certain conditions. The importance of distance within the analysis cannot be neglected. In particular, when shipping companies rationalize their transport network and reduce their distances, then the probability that short sea shipping has a high competitiveness would increase.

Following existing literature, the present article is the first of its kind in examining these specific implications of this potential environmental policy. Given the policy-making discussion related to the promotion of SSS and the concern that environmental policies might swift more cargo from sea to road, this study by exploiting the strength of the BN methodology, showed that the SSS related factors of distance, freight rates, cargo value and capital costs, but also the factor of generalized road transport costs play a determinant role on the sector's competitiveness and on the extent of the levy's implications.

Albeit the insightful results of this research, future research should aim at investigating the levy's implications on SSS competitiveness vis-à-vis other transport modes by means of real data sets application and expert opinions—this was the main limitation of the present article despite the capability of the BN model in dealing with absence of data. Future studies can also relate to the examination of alternative levy schemes or other market-based measures. It is imperative that the academic community sheds light on possible implications that policies might have for the shipping sector, thus adding value to the global debate. Since the launch of the IMO emission strategy, discussions for the appropriateness of various potential policies in achieving the shipping sector's decarbonization have intensified. In order to meet emission reduction targets within given time-frames set by the international community, urgent actions are required.

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Chapter 4

Maritime search and rescue operational response to migration

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Abstract

Economic, social, and environmental reasons have pushed many people around the world to migrate. In effort to cross sea borders, many of them lose their lives. The Mediterranean Sea and the Rohingya cases are characteristic examples. This article looks at search and rescue (SAR) operations linked to migration by sea (MBS) with the aim to improve its operational effectiveness. It builds a theoretical framework based on the literature and on interviews with 25 stakeholders involved in the Mediterranean Sea crisis. This framework presents the factors affecting operational effectiveness and their interactions. The identified stakeholders are: the migrants, illegal networks, humanitarian organizations, security forces, shipping companies, general public, media, and the lobby groups opposing migration. The recent Mediterranean migration flows are used as a case study to validate and update the framework. At an operational level, beyond the challenges of asset availability and capability, cooperation and coordination should be enhanced through resources and information-sharing for increasing operational effectiveness. Nonetheless, the discrepancies in stakeholders' missions and mandates act as a barrier.

Keywords: *Operational effectiveness, migration by sea (MBS), search and rescue (SAR), Mediterranean Sea crisis*.

4.1. Introduction

Globally, the number of forcibly displaced people reached its peak, approximately 65.6 million individuals, in 2016 (United Nations High Commissioner for Refugees [UNHCR], 2017a). According to UNHCR, this number—which mainly includes asylum seekers, refugees, and internally displaced people—is driven, predominantly, by various forms of generalized violence, and human rights violations. A large portion of these people at some point in their migration journeys find themselves at sea. Migration[10] by sea (MBS) is a particularly current example of migratory flows, whose urgency and complexity are exacerbated by the conditions under which people attempt sea crossings, risking their lives. Representative cases are the ongoing movement of both Rohingya (UNHCR, 2017b) and Bangladeshi (UNHCR, 2015a) migrants across the Bay of Bengal and the Andaman Sea (UNHCR, 2015b; Chatterjee, 2016) and the Mediterranean Sea migration crisis that peaked in 2015 and 2016 with over one million people reaching Europe (UNHCR, 2018).

The international community has called for a humanitarian response to mitigate the negative effects associated with migration flows at sea—primarily, avoidance of the loss of life. The maritime humanitarian response was carried out by a wide array of entities and institutions. For instance, in the case of the Bay of Bengal crisis, the need for search and rescue (SAR) operations and cooperation among all stakeholders involved was called upon not only by the humanitarian organizations (HOs) concerned (Catrambone, R., 2017), but also by India, Bangladesh, and Malaysia, among other countries (Ministry of Foreign Affairs of the Kingdom of Thailand, 2015). Humanitarian response was carried out in the Mediterranean Sea case through the involvement in SAR operations by HOs such as Doctors without Borders (MSF) and SOS Méditerranée. National coast guards—e.g., the Italian navy with their "Mare Nostrum" operation, the participants of the European naval security operation "Sophia," and the European border control agency FRONTEX—have also conducted SAR operations in the Mediterranean in conformity with their mandates. So have a large number of commercial ships, especially at the beginning of the crisis, in accordance with international maritime law provisions under the 1974 International Convention for the Safety of Life at Sea (SOLAS) (IMO, 2014) and the 1979 SAR Convention (IMO, 2006).

[10] The term "migration" is used in the paper to refer to the movement of people, irrespective of distance, motivation, and composition (International Organization for Migration [IOM], 2018a).

To date, literature on SAR has mostly focused on the allocation of various resources for specific operational procedures—e.g., Razi and Karatas (2016), Basdemir (2000)—whereas studies on MBS ingeneral and the Mediterranean Sea case, specifically, have concentrated on diverse aspects, such as genetic identification of shipwreck victims (Pallister and Wilkins, 2016), touristic impact (Pappas and Papatheodorou, 2017), and HOs' involvement (Cusumano, 2017, 2018). Only the last two articles can be related to this research, as they argue that policy-makers' (PMs) actions for reducing the flows in the Central Mediterranean Sea can threaten the Non-governmental organizations (NGOs)'s operations and their principles.

The present study, which deals with SAR operations management at sea and focuses on migration, differs from the existing literature because it explores the dynamics among all stakeholders involved in SAR in the context of MBS and describes the constant changing environment within which those stakeholders operate. An exploratory research approach is proposed due to the limited existing literature (Fisher, 2007), through the collection of primary data from participants in response operations associated to migration movements. The study has the operational effectiveness of the SAR mechanism as a unit of analysis and is centered on the Mediterranean Sea case. This geographical focus is justified by the fact that this crisis reflects the operational complexity of MBS, the involvement of multiple stakeholders, and a high rate of incidents related to life loss at sea. As a result, the following questions are addressed: (1) What stakeholders are involved in the maritime SAR operations in the MBS context with respect to disaster management? (2) How do their actions impact SAR operational effectiveness? (3) What additional factors need to be taken into account for enhancing SAR operational effectiveness in the MBS context?

The paper's contribution is threefold. On the one hand, it expands the scientific humanitarian disaster management literature toward the new and unexplored areas of SAR and disaster operations in the MBS context through its theory advancement. Furthermore, suggestions in line with theory development are derived and directions for future studies in operations management (OM) in this context are also provided. On the other hand, the analysis presented in this study advances the understanding of SAR operations in the MBS context and provides recommendations, leading to better disaster management through enhanced SAR operational effectiveness. Consequently, this study benefits PMs, governments, governmental and non-governmental institutions, as well as private

companies and HOs that are the main engaged stakeholders in the crisis, by offering a clear theoretical framework to be used for planning and assessing operational responses to MBS emergencies.

The paper comprises of seven sections. Section 4.1. introduces the study and section 4.2. provides the connection between disaster management and SAR literature. The system under study and the preliminary theoretical framework are presented in section 4.3. In section 4.4., the research design and the data collection and analysis methodology are discussed. Section 4.5. presents the Mediterranean Sea case. This is followed by the main findings and the updated theoretical framework based on primary data collected by the stakeholders involved in the Mediterranean Sea crisis in section 4.6. Section 4.7. concludes the paper, outlines its summary and limitations, and suggests directions for further research.

4.2. Disasters and SAR operations management context

The high number of disasters witnessed thus far worldwide (Guha-Sapir et al., 2017) has attracted the attention of the scientific community. Particularly, academics and emergency management practitioners have turned their focus to the area of humanitarian rescue and relief (Apte, 2010; Sheu, 2007). Disaster management involves multiple stakeholders with, often, diverse goals. This may result in coordination and collaboration challenges within a dynamic and resource-restrained operational environment in which information, despite its availability, might lack reliability (Kovács and Spens, 2007; Van Wassenhove, 2006). In terms of the supply chain, various sources of uncertainty—which could be the uncertain nature (when and where it will strike) and impact of a disaster, the donor-provided financial aid, the supply of relief items, etc.—constitute another challenge that hinders operational effectiveness.

The disaster supply chain can also be affected by policy-makers, i.e., governments, due to their economic and political control (Thomas and Fritz, 2006), which evident in the accessibility of the affected population (Long and Wood, 1995). Governments, through response organizations, are traditionally involved in all disaster management phases either through mitigation activities or action coordination during the preparedness, response, and recovery stages (Duran et al., 2013). Involvement within all phases can also be witnessed from domestic and international HOs (Duran et al., 2013), who work intensively during and in-between the disasters if needed (Van Wassenhove,

2006). Involvement in disasters by security forces (SFs) is also seen, primarily through military operations (either national or international), whose role has evolved from protection provision to humanitarian assistance (Rietjens et al., 2007) over the years.

Moving on to SAR literature, it primarily follows an assets allocation approach. For instance, Afshartous et al. (2009) highlight the importance of modeling uncertainty to determine a robust location of the U.S. Coast Guard air stations. Abi-Zeid and Frost (2005) develop a SAR geographic decision support planning model for the Canadian Forces. Razi and Karatas (2016) construct an optimization model for boat allocation by considering various criteria, e.g. incidents' density and severity, while having as one of their objectives the minimization of the response time. On the same note, Basdemir (2000) deals with SAR helicopter allocation for a predefined demand. Pelot et al. (2015) focus on the allocation of the Canadian coast guard vessels, categorizing those assets and the incidents depending on their capabilities and severity, respectively. Last but not least, and in relation to the present research, the papers by Cusumano (2017, 2018) argue that the code of conduct (CoC) imposed by the Italian authorities on NGOs for regulating their operations can hinder their activities, while the European Union (EU)'s support to the Libyan coast guard as a means of tackling the high influx of migrants can jeopardize the NGOs' principle of humanitarianism.

The identified context highlights the complexities and challenges—which range from the diversity of the stakeholders' mandates and missions to the role of resources and funding—that shape disaster management operations. Despite the existence of SAR literature, the relation of operational effectiveness to MBS has not yet been addressed. The present study expands the existing literature by exploring operational responses to MBS, identifying their dynamics, and capturing the factors that define SAR operational effectiveness. As there is no other similar study, the existing literature works only as the basis for the construction of the preliminary theoretical framework, which is subsequently tested and updated following data analysis that reflects the reality stakeholders face.

4.3. System under study and a preliminary theoretical framework

This section outlines the system under study, which is that of SAR in the MBS context, and describes the paper's preliminary theoretical framework. This includes a taxonomy of stakeholders and their involvement in the crisis. SAR operational effectiveness depends on the number of rescued migrants

and their numbers in attempting sea crossings. Operational effectiveness in this context is defined as a ratio of these two values.

4.3.1. The migration by sea system

Migrants (Ms) undertake a journey to reach their intended destination. When at least one sea crossing is a part of their journey, this can be referred as MBS. The system, which is illustrated in Figure 8, is defined from the point when migrants embark on boats until their disembarkation on land or loss of life occurrence.

The MBS stakeholders are listed in Table 9. They have potentially differing goals that are derived from their mandates, missions, or objectives and that are reflected in the operations they undertake.

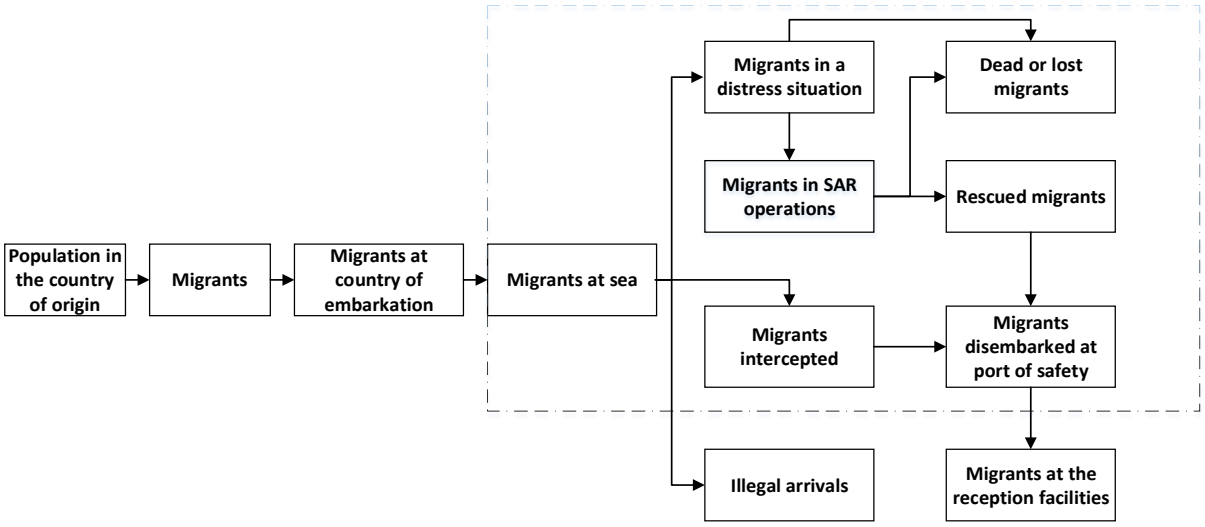
Table 9: The involved stakeholders, their goals, and operations

Stakeholders	Goals	Operations
Migrants (Ms)	Reaching intended destination	Sea crossings
Illegal networks (INs)	Maximization of profit (exploiting the "need" of Ms)	Facilitation of irregular sea crossings
Security forces (SFs)	Prevention of illegal activities	Tackling illegal activities (anti-smuggling and anti-trafficking) and SAR
Humanitarian organizations (HOs)	Provision of humanitarian aid (directly or through implementing partners)	SAR
Commercial shipping companies (CSCs)	Minimization of financial loss (commercial character)	SAR (obligation by international maritime law)

At the beginning of this system there is a number of Ms attempting sea crossings. These crossings can have differentiated progressions and outcomes. The first is the occurrence of a situation in distress at sea, for which international maritime law mandates the provision of rescue assistance. In case the emergency is noticed, SAR operations are conducted by SFs, HOs, and CSCs. At the end of the SAR activities, there is a number of rescued Ms and a number of dead or missing Ms. The SAR event is

considered to be terminated when the rescued, both in national and international waters, have disembarked at a port of safety[11] and have subsequently been transferred to reception facilities.[12] Nevertheless, if the distress situation is not noticed, then the outcome is either missing Ms or the life loss of Ms. The second alternative refers to the interception[13] of these flows by the SFs. Those Ms are then disembarked at a port of safety and, subsequently, transferred to the reception facilities. The flows that do not fall into the above categories represent a third possible outcome—illegal arrivals.

Figure 8: The migration by sea (MBS) system (dotted line indicates the system under study)



4.3.2. A preliminary theoretical framework

The theoretical framework is illustrated in Figure 9 and consists of the factors that affect the MBS system and their interactions. These factors derive from the stakeholders involved and refer to their goals (i.e., mandates, missions, or objectives), resources, and expertise in the SAR activities' context. Operational resources range from the competence of the deployed assets—in terms of capacity, SAR capability, technology, equipment, supplies, number of crew members—to information availability

[11] According to the SAR Convention, the port of safety is the place at which SAR operations are terminated, having as their basic characteristic the insurance of life-safety of the rescued people (IMO, 2006).
[12] The relocation and operation at the reception facilities fall outside of the paper's scope because we focus on SAR operations, which are considered to be terminated as soon the rescued people disembark at a port of safety.
[13] The interception is not always followed by a SAR operation. This can be seen, for example, in the Australian case (Larking, 2017) in contrast to the Mediterranean Sea case.

and funding, while expertise relates to the competence of the stakeholders for SAR operations. The dynamics and interaction effects of those factors translate into the determination of the operational effectiveness of the overall SAR mechanism. In case this ratio is increased, affected by the theoretical framework's factors, a SAR operational effectiveness enhancement is implied. Following Baxter and Jack (2008), the framework continues to develop as the study progresses in accordance with the identification of additional factors and their interaction effects.

Despite the fact that each stakeholder is involved in MBS, only certain attributes—incorporated in the SAR environment—define the theoretical framework because the unit of analysis is SAR operational effectiveness. A brief description of the stakeholders involved in crises, as well as their distinct role in SAR activities, is provided below:

Ms: By pursuing their own individual journey, Ms collectively aim to reach their destination. Their resources affect SAR operational effectiveness (United Nations Office on Drugs and Crime [UNODC], 2011). This can be seen, for instance, when financial resources are able to afford them access to better vessels, safety equipment, or a position above a vessel's deck, enhancing their chances of survival.

INs: They include smugglers and traffickers who enable and facilitate—by providing resources such as boats and equipment to the migrants—the Ms crossings. The deployment of resources such as equipment, assets, information, etc., and their expertise (Europol–Interpol, 2016) also influences the number and outcome of crossings.

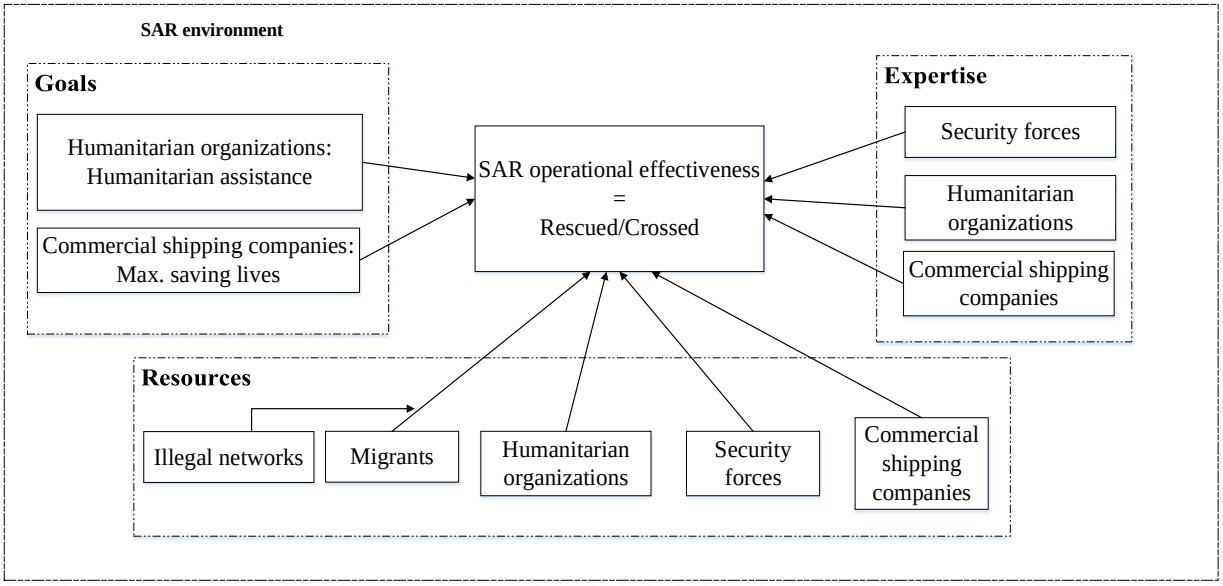
SFs: They respond primarily to illegal activities, consequently affecting the number of crossings (UNODC, 2011). As far as operations at sea are concerned, the SFs under the international maritime law provisions are obliged to assist people in distress and, hence, the deployed resources act as capacity for their SAR activities, affecting operational effectiveness. SAR operational effectiveness is influenced by the SFs' expertise, whose crew is required, under maritime law, to be trained for SAR.

HOs: Their missions are to provide humanitarian assistance. The HOs' involvement at sea is carried out through their direct involvement in SAR operations (Cusumano, 2017). It is important to clarify

that the mandates of HOs are the provision of assistance to people in distress and *not* the facilitation of the crossings. The HOs' resources (e.g., crew, assets, funding) and expertise affect SAR effectiveness (Cusumano, 2018).

CSCs: Due to the business character of these stakeholder, their engagement in SAR operations can reduce their profitability by imposing certain expenses (North Protecting and Indemnity [P&I] Club, 2016). It would be expected that commercial ships would try to avoid involvement in SAR activities as a result, fearing financial losses. This has not been a common behavior for them, notwithstanding a few isolated undocumented cases. Their involvement probably resulted from a moral and legal obligation as well as the long-standing maritime tradition of providing assistance to people in distress at sea (Papanicolopulu, 2016). All in all, their primary pursuit—profit—is subordinate to saving lives at sea. Hence, they can also act as available SAR resources. Furthermore, seafarers are required to have the basic expertise necessary for assisting people in distress. In line with this requirement, SAR operational effectiveness relates to their resources and expertise (IMO, 2006).

Figure 9: Preliminary theoretical framework



It has been argued that an increase in SAR effectiveness acts as a pull factor for the Ms, leading to an increase in the number of crossings. This view supports that Ms, by noticing the better chances of

survival through previous successful SAR operations at sea conducted by the involved stakeholders, would continue attempting life-threating sea crossings (FRONTEX, 2017). This aspect is also explored in the analysis of the manuscript.

4.4. Research design

4.4.1. Research methodology

The research method at the basis of this article is one of an inductive case study that can be used to create theory when none or limited previous constructs exist (Eisenhart, 1989; Gersick, 1988; Yin, 2014). The specific case study methodology is chosen because it allows for an examination of events and for dealing with heterogeneous evidence—e.g., documents and interviews (Yin, 2014; McCutcheon and Meredith, 1993). The case study developed in this paper is exploratory and has SAR operational effectiveness as a unit of analysis (Yin, 2014).

The research questions and the preliminary theoretical framework are defined here based on the literature, interactions with experts, and knowledge derived through participation in conferences, forums, and academic programs focusing on SAR operations linked with MBS. Specifically, two of the authors have participated as experts in a plenary session titled “Rescue at sea,” which was held as a paneled debate at the 2016 International Association Maritime Economists (IAME) conference. In this session, the interaction with other academics and practitioners provided additional insights into the legal, humanitarian, operational, and logistical complexity of responses related to migration crises. The non-presenting attendance to the Forums “SHAred Awareness and DE-confliction in the MEDiterranean Sea (SHADE MED)” (3rd, 4th, and 5th edition), organized by the European Naval Force in the Mediterranean (EUNAFOR MED) operation “Sophia,” contributed to the primary understanding of naval and on-shore operational activities associated with the Mediterranean Sea case. The majority of the parties represented at the Forums were involved in this specific crisis, including naval SFs, HOs, and CSCs associations, while academics represented the minority. Furthermore, the paper has benefitted from interaction with the participants of the academic course “Migration and Human Rights” organized by the United Nations Interregional Crime and Justice Research Institute, during which policy and legal aspects related to displacement crises, as well as initiatives for long-term humanitarian development, were discussed and analyzed.

The participation in these events acted as an instrument for capturing the picture associated with the overall complexity of and operational response in this MBS crisis. In combination with the literature review, it guided the definition of the system under study, the development of the preliminary theoretical framework, and the justification of the data sampling used for the analysis in the manuscript.

4.4.2. Data collection

It is imperative to connect the previous literature and the authors' experiences to empirical evidence for theory development (Glaser and Strauss, 1967). The analysis of the research conducted is based on the collection of primary and secondary data. Due to the paper's exploratory character, the actors' experiences and contexts are important (Bonoma, 1985). The primary data were collected through semi-structured interviews conducted with stakeholders associated with the operational response to migration flows and SAR activities. The data sample was chosen based on the authors' participation in the Forums, academic program, and conference, as described in section 4.4.1. In particular, interviews were held with: a) the HOs involved in the migration crisis and/or conducting SAR operations, b) the CSCs associations representing their members, c) the SFs experts, d) the navy and coast guard experts, e) the policy experts, and f) the migrants. As far as the interviews with the migrants at reception facilities and with the national coast guard are concerned, official permissions were granted by the corresponding national ministries and one of the authors visited the base facilities personally. Furthermore, an interview with a CSC association was also conducted in person.

The interviews were conducted between September 2017 and August 2018. An introductory letter about the project was sent to potential respondents by email or other electronic means. The letter described the project, the scope and aim of the research, and offered the option of answering the questionnaire in written form, via phone, or by analogous means. At the beginning of the interview period, the base questionnaire was not included with the first communication and the response rate was low, which led to multiple reminders. As some potential interviewees requested the base questionnaire before confirming their participation, we decided to attach the base questionnaire to our initial letter for the other potential respondents selected in order to obtain a higher response rate and eliminate extra correspondence exchange. This procedure was followed for each participant, except for the migrants. In their case, the letter and the base questionnaire were sent to the responsible

ministry for permission and approval in order to enter the reception facilities and conduct the interviews.

For each stakeholder, a slightly different questionnaire was used, as presented in Appendix A. Qualitative data was retrieved through semi-structured questions, which generally focused on the involvement of each actor in the migration crisis, the SAR response, the operational and logistical challenges, and suggestions for short- and long-term solutions. In total, the number of participants in the interviews was 26. Nevertheless, as one migrant did not sign the consent form that we provided—which secured anonymity of the migrants and ensured that their data and information is used only for the purpose of this study and is not shared with other parties—because this individual had fears that his signature would be used for other purposes, the authors excluded this participant from the sample. Hence, the information used for the analysis is based on the other remaining 25 interviewees. From 25 participants, we received 7 interviews in written format, 9 were conducted via Skype or phone calls, and 9 in person.

All the interviews were recorded with the participants' permission, except for those with the migrants—as recording was prohibited within the reception facilities. For these cases, notes were taken by the interviewing author. After the completion of the interviews, these notes were transferred into an electronic format. Two migrants were interviewed individually and others in groups of two and three participants, respectively, due to the time constraints imposed by the authorities at the reception facilities. Anonymity was offered to all participants, although this appeared to be fully necessary only for one interviewee and for another one in case of quotations. Moreover, two interviewees expressed their personal experiences and opinions without representing official organizational position. Given the sensitivity of the research subject, the names and affiliations of the interviewees are not disclosed. The number, the organizations, and the participants of the interviews are described in Table 10.

Table 10: Details of the interviewees

No.	Organizations	Positions
8	HOs conducting SAR	camp coordinator/crew member, maritime manager, crew member/office administrator, head of mission, senior humanitarian advisor, medical doctor/former volunteer, volunteer, public relations office coordinator
3	HOs involved in global displacement crises	senior public information associate and senior supply officer: both based at a reception country, human rights officer: based at an embarkation country
7	Migrants	within reception facilities
2	SFs	national coast guard involved in SAR, medical doctor in the navy involved in SAR
3	CSCs' associations	press (media) officer, senior adviser, senior marine adviser
1	Policy/legal expert	former volunteer in two HOs that conducted SAR
1	Security expert	retired navy officer/ professor of security studies

The average duration of an interview was sixty minutes. The recordings were transcribed and sent back to the participants for approval. The study also required the collection of secondary data, primarily from published reports, studies, and websites from stakeholders linked to the crisis—e.g., IOM, UNHCR, FRONTEX, Europol, and the International Chamber of Shipping (ICS), etc.

4.4.3. Data analysis method

The usage of open-ended questions was preferred for the interview process as qualitative information may be disclosed and unexpected interactions may occur (Eisenhardt, 1989). The collected data and information were used for writing the case, selected for the analysis in order to explore evolving operational patterns and procedures that aim inductively at new theory development, following the exploratory character of this research (Benbasat et al., 1987). The data sample can be considered as adequate based on previous methodological literature—e.g., 12 to 60 interviews are suggested by Adler and Adler (2012), while Sandelowski (1995) argues that the determination of an adequate sample is based on the authors' judgement. Defining the appropriate data sample is always a challenge

because smaller samples can miss key aspects, while larger ones face the difficulty of managing excessive information (Ritchie et al., 2013). This study follows the principle that sample adequacy is ensured when data saturation is observed (Guest et al., 2006). Saturation was established in the present data analysis, as no new concepts emerged after a specific number of interviews. In order to add more value to the data analysis, specific patterns were explored through a keyword search on the basis of the preliminary framework, including words such as "*capacity*," "*resources*," "*expertise*," etc., in order to observe repetitions across interviews (Eisenhardt and Graebner, 2007). The analysis revealed additional concepts and causal effects that determine SAR operational effectiveness.

4.5. The Mediterranean Sea case

This part of the manuscript presents the case study explored. The first subsection introduces and provides an overview of the Mediterranean Sea crisis. Subsection 4.5.2. includes the maritime operational response of the various involved stakeholders. Last but not least, subsection 4.5.3. presents the interview findings by identifying the operational challenges and the reality the stakeholders face.

4.5.1. Humanitarian crisis

Europe is the desired destination for multiple Ms attempting to cross the Mediterranean Sea. The drivers for their migratory movements vary—e.g., inequality, poverty, political instability (UNHCR, 2015c), as well as escaping war and persecution (UNHCR, 2015d). They often undertake erratic trips throughout their endeavored journey, either escaping from the countries that they initially fled to or resulting from poor reception facilities, long-delayed refugee status determination and resettlement processes, and family reunification reasons as well (UNHCR, 2017c). The absence of legal pathways is the catalyst of smuggling networks deployment by Ms (UNHCR, 2015c), with approximately 80% of Ms crossing from Africa having turned to smugglers and criminal groups (Reitano, 2014) at a high human and social cost, often in life-threatening conditions (UNHCR, 2015c). As danger exists during the entire journey, within Europe also (UNHCR, 2017d), Ms often become victims of human

trafficking[14] and experience abuses—e.g., murders, sexual violence, forced labor, etc. (UNHCR, 2017c). Attempts by the authorities to prevent the illegal actions of these criminal groups is challenging because they can adapt to increased controls (Europol-Interpol) making their dismantling complex (Aziz et al., 2015).

Smugglers' behavior and certain external factors, e.g. weather and border control practices (Europol-Interpol, 2016), can result in variations of migratory routes. Nevertheless, the main Mediterranean Sea routes deployed are (IOM, 2017): 1) the Eastern, from Turkey to Greece, 2) the Central, mostly from Libya to Italy, and 3) the Western, from Morocco to Spain. The sea crossings are conducted using unseaworthy wooden boats or inflatable rubber dinghies. During the sea trips, the Ms can be intercepted or rescued mainly by European authorities, HOs, and CSCs under the coordination of a responsible Maritime Rescue Coordination Center (MRCC). Then, the Ms should disembark at a place of safety, from whence they are transferred to reception facilities for their status and international protection application examination. Regardless of the Ms' aspiration to reach Northern Europe using countries of arrival as transit points, the European Union's Dublin regulations mandate their return to the country of entry to apply for international protection (European Parliament, Council of the European Union, 2013). This imposes pressure on the southern European border countries, e.g., Greece and Italy, which have consequently requested burden-sharing.[15]

The migration influx of 2015, with 1,046,599 total Ms arrivals (IOM, 2016), reached a record high, surpassing the 2011 record known as "Arab Spring" (FRONTEX, 2016). In 2016, the flows decreased to 387,739 Ms (IOM, 2017a). Specifically, a significant decline was observed on the Eastern route after the EU–Turkey deal[16] of 18 March 2016 (UNHCR, 2017e), which lead to the establishment of the Central Mediterranean as the major entry point for Ms into Europe with the majority of flows departing from Libya (UNHCR, 2017e). The EU supports similar schemes with other countries, such as Libya, aiming for flow reduction despite their questionable legal and moral basis (OXFAM, 2017).

[14] Smuggling and trafficking are phenomena, frequently believed to be identical. Nevertheless, the main distinction is the feature of consent. For the former, it exists between the smuggled person and the smuggler for the migration process; this relationship with the smuggler ends after the completion of the journey. For the latter, there is lack of consent and the person becomes a victim of exploitation. Globally, smuggling and trafficking are two of the most profitable and proliferate illegal businesses (UNODC, 2010).

[15] A better and more robust resolution of the crises might be achieved through collective efforts and not individual actions by nation states (Suhrke, 1998).

[16] Migrants having arrived at the Greek islands are deported to Turkey (European Council, 2016).

Additional political involvement is evident through the EU's restrictions and the ban on the supply of inflatable boats to Libya—but the effectiveness of this measure is doubted (Bershidsky, 2017). Despite these efforts and the decline of the flows, the deaths or incidents of missing Ms at sea remained high, with 2016 being the year (UNHCR, 2016) with the highest number of deaths, approximately 5,096 (UNHCR, 2018). In 2017, the flows decreased further. Nonetheless, the number of life losses—3,139—remained high and the ratio between the dead and the missing at sea increased in comparison to 2015 (UNHCR, 2018). In 2018, probably after increased involvement of the Libyan coast guard in SAR operations, the flows have switched toward the Western Sea route, with Spain becoming the main entry point for that period (UNHCR, 2018). In general, reducing the flows and tackling the drownings may have a conflicting correlation, because the closure of a shorter route can cause a switch to longer and more perilous routes (IOM, 2017b).

4.5.2. Maritime operational response in the Mediterranean Sea

In October 2013, a shipwreck off of Lampedusa claimed 350 lives (United Nations News, 2013), triggering the first appearance of official maritime response, with Italy launching the "Mare Nostrum," a naval security and humanitarian SAR operation (Ministero Della Difesa, n.d.). It lasted for one year but was terminated due to the lack of burden-sharing by other EU member states with Italy (Cusumano, 2017). Since its termination, FRONTEX has been launching border surveillance and security operations (European Commission, 2016) in the Mediterranean Sea. Despite the inclusion of SAR in their mandates, operation "Triton" in the Central Mediterranean received particular criticism by Amnesty International (2015) because the assets are not deployed in high seas, where the majority of the drownings occur. In 2015, the EU set in motion the "EUNAFOR Med Operation Sophia" in the Central Mediterranean. Its mandate has been amended over the years, aiming at surveillance, tackling human trafficking and smuggling networks, SAR, destruction of the vessels deployed by the traffickers, training provision to the Libyan coast guard and navy, assessment of illegal oil export activities from Libya, and information-sharing with FRONTEX and Europol (European Council, 2017). Another response came from the North Atlantic Treaty Organization (NATO), with the operation "Sea Guardian" in the Eastern route, aiming at countering terrorism, maritime situational awareness support, and capacity-building (NATO, 2016). Moreover, the response of the involved countries cannot be excluded. Representatively, beyond the launching of the

naval counter-piracy and surveillance operation "Mare Sicuro" by Italy following the "Mare Nostrum," national coast guards have accounted for SAR as indicated by their mandates.

Lampedusa's shipwreck was also the starting point for HOs' involvement at sea, having entirely humanitarian SAR operational mandates. The majority of HOs' presence at sea is witnessed in the Central and Eastern Mediterranean, where the majority of crossings and drownings occur. Representatively, the engaged HOs have been Sea-Watch, Migrant Offshore Aid Station (MOAS), Sea-Eye, Proactiva Open Arms, Jugend Rettet, Life Boat, MSF, Save the Children, Boat Refugee and SOS Méditerranée, Maydayterraneo, FEOX, EMCRI, etc. These HOs can be split into two categories: the first includes HOs that provide SAR operations and the second consists of *search and secure* cases. SAR operations refer to cases in which the vessel in distress is approached, secured, and the survivors are transshipped to the place of safety. The search and secure refers to the cases in which the transshipment cannot be done by the existing rescue boat and help is provided by larger vessels called to the incident location. A turning point in HOs' involvement at the Central Mediterranean has been the enforcement of the CoC by the Italian government for regulating their activities, which was also supported by the European Union (Cusumano, 2017). The CoC has been negatively criticized (United Nations International Children's Emergency Fund [UNICEF], 2017) because the HOs have accounted for a high share of SAR activities together with CSCs. The latter had accounted for almost 25% of the SAR activities in the Central Mediterranean Sea for the year 2014 (Guerdia Costiera, 2018) before the start of the operations of HOs and "Sophia."

4.5.2.1. Interview Findings

In order to answer the research questions, an in-depth understanding of the challenges as presented by the interview participants is necessary. The interviews reveal interdependent linkages among the various factors that constitute the updated theoretical framework, which is illustrated in Figure 11. The complementary data analysis, based on a keyword search, revealed a set of common factor topics within the transcripts. Those factors are highlighted in bold font, in brackets, presented as follows. For instance, a former HO legal advisor stated that "*there are also major differences between the different NGOs, so the capacity is very different* ***(resources)****, on all aspects, from the number of people you can take on board* ***(resources)*** *to the money you have to fund the operations and the personnel* ***(funding, resources, expertise)****, the competencies, etc.*" Nevertheless, due to the high number of

interviews conducted and the density of information that was retrieved, the section follows the structure of the questionnaires to present the findings with simplicity. The key findings are grouped in sets of common topics that have been identified.

4.5.2.1.1. Operational resources

The operating environment is characterized by uncertainty and dynamic conditions. The Mediterranean Sea is a widespread area and the availability of assets for SAR operations is not always guaranteed—the SFs operate at specific regions according to their missions and mandates—especially during days in which the volume of migratory flows is high. The available operational resources differ among the involved stakeholders, even within same groups—i.e., HOs—which is also reflected in the character and duration of the missions. Specifically, some HOs perform only *search and secure* activities due to their ships' capacities and capabilities. The determining cause is funding because it constitutes a challenge for most HOs, also acting as a barrier in the deployment of other operational assets—i.e., surveillance planes for searching activities. Funding is also directly linked to the time-frame of a mission, particularly for smaller HOs, due to their dependence on volunteer work. The importance of resources is also evident under certain weather conditions. During the summer period, HOs have to deal with a high influx of Ms, but some HOs have to reduce their presence at sea over the winter period because they lack proper assets for operating in bad weather conditions. HOs often rely on merchant ships because they account for additional capacity during a SAR event. Two key challenges are faced during the involvement of the latter. The first is related to the Ms embarking on board and their fatigued physical condition, which does not relate to the design of merchant ships. The second refers to the number of Ms and is linked to limited volumes of SAR operations equipment and crew members available on commercial vessels.

On the other hand, the SFs—e.g., coast guard ships—have demonstrated their competence of carrying out SAR operations. Nonetheless, in the Aegean Sea, the Greek coast guard ships are often more capable due to their flexible size in contrast to the bigger FRONTEX vessels. The coast guards have often shown their competency in successfully conducting numerous SAR events that are challenging by nature due to the Ms' resources used for the sea crossings. Cheap overloaded dinghies—the quality of the used boats has deteriorated over time—without engines, crew, and, often, life-jackets, are deployed by the INs. This behavior is adhered to by the INs for three reasons. The first is the

expansion of the term “distress at sea” by the EU, which requests SAR operations even without the risk to sink. The second is the perception of the INs that SAR will be conducted by the European countries and the HOs, while the third is the aim of the INs to maximize their profit by exploiting the maximum place utilization of the deployed dinghy.

4.5.2.1.2. Expertise

The role of HOs’ expertise appears both during a SAR event and in the planning phase of missions. In particular, HOs put effort into improving their logistics system, aiming for the quickest redeployment of a vessel. Yet, critical differences are witnessed between smaller and bigger HOs, especially when external factors command immediate adaptation to operational changes. This is seen, for instance, when the port of safety changes at the last minute. The port of safety, which should ensure the safety of Ms and the crew members at all times, affects the lead-time for the redeployment of an asset after the completion of a SAR activity. Operational uncertainty has especially arisen after Italy’s refusal to allow HOs to disembark Ms at its national ports during 2018. Bigger HOs have stronger logistical support for dealing with such challenges in comparison to smaller ones. Similar differences are also evident in terms of workforce expertise. Bigger HOs employ professional staff in contrast to smaller HOs that rely on volunteer work due to funding limitations.

In contrast with the volunteer-relying HOs, seafarers of CSCs are always trained for conducting SAR operations in accordance to international legal requirements. Nonetheless, the high influx that may require simultaneous assistance is a challenge. Merchant ships provide aid when necessity exists but the crew cannot be considered as professional for mass SAR operations. On the other hand, despite the SFs having the expertise to effectively conduct SAR, the involved crew can experience psychological issues after the completion of an operation due to facing a heavily distressing situation. Last but not least, as long as the migratory flows remain, the INs will continue their illegal activities due to their demand-driven character. A requirement for the elimination of their activities is the complete disruption of their business models. Otherwise, more criminal and sophisticated groups can appear, aiming to exploit this highly profitable business.

4.5.2.1.3. Cooperation and coordination

In addition to being in the right place at the right time, the aspects of cooperation and coordination among but also within the stakeholder groups constitute another operational challenge. Cooperation and coordination exist among HOs in various forms. In addition to regular meetings and exchange of real-time information using the WhatsApp (communication application) platform, HOs can launch joint operations, as in the case of SOS Méditerranée and MSF, with the former holding accountability for the naval operational part and the latter for the medical treatment of the Ms. In this vein, HOs may assist each other at sea in terms of supply replenishment when this need appears. Nevertheless, despite cooperation among HOs being evident, further improvements can be implemented in terms of quicker and closer collaboration as well as information-sharing in a more systematic way. The establishment of an HO coordinating system was initiated with the purpose to ensure constant capacity availability in the SAR region by transferring the rescued Ms onto a ship with better capacity or one that was already on route to a port. Nevertheless, this initiative was unsuccessful due to differentiated operational reasons among the HOs.

Moving on, cooperation exists among the SFs, even the groups with different missions and nationalities. For instance, the Greek coast guard, besides their combined efforts with FRONTEX, also cooperates and pursues collaboration mainly through information sharing with the Turkish and Italian SFs. The Greek–Turkish cooperation aims at better management and control of the situation in the Aegean, while the Greek–Italian collaboration is evident through information exchange, for instance, in cases of undetected sea crossings with the deployment of yachts instead of dinghies.

As far as cooperation between SFs and HOs is concerned, it can be grouped into cooperation at sea during a SAR activity, at the preparation stage of a SAR mission, and toward the establishment of a humanitarian rescue mechanism. Despite the fact that the former takes place when required, reported cases showed a complete lack of collaboration precisely when assistance was requested by the HOs but no immediate response arrived. Moving on to the latter, the main barrier is represented by the distinctive goals and missions of the stakeholders, which acts also as a barrier in terms of information-sharing among them. When HOs would like to have visibility through the Automatic Identification System (AIS) system, which provides a real-time picture of navy ships' position and other operational information as well, the SFs and related authorities can deny these requests due to their missions'

character. This denial can also occur *vice versa*, although operational information related to a SAR incident is shared between the HOs and the MRCC. One reason for this is the impartial status of HOs—tackling illegal activities does not fall into their mandates. Another reason is the fear that the information will be distributed to the Libyan coast guard.

4.5.2.1.4. Additional stakeholders: General public, media, and unknown-unsafe actors

General public and media—the management of external media arose as an operational challenge for HOs—were attested in the majority of the interviews and have a dynamic relation that affects the funding of HOs. As smaller HOs rely on donations obtained from the public, a switch of the media attention away from the crisis or negative media campaigns, an example of which is seen with the allegations of collusion between HOs and INs, have led to financial limitations. Moreover, funding is also linked to the region a crisis takes place in. The high number of Ms disembarking on European soil is a concern for the public, negatively influencing the donations. This concern can also consequently lead to political instability and, therefore, the mass flows have to be addressed by the PMs. In this direction, the code of conduct (CoC) was enforced as a measure for regulating the operations of HOs at sea. Its implementation, despite minor effects on the HOs' activities—the majority of the HOs experienced a decline in collaboration with the SFs after its introduction—can be characterized as an attempt of the PMs to present their involvement in addressing the crisis to the public.

Another attempt of political involvement was the support of material and funding provisions to the Libyan coast guard by the European navy operation "Sophia" in order for SAR activities to be conducted by the former. This initiative has encountered opposition by HOs, which argue that Libyan coast guard is composed of various militia and unknown groups, thus constituting an insecurity factor for them. There have been instances that the Libyan coast guard has assisted in SAR operations but reported incidents have also presented disruptive and dangerous interactions for the HOs. HOs often navigate exceeding their safety capacity—there is the primary moral responsibility of saving lives in distress—due to the fear of the Libyan coast guard, which would then transfer the rescued to Libya by breaching the *non-refoulement*[17] principle as the country is considered to be non-safe.

[17] This principle states that no refugee or asylum seeker should be sent to a country in which there is fear for his/her safety and freedom because of the person's characteristics such as race, and political opinions (UNHCR, 2007).

Disembarkation on Libyan soil is also a concern expressed by the CSCs that want to ensure the safety of both Ms and their commercial crews, because the possibility of tension creation by the rescued in case they are redirected back to Libya cannot be excluded.

Moving on, the interviews also present the involvement of two other stakeholders, in particular, the so-called engine-fishers and lobby groups. As far as the former is concerned, they aim to collect the engines of the boats used for the sea crossings. Despite the insecurity from the HOs side as to whether these groups are related to INs or not, no negative incidents have been reported. On the contrary, cases have been witnessed where engine-fishers assisted during a SAR activity. Regarding the latter, they refer to right-wing actors—the deployed vessels of those groups has but minor effects thus far—opposing the flows. These most likely have a propagandist mission but possible future hostile behaviors should not be excluded.

4.5.2.1.5. Solutions for the MBS crisis

The interviews also included possible solutions for addressing the crisis. The drivers of migration—e.g., political instability, poor governance, individual aspirations, climate change, etc.—should be tackled. Possible actions in this direction range from long-term development and operational response enhancement to the engagement of PMs. Long-term development, through the provision of migration aid at the countries of origin, can contribute toward addressing the root causes of migration. Since, this is a time-intensive planning process that requires the involvement of PMs and national societies, HOs support the provision of humanitarian assistance at sea as a short-term response. Assets exist due to various missions. Nonetheless, the mandates and goals of the missions determine their usage.

The leading role of PMs is justified in all interviews. In addition to the promotion of long-term development, they can positively determine the provision of asylum access to the Ms in their countries of origin and the promotion of family reunification schemes. These measures, in line with the introduction of protection-sensitive border control policies, can consequently lead to an enhancement of border control. Nonetheless, the implementation of such measures is tortuous, as PMs enforcing such actions can experience a decline of the general public approval and the possibility of the creation of political tension in the reception countries cannot be excluded. This can consequently lead to political backlashes for the Ms. However, PMs should ensure the prevention of pushback practices

and that Ms' disembarkation always occurs at a port of safety. In line with the port of safety insurance, the provision of material and capacity building support from the EU to the Libyan coast guard in response to increasing flows should be closely monitored. This is necessary to ensure Libyan compliance with international law and prevention of illegal activities, such as cooperation with INs. Since Libya is not safe, criminalizes migration, and allows arbitrary detention of Ms, PMs' involvement becomes more essential.

4.6. Final theoretical framework and propositions

The updated theoretical framework is illustrated in Figure 10. The newly identified elements, the links between all factors, and their interactions are highlighted in bold font. The effects of the interactions are represented with the signs (+) and (–) at the upper end of the interaction lines. The variables change in the same direction when the (+) sign is used and in the opposite direction when the sign is (–). In addition to the attributes of the SAR environment, operational effectiveness is also influenced by factors incorporated in the external environment. The factors constituting the external environment determine the size of the migratory flows and sea crossings and are:

Problematic context (PC): It refers to the drivers of migration, which include economic and political conditions or natural disasters (UNHCR, 2017d).

Refugee and migratory regulatory framework (RMRF): It refers to the legal alternatives, e.g., family reunification schemes, asylum procedures availability—IOM and UNHCR cooperate for the provision of resettlement[18] opportunities to people in need of international protection (IOM, 2018b)—and other human rights protection schemes. PMs, through the establishment of legal alternatives for migration, affect the number of crossings (Larking, 2017).

Border control ineffectiveness (BCI): The lack of success with border control regimes have an effect on the number of crossings (El-Enany, 2013).

[18] The mandate of IOM includes the provision of international migration services to refugees, displaced people and other individuals (IOM, 2018).

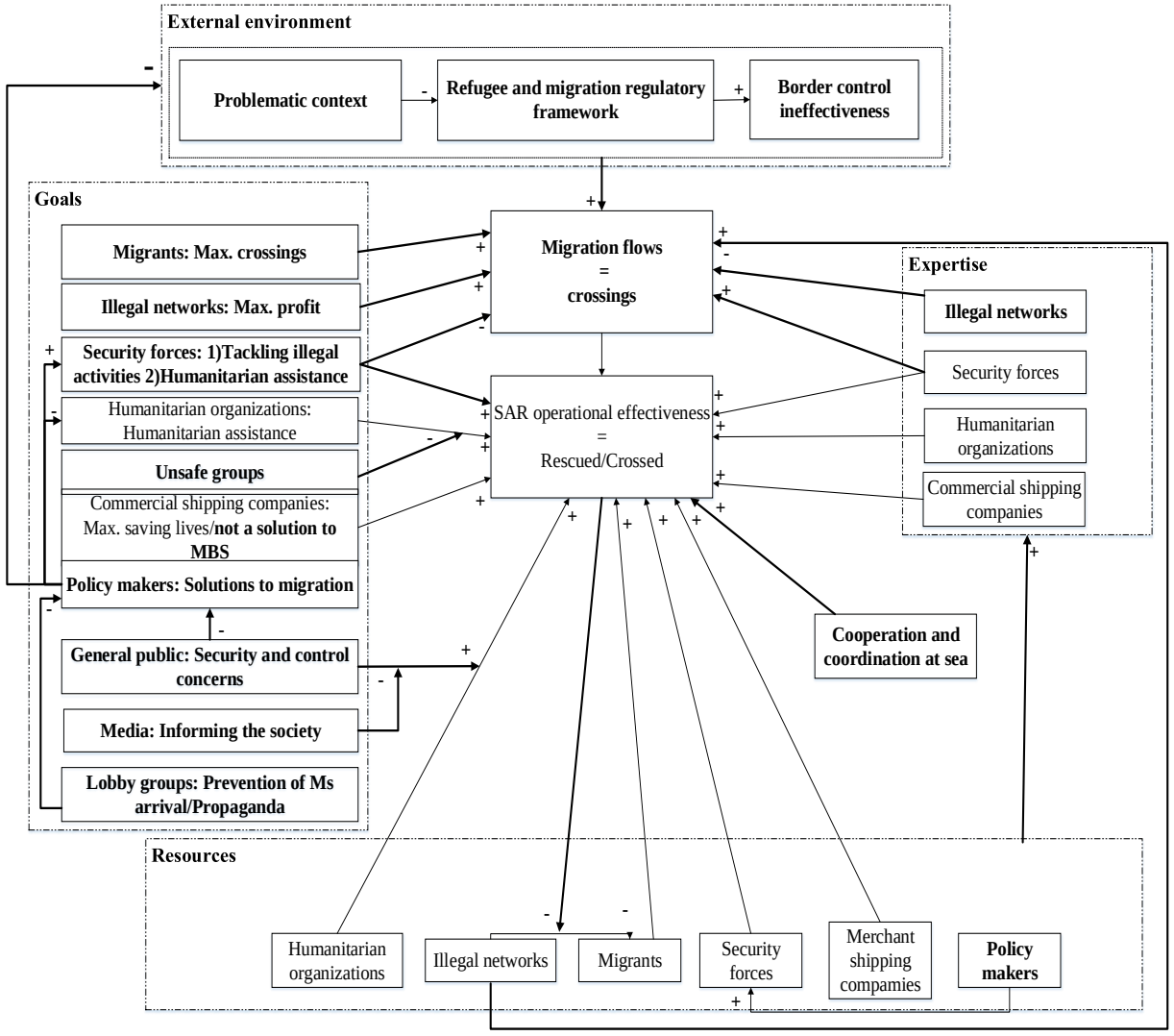
In case that a PC, BCI, and a "weak" RMRF exist, then the crossings will increase and ultimately influence SAR effectiveness (new link). Furthermore, the analysis reveals a new group of stakeholders that affect SAR operational effectiveness indirectly. Those stakeholders are:

PMs: They can define the character of the SFs' missions (new link) and their resources (new link), which is justified by previous literature (see Larking, 2017). The missions range from the provision of humanitarian assistance (new link) to anti-illegal and border control operations and their available operational resources. For instance, "Mare Nostrum" showed that SFs can increase SAR effectiveness. PMs also have an effect on the HOs' missions through their regulatory characters. In the Mediterranean Sea case, we could argue that, due to the code of conduct, the allegations of HOs' possible collaboration with INs and the EU's provision of financial and material support to the Libyan coast guard, this effect can be characterized as negative (new link). PMs also have responsibility for the regulatory issues linked to the engagement of CSCs and HOs, particularly for cases of Ms' disembarkation at ports where their life-safety is questionable. A representative example of this is the involvement of the Libyan coast guard in SAR operations. Hence, the possibility of Ms' disembarkation at a country accused of human rights violations is disquieting.

General public and media: Without loss of generality, the general public is skeptical about accepting high volumes of Ms, which subsequently negatively affects the goals of PMs (new link). On the contrary, it still remains the main source of funding for small HOs (new link). Nevertheless, donations are negatively influenced by the media—which has an impact on society in terms of informing the public—as witnessed for the current case (new link). For instance, a switch of media attention away from the crisis and the criticism toward HOs' activities have resulted in funding challenges for HOs.

The case study shows the involvement of "unknown-unsafe" groups as additional stakeholder within the SAR environment. This group consists of various militia, included in the Libyan coast guard that have a direct negative effect on SAR effectiveness (new link), and of the lobby groups that oppose migration. The latter has not had a direct effect until now but they do have an additional indirect effect on SAR effectiveness, as their propaganda character affects the goals of PMs.

Figure 10: The SAR operational complexity (updated framework)



On the basis of the data's—both primary and secondary—analysis, this study comes up with four propositions within which also the newly identified linkages, stakeholders, and their causal effects are presented and discussed. Given the constant changing interactions and dynamics of the various factors from the internal and external environment that affect the SAR operational effectiveness, it is imperative that future studies delve deeper into the composition and behavior of the sub-systems that determine the effectiveness under analysis. The propositions suggested by the present research move toward this direction and can constitute topics for future research through their validation and expansion.

Proposition I: The problematic context driving the flows should be tackled, the migratory legal framework and border controls should be improved in order to enhance SAR operational effectiveness.

The root causes of migration can be tackled through long-term development. The provision of incentives, e.g., political stability, security, economic sustainability, to Ms at the origin and transit countries by the PMs is required. Despite the fact that this is time-intensive and cannot be seen as a short-term solution, the treatment of the PC is necessary. Otherwise it negatively affects the RMRF, especially of the destination countries, driven by the fears of internal security or political instability resulting from the mass flows. An RMRF enhanced by PMs can prevent the Ms from undertaking these dangerous journeys. The promotion and expansion of legal pathways (e.g. family reunification and resettlement schemes) can, at the very least, reduce the crossings of migrants who are in genuine need of international protection. Consequently, border control, which is desired by transit and reception countries, is reinforced by a RMRF enhancement as visibility and control of the Ms is achieved. At the same time, the safety of Ms would also be ensured, contrary to the case of the application of stricter control regimes that can result in a switch toward riskier migratory paths despite decreasing the flows at specific routes.

Proposition II: The shipping industry is not a viable solution for tackling tragedies at sea.

The migratory by sea emergencies require the involvement of the commercial shipping sector—often at a high intensity. This involvement leads to financial costs—e.g., port and deviation expenses—that have to be covered by the sector. Notwithstanding the contribution of the sector to migration by sea emergencies—regardless of whether this contribution is driven by legal obligations or the maritime tradition of safety of life at sea—and despite the fact that CSCs are investing in preparedness for a SAR operation, the role of the shipping industry in the crisis should not be institutionalized because this is not a sustainable policy solution. The legal obligation that dictates their involvement in SAR has not been designed for such high influxes.

Proposition III: Cooperation and coordination amongst all stakeholders, who are hindered by their differentiated mandates, are imperative in order to enhance SAR operational effectiveness.

Cooperation among the stakeholders, excluding INs, but also within—referring to resource sharing, e.g., assets, information, and expertise—can increase operational effectiveness. The overall goals of the involved stakeholders define the cooperation level. In the present case, for instance, this is witnessed in terms of information-sharing, which especially lacks between the HOs and the SFs due to their differing missions and mandates. Similarly, coordination enhancement contributes to the enhancement of SAR operational effectiveness. The responsible MRCC has a critical role in terms of coordinating the available SAR assets—it has a complete picture of asset availability—by having the overall responsibility over a SAR operation. In this direction, the study proposes the establishment of a cooperation and coordination scheme among the MRCCs around the sea area for mass SAR operations. For instance, the Italian MRCC deals with an immense number of distress situations despite the existence of additional MRCCs in the region, e.g., Malta and France.

Proposition IV: Increased SAR operational effectiveness is not a pull factor.

The migratory flows and sea crossings will continue to take place unless the problematic context is addressed. The need for the facilitation of crossings drives the demand for INs, which will ultimately prevail unless they are completely dismantled. Migrants will undertake their journey regardless the possible dangers (e.g., no life vests) or their potential failing attempts to find refuge (new link). There have been reported cases in which migrants had been intercepted many times (new link) but continued to attempt the sea crossings until they reached Europe. Another important factor that needs to be taken into consideration is the role of Libya and its implications within the migratory by sea crisis. Given the overall situation in the country and the accusations related to political instability, human right violations and criminalization of migration, migrants can see the sea crossings as the only solution for not staying in Libya.

INs exploit this need by maximizing the number of Ms on a dinghy—one of the strategies followed by INs is the removal of life vests to increase their capacities and, thus, profits (new link). It needs to be highlighted that INs have become more sophisticated and ruthless in terms of their *modus operandi* since smuggling and trafficking of migrants are profitable businesses. Therefore, this study argues

that the aim of the INs to maximize their profits and their perception that SAR will be conducted by other stakeholders, results in the decline of the quality of the assets and equipment for the sea crossings that are provided to the Ms (new link).

4.7. Conclusion and directions for further research

Migration flows are part of the global displacement crisis, a large portion of which involves Ms and often leads to loss of lives. Providing assistance to people in distress at sea is an obligation under international maritime law conventions, but it is also perceived to be a moral duty of coastal states and other governmental and non-governmental agencies. Notwithstanding the increasing importance of Ms in the global displacement crisis, this paper is the first one to investigate operational response through SAR at sea. The paper provides a taxonomy of the factors and stakeholders that contribute and influence operations at sea and investigates their impact on SAR operational effectiveness. Due to limited pre-existing theory, the paper proceeds to develop a conceptual framework that has SAR operational effectiveness as its main unit of analysis. However, further practical cases should be studied to test the coherence and completeness of the proposed framework.

The system under study is defined as SAR operations at sea. Other studies could expand the scope of the analysis by investigating other systems, such as the migration networks on land, the arrival and disembarkation processes at port, the onward migration journeys, the management of camps hosting displaced people, or enhancing sustainability of the system related to burden-sharing for reception countries. In the case of SAR operations at sea, a preliminary theoretical framework is proposed on the basis of existing disaster management literature and the participation of the authors in conferences, forums, and academic programs. In order to test and update the theoretical framework, primary and secondary data were collected and analyzed by means of 25 interviews with experts and stakeholders associated with the Mediterranean MBS crisis, such as humanitarian organizations, commercial shipping associations, security forces, and policy experts. The secondary data were collected from official reports, verifiable news sources, and other published materials. As further data becomes available in this area, future studies should enrich the understanding of the operations connected to MBS though empirical studies.

The framework comprises of factors that consist of the external environmental and factors related to the internal SAR environment. The former refer to the problematic context, the refugee and migration regulatory framework, and border control effectiveness. The external factors influence the number of people that embark on a sea crossing. The long-term solution for the mass migration movements is to tackle the root causes driving those movements. This is a challenging and time-demanding process that necessitates the involvement of governmental and non-governmental stakeholders at multiple levels. An enhanced refugee and migration regulatory framework, through the promotion and establishment of alternative legal pathways, such as family reunification and resettlement schemes, can reduce the flows of people in genuine need of international protection. As far as border control effectiveness is concerned, it can be achieved by means of stricter control regimes and enhanced surveillance, but it could also result in migrants being channeled through other, more dangerous routes, as migration networks are particularly resilient and adaptable.

The internal factors consist of the stakeholders' goals, missions, and objectives, their operational resources and expertise, and cooperation and coordination among them. The research identifies the migrants, the illegal networks, the HOs, the security forces, the shipping companies, the general public, the media, unknown actors, and the lobby groups opposing migration as stakeholders. The policy-makers emerge as the most critical stakeholder in the definition of the legal framework within which the operational responses of the SFs and the activities of the HOs take place. The latter rely on donations, which are shown to be influenced by public opinion and the media. The study indicates that the commercial shipping sector, despite its high involvement in SAR operations, should not be relied upon as a long-term solution. The existing SAR provisions included in the International Convention for the safety of Life at Sea (SOLAS) and the United Nations Convention on the Law of the Sea (UNCLOS) are not designed to deal with an MBS crises.

At an operational level, this research shows that beyond the challenges associated with assets availability, cooperation and coordination have to be enhanced through resources and information sharing in order to increase SAR operational effectiveness. The divergence among the missions of SAR stakeholders can be a barrier to effective cooperation. The paper suggests that an increase in SAR effectiveness does not act as a substantial pull factor for migration flows, which are demand-driven and primarily influenced by external factors. Increased SAR effectiveness appears, however,

to reduce the resources provided to the migrants by illegal networks. These networks have to be dismantled completely in order to affect MBS because partial disruptions combined with incomplete information and unabated demand favor the emergence of more sophisticated and ruthless criminal groups, thus only increasing the dangers associated with MBS.

This paper combines a theoretical contribution with analysis of a practical MBS case through the Mediterranean Sea crisis. Such empirical focus is justified by the complex operational dynamics of the Mediterranean MBS case and the need to coordinate the involvement of its multiple stakeholders, including commercial shipping companies, who engage in SAR operations as a result of, often, very diverse incentives. The analysis of the Mediterranean Sea case lead to the identification of cooperation and coordination at sea as one additional influential factors, as well as to the identification of three additional stakeholders—i.e., the public, the media, and the lobby groups opposed to migration. The case analysis also leads to a refinement and expansion of the goals of the stakeholders and to a better understanding of the linkages and impacts of various factors and stakeholders on the SAR operational framework.

The paper represents the first contribution to the investigation of SAR operations in the MBS context, whose complexity and richness opens a wide variety of opportunities for further research within various scientific areas, in addition to those already mentioned above. The understanding of MBS could benefit from the application of the framework to other cases, such as the Rohingya crisis. Furthermore, since MBS involves stakeholders both at sea and on land, the factors of coordination and cooperation among them and their behavior at operational and strategic levels also require further research. At an individual level, since HOs are only involved in sea operations through the provision of SAR assistance, studies should aim to optimize the use of their limited resources through an increased coordination. With this goal in mind, studies from an operations management and operations research approach could be undertaken to optimize the allocation of HOs' assets, aiming at higher SAR area coverage at sea, depending on weather conditions, historical data, and resource limitations. In this vein, a better understanding of the structure and functioning of the INs, which facilitate the crossings, and how they react under the influences of the other actors within the system would be beneficial in order to effectively disrupt their activities. Linked to the activities of the INs, another research topic could relate to the examination of the operational tradeoff that takes place in

terms of migration route closure and reduction of loss of life at sea. Overall, the external environment and internal factors could also be the subject of a more detailed investigation. It is the hope of the authors that, by stimulating research on this urgent and complex topic, academic efforts can contribute to lower the costs of crisis management, improve the coordination of SAR operations in the MBS context, enhance SAR effectiveness, and, ultimately, reduce the human death toll.

Appendix A: Base questionnaire

Questions in all interviews: Can you describe the organization's involvement in the crisis? What are the challenges that you face during your operations? Are there factors that may affect your operational response and activities? Do you experience challenges from a logistics perspective? Are you adequately equipped for large-scale SAR operations? Do you cooperate with other involved stakeholders? Do you have any cooperation issues with the other involved stakeholders that may hinder your operations? How is the financial budget allocated along the operational activities? How are those decisions taken? Are there any constraints in the budget that may hinder the operations? Are you planning to expand your operations? Can you comment on the support provided by the European Union (EU) to the Libyan coast guard? Do you believe that investments in migration aid in the countries of origin or the transit countries could mitigate the current humanitarian disaster? Is there any other long-term action that could contribute? Is there any short-term action that could reduce the humanitarian crisis at sea? What are the next steps of your organization within the crisis and general comments on it?

Additional questions for HOs on land: How is your organization involved in the operations that take place in the Mediterranean Sea and are associated with the migration crisis, for example, through implementing partners? Do you cooperate with stakeholders that operate at sea? Are you planning to get involved in sea operations? General comments?

Additional questions for CSCs: Have shipping companies started training their crew for large-scale SAR operations? Do you believe that regulations from various conventions and treaties regarding "rescue at sea" should be amended? Do you cooperate with other agencies or organizations regarding the high involvement of merchant ships in SAR activities? Have merchant ships considered being a part of the SMART system (information-sharing platform) applied by the SFs? What is your opinion on the system? Do you have any suggestions for improvement regarding information-sharing? Are there other costs (besides deviation) that arise due to the involvement of a commercial ship in SAR activities and what is their extent? Have SAR activities resulted to operational and logistical issues in the commercial activities of the CSCs? Is there any kind of support provided to the companies that are involved in SAR operations?

Additional questions for SFs: Do you believe that anti-smuggling operations will reduce the death toll?

Questions to the migrants: Can you describe your involvement in the migration crisis? Did you cooperate with other involved stakeholders during your trip? What are the challenges that you have faced during your trip and the sea crossing? Were you adequately equipped for the sea crossing? What role does the payment to the INs play for your sea crossing? Can you suggest a short- and long-term solution to the crisis? What are your next steps in the migration crisis?

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Chapter 5

Conclusion of the Ph.D. project

5.1. Concluding overview of the Ph.D. project

This Ph.D. project focused on complex environmental and social global supply chain issues. Within the international efforts for meeting the UN's SDGs, the role of the maritime transport sector is undeniable. Despite the sector's contribution to the SDGs, the targets that have been set by the policy-makers add pressure to the shipping industry as well. From an environmental perspective, the industry can take steps toward the reduction of its produced emissions, while it can contribute to SAR operational effectiveness in the context of migration by sea from a social perspective. These two areas constituted the foundation of this project, which had as its main objective the structuring of the status quo of the issues and the provision of guidance to both the maritime and international communities for their addressment.

Particularly, as far as the achievement of emission reduction in the maritime transport industry is concerned, the project concentrated on the enforcement of a bunker levy scheme as a possible regulatory measure in this direction. The motivation behind this research was provided by the importance of the industry as a crucial component for both global supply chains and world economic growth; the amount of exhaust gases produced by the sector's operations, which accounts for a significant proportion of global emissions; and the urgency for regulatory intervention in order to enhance the industry's environmental performance, especially after the ambitious reduction targets were recently set by the International Maritime Organization.

Moving on to the societal contribution of the industry, the project dwelled on how the effectiveness of the maritime search and rescue operations in the context of migration by sea emergencies can be improved. Despite the importance of the shipping industry within such emergencies, the sector represents only one of the many other involved stakeholders (e.g., humanitarian organizations, navies, coast guards). The initiating motivating factors for this research topic included: the consistency of the migration by sea phenomenon linked to its associated negative effects (i.e., life loss); the operational complexity of search and rescue; the complexity of the search and rescue phenomenon deriving from

the differentiated goals and roles of the involved stakeholders hold within that context. This Ph.D. project produced three research articles. This, final, chapter concludes the project, presents its main findings, scientific, and practical contributions, and provides further research directions.

5.1.1. Bunker levy scheme enforcement in the maritime transport industry

The enforcement of a bunker levy scheme aligns with the IMO's principle of "polluter pays," which requires all parties to provide financial compensation for its produced GHG emissions. Chapter 2 focused on the scheme's economic and environmental implications on international shipping, through the examination of two different scheme structures. The first referred to a unit tax and the second to an *ad valorem*. Despite the fact that both schemes would be imposed onto bunker costs, the estimation of the former would be easier, based on past fuel consumption, whereas for the latter the extra costs would vary in proportion to the bunker prices. Thus, an *ad valorem* scheme would add more uncertainty and cost volatility within an already volatile and uncertain industry, resulting in complexity of predicting the levy's economic consequences.

The chapter developed a bunker levy market equilibrium model, which captures the industry's supply and demand interactions and incorporates a tax parameter as a novelty, on the basis of the cobweb theorem. The industry would experience a profit decline with both schemes. Due to the operational cost increase, short-term and long-term responses from shipowners and operators would be anticipated. The initial reaction would be speed optimization through application of *slow steaming* (i.e., sailing speed reduction in order to reduce fuel consumption). The speed decrease would differ accordingly to the scheme's structure. Specifically, for unity tax, both bunker prices and imposed levy amount would define the reduction rate, whereas, for the *ad valorem* scenario, the enforced percentage would indicate the reduction level independent of the fuel expenses. Even so, *slow steaming* as a response strategy could not last indefinitely. Consequently, companies would be pushed toward finding other ways to cope with the levy costs by means of investments in environmentally friendly technologies.

Notwithstanding the main goal of bunker levy scheme enforcement, an opposing argument that was expressed within the policy debate refers to the transfer of the imposed costs along the supply chain, which would result in the ineffectiveness of the measure and higher freight transport costs. The

research highlighted the importance of market conditions and alterations in supply and demand to the allocation of the levy cost from the shipowners to the shippers.

On the basis of the continuously increase of GHG emissions and the urgency of regulatory actions, a bunker levy scheme could ultimately lead to enhancing the environmental performance of the sector. Nonetheless, to prevent a possible economical backlash to the industry, the research suggested the linkage of this policy to a levy redistribution scheme. The establishment of such a redistribution scheme, besides financial provision to owners and operators for green investments that would also ease the acceptance of such a policy by the shipping industry, should also foster research aimed at enhancing the environmental performance of the industry through the development of new technologies and low-emission alternative fuels.

Notwithstanding the intuitive and promising appeal of the implementation of such a market-based measure, caution is suggested to policy-makers because of possible negative implications for the competitiveness of the maritime transport industry vis-à-vis other transport modes. This argument especially stands for the short sea shipping sector that faces competition with alternative transportation modes. Chapter 3 concentrated on this issue. It investigated the policy's implications on the competitiveness of the short sea shipping sector and, additionally, looked into other factors that influence the competitiveness under study.

Chapter 3 constructed a Bayesian network modal split model on the basis of the generalized transport cost approach. A sensitivity analysis was conducted, followed by the investigation of 16 indicative scenarios. The analysis showed that high bunker prices and a high levy amount would lead to a decline of the probability that short sea shipping has a high competitiveness. Furthermore, the values of freight rates, shipment's opportunity cost, cargo value, and distance all play an important role in the final outcome. When these factors have low values, then an increase of the probability that short sea shipping has a high competitiveness would be expected.

On the same note, the cargo value and the opportunity cost of the shipment relates to the importance of the monetary value of time within the shippers' modal choice decision. Another important finding relates to the factor of distance. This does not refer to an origin–destination distance but to the distance of the shipping companies' transportation network. The analysis points out that, when companies

could rationalize their network and reduce its distance, then an increase in the probability that the mode's competitiveness is high would be expected. Last but not least, the bunker levy scheme's implications are highly dependent on the generalized road transportation costs.

5.1.1.1. Contributions and further research directions.

This research project represents one of the first attempts to capture the implications of bunker levy scheme enforcement on the maritime transport industry. Within the value added to the existing, scant literature, the construction of a bunker levy market equilibrium model (Chapter 2), which incorporates a tax parameter as a novelty, and the design of a modal shift model on the basis of the Bayesian network theory (Chapter 3) complements the scientific contribution of the study. In addition, this research sheds light on the prevailing blurred picture of a levy policy implementation because its findings and the suggestions provided contribute to this policy-making debate. Last but not least, practitioners can benefit from the study's results because, first, the uncertainty derived from such a measure is decreased and, second, they can act proactively in case this policy is enforced.

Despite the study's contributions, several topics remain open and provide fruitful opportunities for further research. On the basis of applying *slow steaming* as a response to imposed costs, challenges in the context of shipping operations and logistics should be addressed. Just-in-time delivery problems, changes in shipping networks, and trading patterns and implications for specific trade sectors are just indicative potential research ideas. An examination of the economic feasibility and applicability of green innovation as a way for coping with the levy costs would be of great interest. Moreover, an examination of other tax scheme structures, which could also be incorporated in the Bayesian modal shift network model, provide ideas for additional studies. The urgency for tackling climate change, in combination with the ambitious emission reduction goals set by the international community, requires immediate regulatory action. Research can contribute toward the facilitation of an informed policy debate that could ultimately lead to enhancing the environmental performance of the maritime transport industry without jeopardizing its wellbeing.

5.1.2. Maritime search and rescue operations in the context of migration by sea

Migration by sea constitutes a part of the global displacement crisis that has led to a call for response by the international community, mainly due to its associated negative effect of life loss. Attempted

sea crossings often result in the request for search and rescue assistance dictated under maritime law provisions; such assistance has to be provided regardless of the mandates or the character of the sea activities by any involved stakeholder. This part of the Ph.D. project had, as its main objective, the enhancement of the maritime search and rescue operational response effectiveness in the migration by sea context. The Mediterranean Sea crisis was taken as the case under study due to its persistent associated migratory movements and the reported high numbers of life losses resulting from the migratory movements despite the engagement of various stakeholders. Initially, a preliminary theoretical framework of SAR operations in the migration by sea context was designed on the basis of existing literature. In addition, the authors (see Chapter 5) also attended and participated in conferences, forums, and academic programs in the context of human rights, operational response, and policy topics related to the crisis in order to stay constantly informed about the evolution of the situation but, more importantly, to also develop an informed view of the various components that constitute this phenomenon.

The exploratory research design followed in the study was grounded on the analysis of primary and secondary data. The latter was collected through verified reports of various organizations (e.g., UNHCR, FRONTEX) and the former through the 25 interviews conducted with stakeholders and experts engaged in the Mediterranean Sea crisis. The main outcome of the analysis was the update of the theoretical framework, composed of internal and external influential factors for the effectiveness of search and rescue operations. External factors refer to the problematic contexts that initiate the migratory movements, the regulatory migration and refugee frameworks, and the border control ineffectiveness. Although long-term development is imperative for the effective treatment of the migration drivers, a short-term response to the crisis would include the promotion and expansion of alternative legal migratory ways in order to, at least, provide assistance to migrants that are in genuine need of international protection. This option would also enhance border control effectiveness that can similarly be achieved through the enforcement of stricter control regimes. Nevertheless, a trade-off is witnessed as, despite the reduction effect on the flows through stricter control regimes, the illegal networks would still facilitate crossings via more dangerous routes for the migrants.

Moving on to the internal factors of the framework, they relate to the goals of the involved stakeholders and their respective SAR resources and expertise. Policy-makers emerge as one of the

most critical stakeholders because their influential role on the external factors as well as on the operations conducted by the security forces and humanitarian organizations. The former have the capability and expertise of effectively conducting SAR operations, while the latter, which have accounted for a high proportion of recent SAR activities, face challenges related to fundraising, which determine their operations' characteristics. Many humanitarian organizations rely on funding from the general public, which, nonetheless, is concerned about the high influx of migrant arrivals and is further influenced by media coverage. Additionally, the analysis showed that despite the contribution of commercial vessels to SAR activities, their role should not be institutionalized as it cannot provide a sustainable solution to a migration by sea crisis. A complete dismantling of the illegal networks is imperative, otherwise, driven by the profitability of this "business," more dangerous and ruthless groups would be established. Last but not least, unknown actors and the extreme groups opposing migration are two additional stakeholders that can have a negative influence on SAR effectiveness.

The study identifies the SAR operational challenges that relate to ships' availability, ships' SAR competency, crew expertise, and lack of cooperation among the stakeholders. Cooperation and coordination among them is required through resource sharing (e.g., information, assets), which is essential for enhancing SAR effectiveness. Nonetheless, the differences in the mandates and missions of the stakeholders act as a prevailing obstacle in this direction. In addition to the construction of a first-of-its-kind theoretical framework for SAR operations in the context of migration by sea emergencies, the study also provided several propositions that arose through the analysis and need further research validation. For instance, it was argued that an enhancement of SAR effectiveness does not constitute a pull factor for the migration movements. Regardless, it affects the resources (e.g., life jackets) provided by the illegal networks to the migrants and, thus, increases life-risk during sea crossings.

5.1.2.1. Contribution and further research directions.

This study had theoretical, practical and policy-related contributions. On the one hand, its research expanded the disaster management literature in the area of SAR linked to migration by sea. On the other hand, through the analysis of the dynamics and the impact of the factors and stakeholders that affect operational effectiveness, this research also added value through increasing the understanding of such activities within migration by sea emergencies. Thus, policy-makers, shipping companies,

and non-governmental organizations could also benefit from finding a sustainable solution to this phenomenon. The study supported that policy-makers should not perceive the involvement of the commercial shipping sector in the migration by sea phenomenon as a viable policy. Any possible solution to the migration by sea phenomenon taken into consideration by the policy-makers should respect the human rights of the migrants. Since tackling the root causes of migratory movements refers to a long-term solution, policy-makers should consider the expansion and promotion of legal alternative pathways (e.g. family reunification schemes) as an additional mitigation measure that would ensure both the safety of migrants that are in genuine need for international protection and better border control visibility.

This study represents the first study of its kind by examining the enhancement of SAR operational effectiveness in the migration by sea context, and paves the way for additional research areas that need to be undertaken and explored in the hope that the existent migrant death toll would eventually be tackled. First, the theoretical framework should be enriched and the propositions should be tested through examination of other migration by sea cases—e.g., the Rohingya crisis. Furthermore, an examination of the structure and operational changes of the illegal networks would be beneficial in order to achieve their complete disruption. Other topics of interest for further research could include examinations of the migratory networks on land, the efficient allocation of the humanitarian organizations' assets dependent on their funding limitations, and analyses of each internal and external factor that influences SAR effectiveness.

5.1.3. The way forward

SDGs are ambitious but necessary for both society and environment. In order to be met, they require the joint efforts of national governments, corporations, governmental and non-governmental organizations, and all individuals. The two topics that constituted this Ph.D. project cannot be addressed at a national level exclusively but require a global response, which results in additional complexity. The international community stands at a critical point in history. Decisions at all levels, by all possible stakeholders, are urgently required. This Ph.D. project focused on the topics for which existing literature is scarce and established a first step for future studies in this arena. As is shown in the project, policy makers are one of the most critical stakeholders within both topics under research.

On the one hand, regulatory enforcement is imperative and necessary for enhancing the environmental performance of the maritime transport industry. The emission reduction strategy introduced by the IMO represents a milestone decision for the decarbonization of the sector. Nevertheless, since the strategy encompasses a broad range of possible measures, which will be discussed in the years to come, and considering the amount of time that a policy discussion requires until it enters into force at an IMO level, meeting the emission reduction targets within the defined time-frame is questionable. Hence, required actions cannot be delayed. Policy-makers have taken an important step toward contributing to the SDGs with the IMO emission reduction strategy. At this point, they need to agree upon the potential short, medium and long term measures that need to be implemented. The present Ph.D. project contributed to the discussion of medium term actions. It is the author's belief that a bunker levy scheme enforcement is the way forward for achieving the decarbonization of the industry. This MBM has started to gain even more attention within the shipping community throughout the last years. Policy-makers need to support the "polluter pays" principle and provide the necessary incentives to the shipping companies so as to drive the enhancement of the environmental performance of the industry. The present study showed that a bunker levy can act as suitable measure by imposing financial pressure to the companies.

On the other hand, addressing migration by sea emergencies, which constitute a long-lasting global phenomenon, requires the coordination and cooperation among all those stakeholders involved in such crises at different levels. The dynamic environment of such emergencies is composed of continuously changing operational layers that add more complexity to the mitigation efforts of their negative effects. The disasters that occur at sea are not an isolated phenomenon but are linked to problematic factors on land. Within migration by sea emergencies, policy-makers represent a critical stakeholder who can shape both the mitigation of the drivers that push toward a people mobility increase and the operations that take place at sea. Overall, policy-makers should always ensure the respect of the human rights of the migrants when trying to find solutions that address the migration by sea phenomenon.

Given the importance of the two topics that were investigated, the role of the academic community cannot be excluded from the global debate. Its contribution to the SDGs, by providing clear insights into multifold economic, environmental, and social directions on the basis of scientific evidence, is

eminent and required. By delving into those areas for which the existing literature is limited, this Ph.D. project paves the way for further studies that are needed to avoid jeopardizing the wellbeing of global supply chains as well as to provide solutions that respect the environment and the society. It is the hope of the author that this project will stimulate further research into how emission reduction in the shipping sector can be achieved as well as for the mitigation of the human death toll in the migration by sea context.

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