CHALMERS

The EU ETS and its Effects on RoRo and Container Shipping

A Comparative Study on the Cost Structure and Volume Shifts

Bachelor thesis for International Logistics Program

GUSTAV AMUNDSSON
MAGDALENA ANNAORAZOVA

DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2025

The EU ETS and its Effects on RoRo and Container Shipping

A Comparative Study on the Cost Structure and Volume Shifts

Bachelor thesis for International Logistics Program

GUSTAV AMUNDSSON
MAGDALENA ANNAORAZOVA

Department of Mechanics and Maritime Sciences
Division for Maritime Studies
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2025

The EU ETS and its Effects on RoRo and Container Shipping
A Comparative Study on the Cost Structure and Volume Shifts

GUSTAV AMUNDSSON
MAGDALENA ANNAORAZOVA

Department of Mechanics and Maritime Sciences
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Cover: A RoRo and a container vessel sailing side by side. Created with the use of Open AI.

Department of Mechanics and Maritime Sciences
Chalmers University of Technology
Göteborg, Sweden 2025

PREFACE

This thesis has been conducted as part of the Bachelors' program in International Logistics at Chalmers University of Technology, under the Department of Mechanical and Maritime Sciences. The thesis corresponds to 15 of the total 180 credits of the program.

We would like to begin by extending our sincere gratitude to all the companies who chose to participate in this study. Your willingness to share your experience and knowledge from your respective markets made this thesis possible. Furthermore, we would like to extend our deepest gratitude to our supervisor Fredrik Olindersson, whose guidance, expertise and continuous support were invaluable through the entire process. Finally, we wish to express our appreciation to all lecturers and academic staff who, through their teaching and guidance, have contributed to our academic accomplishments and prepared us for future careers.

The EU ETS and its Effects on RoRo and Container Shipping

A Comparative Study on the Cost Structure and Volume Shifts

GUSTAV AMUNDSSON
MAGDALENA ANNAORAZOVA

Department of Mechanics and Maritime Sciences
Chalmers University of Technology

SAMMANDRAG

Sjöfartsindustrin inkluderades nyligen i EU:s system för handel med utsläppsrätter (EU ETS) som ett incitament för att minska utsläppen från transportsektorn. Denna reglering introducerar en ny kostnadsstruktur för rederier genom kravet att köpa EU:s utsläppsrätter (EUA). Syftet med denna policy är att främja användningen av förnybara bränslen genom att öka den relativa kostnaden för att använda konventionella, ohållbara bränslen.

Denna uppsats undersöker EU ETS:s påverkan på kostnadsstrukturen inom Roll-on Roll-off (RoRo) och containersegmentet, samt utvärderar potentialen för volymskiften som en följd av regleringen. Studien bygger på en kvalitativ metod och genomförs via semistrukturerade intervjuer med tio företag: sex rederier, två terminaler och två transportköpare.

Resultaten visar att alla rederier i stor utsträckning för vidare sina ETS-kostnader till kunderna genom tilläggsavgifter, vilket begränsar den direkta effekten av ETS. Containerrederier gynnas av skalekonomi och globala operationer, vilket leder till relativt låga tillägg per transportenhet. Likaledes har oceangående RoRo-rederier begränsad exponering för ETS, eftersom endast en liten del av deras resor sker inom det reglerade geografiska området. Däremot kan deras begränsade kundbas och längden på kontrakt utgöra hinder för att fullt ut vidarebefordra tilläggen.

I kontrast möter intra-europeiska operationer, framför allt RoRo-rederier, en större exponering för ETS-kostnader på grund av högre operativ hastighet, seglingsfrekvens och lägre kapacitetsutnyttjande. Även om dessa rederier tillämpar olika metoder för att föra vidare kostnaderna, tvingas de ofta absorbera en del av utgifterna, antingen genom att sänka hastigheten eller minska sina fraktrater.

Trots att containertransport erbjuder lägre ETS-kostnader är det sällan ett genomförbart alternativ till RoRo inom kortsjöfarten på grund av operativa begränsningar. Följaktligen visar resultaten inga betydande volymskiften mellan segmenten, eftersom operativa skillnader väger tyngre än de marginella kostnadseffekterna. Dock kan stigande ETS-kostnader på sikt stimulera ett skifte av lågvärdigt, volymintensivt och tidsokänsligt gods mot containertrafik.

Nyckelord: EU ETS, marina utsläpp, RoRo, containertrafik, volymskiften, kostnadsstruktur, kortsjöfart, oceangående

The EU ETS and its Effects on RoRo and Container Shipping

A Comparative Study on the Cost Structure and Volume Shifts

GUSTAV AMUNDSSON
MAGDALENA ANNAORAZOVA

Department of Mechanics and Maritime Sciences
Chalmers University of Technology

ABSTRACT

The shipping industry was recently included in the EU Emission Trading System (EU ETS), as an incentive to reduce emissions from the transport industry. This regulation introduces maritime operators to a new cost structure, through the requirement of purchasing EU emission allowances (EUAs). This policy seeks to promote the use of renewable fuels by increasing the relative cost of using conventional, carbon-intensive fuels.

This thesis examines the impact of EU ETS on the cost structure within the Roll-on Roll-off (RoRo) and container shipping segment and evaluates the potential for volume shifts resulting from the regulation. The study is based on a qualitative approach and is conducted through semi-structured interviews with ten companies, six shipping lines, two terminals and two transport buyers.

The findings reveal that all carriers largely transfer their ETS costs to their customers through surcharges, limiting the impact of ETS. Container carriers benefit from economies of scale and their global operations, which results in relatively low surcharges per transported unit. Likewise, deep-sea RoRo carriers have limited exposure to ETS as only a small portion of their voyages occur inside the regulated geographic scope. However, their customer base and contract length can impose challenges in fully transferring the surcharges. In contrast, intra-European operations, primarily RoRo carriers, encounter greater exposure to ETS costs, due to higher operational speed, sailing frequency and lower capacity utilization. Although these carriers apply different methods to transfer their costs, they are often forced to absorb a portion of the expenses, either by lowering their speed or reducing their net freight rates.

Although container shipping offers lower ETS costs, it is rarely a feasible alternative to RoRo in short-sea shipping due to operational limitations. Consequently, the findings show no significant volume shifts between the segments, as operational differences outweigh the marginal cost impact. However, rising ETS costs could incentivize a shift of low-value, high-volume, and time-insensitive cargo toward container shipping.

Keywords: EU ETS, maritime emissions, RoRo, Container shipping, volume shifts, cost structure, short sea shipping, deep sea shipping

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND TERMINOLOGY

AI	Artificial Intelligence
BAF	Bunker Adjustment Factor
CAF	Currency Adjustment Factor
CO_2	Carbon Dioxide
EEA	European Economic Area
ETS	Emission Trading System
EUA	European Union Allowance
EU ETS	European Union Emissions Trading System
FAK	Freight All Kinds
FEU	Forty-foot Equivalent Unit
GHG	Greenhouse Gas
GT	Gross Tonnage
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
LNG	Liquified Natural Gas
MRV	Monitoring, Reporting and Verification
NOx	Nitrogen Oxides
PM	Particulate Matter
RoRo	Roll on Roll off
SOx	Sulfur Oxides
SSS	Short Sea Shipping
TEU	Twenty-foot Equivalent Unit

1. INTRODUCTION

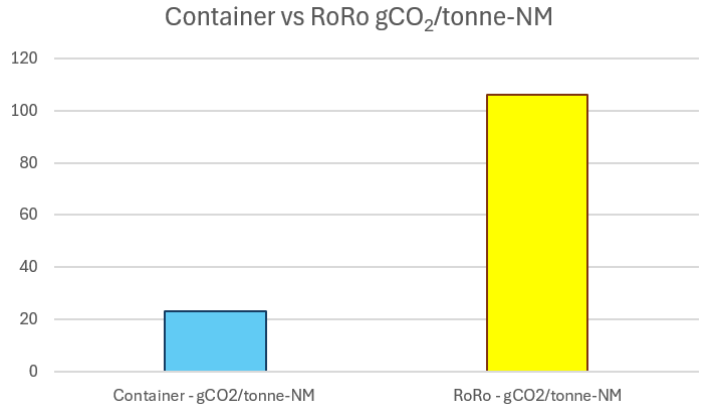
The shipping industry plays a vital role in global trade, facilitating the movement of goods across continents. However, the industry is also a significant contributor to greenhouse gas emissions, accounting for 2-3 % of global emissions (Sun et al., 2024). This impact is a result of the industry's substantial growth, which has led to larger fleets and vessels operating globally. Key drivers, including containerization, globalization and consumerism, contribute to further growth of shipping, creating a growing source of harmful emissions (Notteboom et al., 2021).

According to the European Commission (n.d.-e) the shipping industry within the EU is accountable for 3 - 4% of the overall emissions in the continent. These emissions show a continuous increase throughout the years and according to the International Maritime Organization (IMO, n.d.) the total GHG emissions increased from 977 million tons in 2012 to 1076 million tons in 2018 (IMO, n.d.). Additionally, IMO estimates that emissions could rise to 130% above 2008 levels, which opposes the Paris Agreements. To address the environmental concerns associated with shipping, several initiatives have been implemented to mitigate the impacts through international organizations like IMO, and regional institutions like the European Union (EU). In 2019, the European Commission launched the European Green Deal which includes policies and regulations aimed at reaching climate neutrality by 2050. As part of this initiative, the EU adopted the "Fit for 55" legislation to reach their 2030 target goal - a 55% reduction in emissions (European Commission, n.d.-b). To reach their goal by 2030, fit for 55 decided to strengthen the EU Emission trade system (ETS), by updating and expanding its scope. The EU ETS has since January 2024, covered the emissions from vessels larger than 5000 gross tonnage (GT), entering EU ports, regardless of the vessels flag. The trading system is based on emission allowances, called European Union Allowances (EUA) which shipping operators must purchase for each ton of reported CO_2.

EU ETS entails increased costs for shipping companies operating in the European Economic Area (EEA), and according to Christodoulou et al. (2021) the economic impact will be different among different segments. This means that the high emitting segments will face increased costs, which will be transferred to their customers as a surcharge. Liner shipping is a significant source of CO_2 emissions as the container segment accounts for 29,91% of the total emissions from international shipping (Adamopoulos, 2021). However, in accordance with Christodoulou et al. (2021), the Roll-on Roll-off (RoRo) segment produces approximately four times the CO_2 emissions per transport work compared to the container segment, due to higher fuel consumption per transport work (Adamopoulos, 2021), which can be explained by their normally high transportation speed in contrast of amount of freight.

Figure 1

Difference in transport work and CO_2 *emissions*



Note. Figure 1. The figure shows the gCO_2/tonne-NM for the container segment and the RoRo segment. Data from (Christodoulou et al., 2021).

Liner shipping is characterized by predetermined routes with fixed schedules, which applies for both container- and RoRo operators. The RoRo segment has been identified as the more affected segment in terms of increased costs and volume shifts to other transport modes (Flodén et al., 2024). As RoRo vessels show inefficiencies in fuel consumption per transport work compared to containerships, it creates an opportunity to explore the impacts in correlation to the two segments. This is particularly of interest for the transport buyers regarding the impact which EU ETS might have on customers' decision to choose transport mode, based on emissions of transport work.

1.1 Background

Since the implementation of EU ETS within the shipping sector in 2024, a few studies have been conducted to predict and determine the impact of the trading system on the different segments. As the studies are based on the early stages of the implementation, there is a need for further research on the subject with a more specific perspective. Segments with similar operations, such as liner service providers, have different impacts which might alter trade patterns. Therefore, it is valuable to investigate how EU ETS impacts the cost structure of similar segments and analyze the consequences, such as potential shifts in volume.

Both the RoRo and container segments operate in liner services, transporting cargo according to a set schedule and preplanned port calls. The structural design of the vessels enables similar types of cargo to be accommodated, as containers can be loaded on RoRo using trailers, while cars can be stuffed and transported onboard containerships. Despite interchangeability, other factors, such as time efficiency, are more impactful in decision making. Therefore, transport buyers continue to prefer their designated vessel type for increased efficiency and continuously.

However, as transportation costs increase with the implementation of EU ETS, transport buyers may seek alternative solutions to mitigate these costs. As a result, they may be more inclined to switch transportation segments. To predict such shifts, it is essential to analyze the impact on cost structure and identify the most viable alternatives.

1.2 Aim of the study

The aim of this study is to examine the impact of EU ETS on the cost structure of the container and RoRo segments, and whether the implementation of the EU ETS will lead to volume shifts between the segments. Through interviews with terminals, shipping companies, and transport buyers, along with existing research, the study explores whether transport buyers may switch shipping segments to reduce transportation costs, and how such shifts could impact both segments

1.3 Research questions

This study aims to analyze the following questions:

- How does EU ETS impact the cost-structure of the container segment in contrast to RoRo?
- How will the consequences of the EU ETS influence volume shifts between the container and RoRo segments?

1.4 Delimitations

This study is limited to the container and RoRo segments and will not cover intermodal transport or RoPax vessels. This is due to the similarities between container and RoRo freight, which make them comparable. Furthermore, the research is limited to stakeholders with operations in Sweden and intra-European transports.

2. THEORY

The shipping industry has a long and rich history, shaping and driving global development. Its history is characterized by continuous transformation representing the evolution of trade patterns, technological advancements and economical systems. To manage the continuous expansion and complexity of shipping, a set of regulatory frameworks are required. Classification societies, governments and regulatory bodies like IMO and EU have taken a large part of the responsibility to regulate the shipping industry, to ensure safe and lawful trade. Today, most regulations are aimed at lowering the environmental impacts of shipping (Stopford, 2009).

2.1 Liner shipping and the market

The essence of liner shipping lies in regular scheduled services between ports, with vessels sailing on predetermined dates regardless of whether they are full. This requires a complex organization onshore, consisting of branch offices and specialized departments (Institute of Chartered Shipbrokers, 2018).

Liner vessels are not defined by their size or speed, but rather their function. As long as a vessel operates according to a predetermined schedule, it is considered to be a liner vessel. The most common liner vessels consist of containerships, followed by reefer vessels which carry refrigerated vessels, multipurpose vessels and RoRo vessels (Institute of Chartered Shipbrokers, 2018).

The economy of maritime operations, including liner shipping, is dependent on the demand and supply of their services. This is closely linked to freight prices, as shippers can charge higher prices when demand exceeds supply, as customers are competing for their services. However, when supply exceeds the demand and there is an overcapacity, shipping companies tend to only charge marginal operational costs. Due to its volatile nature, demand can change quickly and unpredictably. In contrast, supply is slower to change and adjust, which decreases the overall predictability of the market (Stopford, 2009).

2.1.1 Container Shipping Segment

The container shipping segment has been a dominant part of liner shipping since the containerization in the 50-60s, when Malcolm McLean introduced standardized units to streamline cargo handling between shore and ship. This increased the efficiency and automation of port operations, and enabled ship owners to leverage economies of scale (Notteboom et al., 2021).

Today, the container shipping segment includes a few large containers shipping companies operating their fleets in liner services. The loading capacity of containerships are measured in number of 20-foot equivalent units (TEU), although the 40-foot container (FEU) has become more common to accommodate cargo. The capacity of containerships ranges from 100 TEU to over 18000 TEU, as demand and geographical limitations determine the number of containers to be transported. The larger vessels benefit from economies of scale, as more cargo can be transported over the same distance and similarly size crew. However, these vessels require significant capital investments which shipowners might not be able to afford,

and it limits the range of available ports. This presents challenges to reach economies of scale and maintain profitability (Institute of Chartered Shipbrokers, 2018).

Container services operate on major trade lanes (East–West, North–South, and intra-regional routes) and often use hub-and-spoke networks, which consists of delivering cargo to major hubs and distributing it to smaller ports through feeder vessels. The demand of goods from Asia to Europe is higher than the backhaul, often causing empty container returns. The imbalance of container flows puts pressure on container lines, impacting their pricing strategies and freight rates. Additionally, as all container shipping companies strive for economies of scale, the market suffers from overcapacity, resulting in intense competition (Park et al., 2024). Mainliners primarily compete on a cost basis, as container traffic has a low differentiation in service levels. In response to this constraint, major container lines have chosen to cooperate through alliances. This strategy strengthens their operational efficiency, reduces costs and mitigates risk exposure by sharing vessel capacity and thereby expanding the scope of services (Lee & Song, 2017).

Containerized trade includes a variety of commodities, which gives a broad market of customers. The commodities range from consumer goods like textiles and electronics, to high value machinery and automative parts. However, due to the intense competition in the market, as well as volatility, container shipping companies often apply freight all kind (FAK) rates, where the same rate applies despite cargo type. Instead, pricing is focused on volume (Institute of Chartered Shipbrokers, 2018).

2.1.2 RoRo Shipping Segment

RoRo, or Roll-on Roll-off, is a specialized market which offers haulage of wheeled cargo. RoRo vessels are designed with large open spaces and multiple decks, which allow cargo to be wheeled onboard or off the vessel through ramps. This reduces dwell time and increases efficiency of cargo handling. Similar to containers, RoRo vessels can transport unitized cargo with semi-trailers and cassettes, which can also be used to transport oversized cargo (Øvstebø et al., 2011). Additionally, most RoRo vessels operate with high departure frequency which results in a fast-moving transport system with connections to intermodal solutions. This is essential for the RoRo segment to be economically viable, as operations can become costly due to lower cargo capacity than containerships. Equipment such as cassettes are heavy, large and expensive which further requires efficient handling and cargo planning (Christodoulou & Woxenius, 2020).

The size and tied up capital of the equipment make RoRo transport less efficient over longer distances. Furthermore, RoRo vessels require higher initial capital costs compared to containerships or feeders. To maintain competitive and economically viability, RoRo vessels must cooperate with port terminals to limit handling costs and time (Christodoulou et al., 2019).

RoRo shipping can be divided into 4 different segments: the deep-sea trade involving global seaborne vehicle transports via Pure Car and Truck Carriers (PCTCs), the deep-sea liner trade with RoRo facilities, known as the ‘ConRo’ submarket, the short-sea RoPax market with ferries to transport cargo and passengers, and lastly the short-sea RoRo market with unaccompanied cargo. This study focuses on the first and last segments (Christodoulou et al., 2019).

The RoRo market is mainly driven by the automotive industry, as newly manufactured vehicles constitute the largest segment of the market. In 2023, the deep-sea car trade reached 23,7 million cars (Notteboom et al., 2021). Trucks, heavy machinery and military equipment are also transported deep seas. On the other hand, shortsea RoRo are smaller in size compared to deep-sea and transports vehicles as well as a large portion of semi-trailers. Due to EU import tariffs, there was a surge of exported cars from China to European ports before they could be subject to the increased tariffs in July of 2024. This led to an overflow of vehicles, in particular electric cars, in European ports which had to expand their operations and even open new car terminals. Today, the global RoRo market consists of a few RoRo carriers with large market shares and fleets (Notteboom et al., 2021).

Although the demand for RoRo services exceeds capacity, the rates are volatile and highly dependent on geopolitical factors, seasonal demand, car manufacturers, vehicle sales, fuel prices and trade agreements. Nevertheless, growing urbanization and an increase of middle class purchasing new vehicles creates an upward trend in the market, especially in the Asia-pacific region as China, Korea and Japan remain as major contributors. Furthermore, there was an expansion of intra-regional short sea RoRo activity, mainly in Europe (Notteboom et al., 2021).

2.1.3 European short sea shipping

Short sea shipping, or SSS, is a term frequently used to describe sea transport between European ports or between European and nearby non-European ports. The RoRo segment has a significant role in SSS, as it offers cost- and time efficient loading and unloading, as well as modal shift. Unaccompanied RoRo are mainly employed in northern Europe, meeting the high demand of transport from machinery and forestry manufacturers (Christodoulou & Kappelin, 2020)

Container feeder vessels operate in intercontinental and intraregional trade, supporting the hub-and-spoke distribution model in SSS. This system enables the transshipment of containers from large deep-sea container vessels to smaller feeder vessels that serve local regions. While container services typically offer weekly services, shippers can attain near weekly services by using multiple shipping lines (Christodoulou & Woxenius, 2020) . However, these services are subject to delays and port congestion, causing capacity fluctuations and extended port time. Therefore, shippers can choose to transport their containers with RoRo vessels to reduce transit time, at a higher freight rate due to lower capacity utilization (Zheng et al., 2021).

In contrast to container services in SSS, RoRo shipping enables efficient integration with intermodal transport, as the same loading unit (semi-trailers) can be transferred door to door. This is particularly attractive for European trade, which gives RoRo and advantage within the SSS segment. These routes act as substitutes for roads and bridges, connecting regions, such as the UK and Scandinavia to continental Europe. However, this is mainly applied to shorter distances, as semi-trailers are less suitable for railway transportation. In contrast to container freight, they are less standardized and require more complex handling equipment (Woxenius & Bergqvist, 2011).

2.2 Cost structure in Liner shipping

The total cost structure of the shipping industry can be divided into three categories: operational costs, voyage costs and fixed costs. Fixed costs, such as capital costs, incur

whether the vessel is in operation or not. Operational costs occur when the ship is active, such as crew wages, maintenance, and lubricants. Voyage costs relate to costs generated from the voyage, such as port- and fuel costs (Stopford, 2008).

Although one of several cost components, fuel costs make up a significant amount of the total costs. Consumption increases with sailing speed, enabling faster transit times yet higher fuel costs. Other affecting factors include the age of the vessel, energy efficiency and fuel type. There is a variety of fuel types, each differing in price and environmental impact (Elgohary et al., 2015).

Bunker costs fluctuate in correlation with crude oil prices. The cheapest options include fossil fuels, such as Marine Gas oil (MGO) and Heavy fuel oil (HFO). While their prices are lower, they are highly pollutant and emit high levels of CO_2, nitrogen oxides (NOx), sulfur oxides (SOx) and particular matter (PM). As an incentive to reduce pollution, fuels such as liquified natural gas (LNG) and methanol were introduced as alternatives (Elgohary et al., 2015). Switching from HFO to LNG can offer cost savings in fuel consumption. However, the high cost of vessel conversion and LNG's limited availability still pose financial challenges. Despite these constraints, LNG significantly reduces emissions, making it a more environmentally sustainable option (Notteboom, 2020).

A common measure to mitigate bunker costs and reduce emissions is by speed reduction, also called slow steaming. This method is frequently used and can be beneficial for carriers when fuel prices increase, or when vessels are on longer routes. According to Sun et al. (2024), speed reduction can significantly reduce CO_2 emissions from liner shipping and be cost effective, only when the speed exceeds 8,29 knots. If the speed reduces below 8.29 knots, the opposite effect occurs.

2.2.1 Chartering costs

Chartering expenses are an additional component of the cost structure. Shipping companies can charter vessels to expand their fleet, depending on the market conditions and demand. The most common type in liner shipping is time charter, where a ship is leased on a fixed period at a hire rate. During a time charter, the shipping company will pay for the fuel and port expenses. Time charter contracts can be costly when vessel demand and market capacity is high, largely due to seasonal changes and the need to replace tonnage (Institute of Chartered Shipbrokers, 2018).

2.2.2 Surcharges

Over time, the structure of freight rates has developed in complexity, primarily due to the use of additional fees called surcharges. Most common types of surcharges include the Currency Adjustment factor (CAF) and Bunker adjustment factor (BAF) which help to compensate for fluctuations in expenses like currency and bunker prices. These fees are added to the quoted base rates, and can vary in amount depending on customer contracts, trade routes and market dynamics. This enables shipping companies to mitigate risks by transferring costs to customers, especially in container shipping where the cycle of demand and supply fluctuate (Slack & Gouvernal, 2011). According to Slack & Gouvernal (2011), surcharges introduce a high level of unpredictability in freight cost forecasting, as well as supply chain planning.

Moreover, surcharges are not always transparent toward shippers and can be unequal based on trade.

2.3 European Union - Emission Trading System

The EU ETS was created in response to the 1997 Kyoto Protocol, which set a legally binding target for the EU to reduce emissions by at least 8% compared to the 1990 emission levels between 2008–2012 (European Commission, n.d.-c). The EU ETS Directive was adopted in 2003, and the system was published in 2005, becoming the first international greenhouse gas emissions trading system (European Commission, n.d.-d).

The EU ETS operates in trading phases and is currently in its fourth phase (2021–2030). Each phase introduces new policies and regulations to reduce emissions. In phase 4, the system was integrated into the Fit for 55 package to align with the EU's net-zero targets (European Commission, n.d.-c) The trading system operates on a cap-and-trade principle, meaning there is a fixed limit (cap) on greenhouse gas emissions covered by the system. Each European Union Allowance (EUA) permits the emission of one tonne of CO_2 equivalent. The EUAs are primarily auctioned but can also be traded on the secondary market, and while the total supply is capped, companies can buy and sell EUA as needed (European Commission, n.d.-a).

As mentioned, EU ETS is a component of the fit for 55, which aims to reduce the emissions by at least 55% by 2030, in comparison to the 1990 levels, and to become completely free from greenhouse gases by the year 2050. The shipping industry was included in the EU ETS in 2024, requiring vessels over 5000 gross tonnages (GT) operating to or from EU-ports, obligated to purchase EUA to operate. However, voyages where either the departure or arrival port is outside of the EEA, they only need EUAs for 50% of their emissions (European Commission, n.d.-d).

Maritime emissions are included in the overall ETS cap, which means that the sector is under the same EUA regulations as other industries. The cap, which is total amount of EUAs, will decrease over time to ensure that the system can reach the EU´s climate goals. In accordance with European Commission (n.d.-e), lowering the cap will lead to a decrease in the price gap between the conventional fuels and the environmentally friendly options. As of early 2025, the price of one EUA is approximately €80 per tonne of CO_2 equivalent. The prices fluctuate based on market conditions (Trading Economics, n.d.)

2.3.1 EU ETS – Maritime sector

The inclusion of the EU ETS in the maritime sector is expected to influence the decision of transport buyers within the transportation chain, in accordance with Flodén et al. (2024). One mentioned effect by Flodén et al. (2024), is an increased shift to intermodal transport, as shipping lines may be avoiding routes to avoid ETS-costs. This means that shipping companies may call ports outside of the EU, in order to avoid the surcharges, which in practice are called evasion ports (Lagouvardou & Psaraftis, 2022).

The primary objective of the EU ETS is to accelerate emission reductions within the EU and EEA regions. To promote investments in greener fuels and emission reduction, the EUA prices must increase to a level comparable to low-carbon alternatives, to ensure that higher costs will encourage shipowners to transition to cleaner energy sources (Flodén et al., 2024).

To ease the transition, the EU has implemented a phased approach between 2024 and 2026. As opposed to an immediate full compliance, the target is introduced and increased across a period of three years to prevent any market shocks. By 2026, shipping companies will be required to purchase EUAs for 100% of their emissions, with a granted exception for routes involving one EU port call (European Commission, n.d.-e). This gradual implementation gives the industry time to adapt to the new regulations, ensuring a steady move toward full compliance with the EU goals.

Christodoulou et al. (2021) reports that the container sector accounts for 44.3% of total emissions, while the RoRo sector contributes to 6.2%. This indicates that the container sector requires a larger allocation of EUAs than the RoRo sector. However, the emissions per transport work in the container sector is 23,2 gCO-2/tonne-NM, compared to the RoRo sector with 106,2 g CO_2/tonne-NM. As stated by Christodoulou et al. (2021) the RoRo sector is the least energy efficient maritime segment, implying that it will require a higher number of EUAs per unit of transport work. The study also highlights that the EU ETS will impact maritime sectors disproportionately, with the RoRo segment being particularly affected because of their high fuel consumption, compared to the volumes transported.

3. METHODS

This study was conducted as qualitative research to analyze and evaluate the impact of EU ETS on the RoRo segment compared to container segment, with a focus on cost structures and potential volume shifts. According to Denscombe (2018), qualitative research is characterized by the use of written sources or visual images to analyze studies with a comprehensive approach. This type of study can be done through different methodologies, based on the selected approach to data collection. As the aim of this study is to analyze a new regulation in an environment with limited former studies, semi-structured interviews were chosen as the most appropriate method of collecting data as it would give real life data from representatives of the studies areas (Denscombe, 2018).

This study used a survey-based approach to gather the necessary data for analysis. A survey allows for the integration of various research strategies, with interviews serving as the primary source of information. As noted by Denscombe (2018), face-to-face surveys facilitate more in-depth information gathering, which is why interviews were chosen for this study. This approach allows for real-life insights from representatives within the studied industry. Although prior research was limited, the published studies were analyzed and informative to construct the theory section of this paper.

3.1 Interviews and sampling

Interviews were conducted as a method of collecting data, which aligns with the survey methodology. In order to receive relevant and suitable data, at least two interviews were conducted within each of the four sectors included in the study, as shown in Table 1. The sectors are all within the maritime shipping industry, with significant impact in container and RoRo segment. The sampling of the interviews was mainly based on convenience, as there were limitations in time and other resources. Company representatives with suitable roles and experience, primary located in the Gothenburg area, were asked to participate in the interviews. To complete the sample, the snowball method was applied, where new interviews were conducted based on references provided by the informants, which led to more interviews as seen in table 2 (Denscombe, 2018).

Before any interviews could be carried out, consent from each participant was required, using a pre-designed template. This provided transparency to all interviews and ethical data collection.

Table 1
Distribution of Interviews by Sector and Sampling Strategy

Sector	Convenience	Snowball	Total
Container shipping Company	2	1	3
RoRo shipping Company	2	1	3
Port terminal	2		2
Transport buyers	1	1	2

Note. Table 1. The table shows the four sectors that were included in the study, and the number of stakeholders included in each sector.

Table 2
Transport operators and their scope of services

Respondent	Scope
Container Carrier 1	Deep-sea container services, mainliner
Container Carrier 2	Deep-sea container services, mainliner
Feeder operator 1	Intra-European feeder services (SSS)
RoRo Carrier 1	Deep-Sea RoRo services
RoRo Carrier 2	Intra-European RoRo services (SSS)
RoRo Carrier 3	Intra-European RoRo and container services (ConRo)
Terminal 1	RoRo
Terminal 2	Container
Transport buyer 1	Freight forwarder
Transport buyer 2	Cargo owner

Note. Table 2. The table shows the respondents and their scope of operations. RoRo carrier 3 has ConRo services as well, however, the collected data was focused on their RoRo services.

3.1.1 Structure of the interviews

The structure of the interview included seven main categories, background and introduction, adaptation, pricing and costs, volume shifts and customer behavior, transport changes and limitations, alternative fuels and environmental measures, and future prospects and market changes. Each category contained several questions designed to collect relevant insights, and every category was given a color in order to organize the data. While the main categories remained the same through all the interviews, the asked questions were adapted based on the specific sector. According to Denscombe, (2018) the color-coordinated categories are part of thematic analysis method. A thematic analysis is a qualitative method that is used to analyze patterns in the research findings.

The interviews were primarily conducted using predesigned questions. However, to obtain the needed insight, the questions were adapted during the interviews, with the aim of finding the appropriate and relevant answers. This method is referred to as semi-structured interviews, which increases the scope of questions by exploring broader topics. This is useful when the number of interviews with a representative is limited, and when the research question is exploratory in nature (Denscombe, 2018). Due to the complexity of the research questions and the variation of stakeholders, the length of the interviews varied, typically lasting between 45 and 75 minutes.

3.1.2 Transcription

The interviews were recorded and transcribed. This allowed full focus during the interviews, and eliminated potential human errors, such as mishearing or missing important details. The recordings were reviewed and transcribed by the assistance of Klang AI. The transcribed text was color-coordinated according to the mentioned categories, to organize and identify relevant data and patterns. This ensured a clearer comparison between the stakeholders.

3.2 Literature

To obtain necessary information regarding the study, a literature review was conducted (Denscombe, 2018). To identify relevant sources for the study Google Scholar, Chalmers Library, and Scopus were used. The platforms provide options to filter for peer reviewed studies, ensuring reliability and academically reliable sources. Key words were used to search information, such as liner shipping, Shipping EU ETS, RoRo shipping, container shipping, liner shipping emissions, European shipping segments, short sea RoRo, feeder.

3.3 Artificial intelligence (AI)

To obtain accurate information on the subject, Scopus AI was utilized. This built-in AI within Scopus assists researchers in finding relevant sources (Elsevier, n.d.) To manage the transcription process, Klang AI was used to transcribe the interviews. Before any usage of AI on the interviews, consent from the stakeholders were received. Klang AI is a tool focused on transcription and communication, enabling a more structured and efficient analysis of the collected data (*Klang.Ai*, n.d.). Chat GPT – OpenAI was used for grammatical correction and language refinement during the writing process, without any changes to the written information or collected data.

4. RESULTS

This section of the report presents the information obtained from the conducted interviews. The results illustrate the impact of EU ETS on the cost structures within both RoRo and container shipping, based on the perspectives of shipping companies, terminal operators and transport buyers. The aim is to highlight how the cost is perceived across different levels of the supply chain, presenting a multiangled view. Additionally, this section includes information regarding potential volume shifts.

4.1 EU ETS costs in container shipping

This section presents the effects of the EU ETS in container shipping, based on interviews conducted with three container shipping companies: two global carriers and one intra-European feeder operator. A common perspective among the global container carriers is that the EU ETS represents a relatively minor cost component in comparison to other operational expenses. While the feeder carrier primarily agrees with this assessment, they point out that intra-European services encounter greater constraints, which is presented in section 4.1.1.

Global container carriers 1 and 2 apply a similar strategy for managing the expenses from purchasing EUAs by incorporating these costs into customer quotations. As a result, the expenses from EU ETS are not absorbed by the carriers but are instead transferred to the customers as an ETS surcharge. For deep sea routes, which operate between European ports and third countries, only a portion of the voyage is subject to EUA allowances, minimizing the significance of the expenses to global container carriers. Additionally, due to the high number of containers transported per vessel, the surcharge per TEU remains minor as the total cost is distributed across several units and customers. To calculate the ETS surcharge, both carriers utilize historical data to estimate the cost per TEU, which is then applied to customer contracts. These quotations are adjusted quarterly to reflect the changes in allowance prices. However, some larger customers with long-term contracts prefer a fixed, all-in price rather than a separate surcharge. In such scenarios, the carriers perform more complex calculations to ensure that the determined price adequately reflects the variations in allowance pricing over extended periods.

When discussing the use of alternative, more sustainable fuel, both carriers explain that the customers are given a choice to either pay the ETS surcharge or opt for a more expensive transport powered by environmentally friendlier fuels. While using these fuels often removes the need to purchase EUAs, their costs generally exceed that of the ETS itself. In practice, most customers still choose the cheaper options, which often means a higher emission alternative. Container carrier 2 reveals that some container carriers offer customers the option of transshipping the cargo at evasion ports, thereby reducing the portion of the journey subject to ETS regulations.

Both container carriers do emphasize that their customers demand transparency in ETS cost and surcharge calculation to conduct contract negotiations and integrate the pricing in their internal cost structure. However, this level of transparency is complex as the EUA pricing fluctuates depending on various factors, such as vessel size and trade pattern, which requires separate and customized calculations. Despite this uncertainty in cost estimations, neither container carrier has experienced significant financial loss or gain as a result of the surcharges. The overall experience from both carriers is that the customer sensitivity to the ETS surcharge remains low, with most customers focusing on the total transportation cost, rather than detailed

breakdowns of surcharges. Given the volatile nature of container freight rates and tariffs, customers are generally more accepting of the additional surcharges, especially since container transport remains the most cost-effective mode intercontinentally. The combination of basic ocean freight and ETS surcharge will still be less expensive than a substitute between Europe and other continents. As a result, ETS costs are not a decisive factor for major changes in customer preferences or volumes at present. However, the carriers note that an expansion of ETS coverage to 100% of emissions might pressure customers to choose more sustainable fuel or find alternative routes to mitigate the costs. Nonetheless, the consensus among container carriers 1 and 2 is that the current ETS cost are insufficient to their profit margins, even in cases of miscalculation. Instead, other costs such as chartering prices are perceived as more critical for the cost structure

4.1.1 EU ETS costs for short sea container shipping

The feeder operator operates exclusively in intra-European container traffic and reports that the financial impact of EU ETS is relatively limited, similar to the experience of deep-sea container shipping companies (container carrier 1 and 2). Although the ETS costs increase with the number of European port calls, the overall financial impact is a minor portion of the total operational costs. To manage the expenses, the feeder operator implements a three-level surcharge structure according to theoretical distances and port pairs. These surcharges are transferred to their customers, which exclusively include global container carriers. The acceptance of the surchargers has been extensive, as the obligations of ETS apply equally to them.

When comparing the ETS surcharge enforced by the feeder operator with that of the global container carriers, the former is higher due to greater exposure to European ports and smaller vessel capacity. While global container carriers can allocate ETS costs across larger number of customers and containers, the feeder operator has a more restricted foundation for cost allocation. According to the feeder operator, obstacles can arise regarding the calculation methods, as well as the transparency of surcharges. Since global carriers apply similar calculations, any discrepancies will be subject to complaints. To minimize such disputes, the feeder operator continuously purchases EUAs and adjusts the surcharges according to actual EUA purchase costs, rather than relying on historical data. This measure aims to prevent generating profits or incurring losses from the applied surcharges. Although the surcharge itself is accepted by the mainliners, the actual amount is often subject to negotiations. The feeder operator outlines that mainliners can argue for lower surcharges, referencing capacity maximization as a basis. If the capacity utilization is low, the ETS surcharge is higher per TEU, which gives mainliners grounds to challenge the sum. Therefore, the feeder operator may settle for lower surcharges than the actual cost incurred and absorb part of the expense. Nevertheless, the cost implications arising from these concessions are regarded as minor and not material to their overall operations.

4.1.2 Container transport buyer perspective on EU ETS Costs

Based on the information provided by transport buyers 1 and 2, they exclusively procure deep-sea container services. One of the transport buyers handles nearly all inbound shipments via containerships, mainly originating from Asia.

Both buyers confirm that container carriers apply an ETS surcharge. Transport buyer 1 accepts the surcharges and the pricing model, as they impose the same approach by passing

the cost onto their own customers. Transport buyer 2, however, offers further insights regarding the negotiation process of the surcharges. They explain that container carriers adopt a single sided approach, attempting to pass 100% of the ETS costs onto them as buyers, which often instigates negotiations. The possibility of negotiating the surcharge mainly depends on prevailing market conditions, as markets with higher competition among carriers give transport buyers greater leverage to reduce the surcharge. Nonetheless, carriers generally present a unified stance regarding the surcharge, making significant reductions challenging.

The cost impact of the EU ETS on deep-sea container companies varies on a per-container basis depending on whether the route is from Southeast Asia or from Europe. Demand for containers fluctuates significantly depending on whether the destination is Europe or Southeast Asia. According to container carrier 2, the price per container on routes towards Europe can reach above USD 3000 because of the high demand for Southeast Asia-Europe trade. However, in Europe-Southeast Asia, where the demand is significantly lower, the cost per container could reach USD 75. The ETS cost for these alternatives will remain the same, while the percentual difference will be significant.

4.2 EU ETS costs in RoRo shipping

This section presents the effects of the EU ETS in RoRo shipping, based on interviews with three RoRo shipping companies: one deep-sea carrier, one short-sea carrier and one short-sea carrier with both container and RoRo services. The short sea RoRo carriers will be further reported in section 4.2.1.

RoRo carrier 1 reports that EU ETS has had a marginal impact on their cost structure, mainly due to their intercontinental services with a high number of cargo units transported over long distances. Similar to deep-sea container carriers, only a portion of the voyage is exposed to the scope of ETS. As a result, the ETS-related costs accounted for less than 1% of their total revenue in 2024, a level which is considered manageable. To lessen the impact, they apply separate ETS surcharges to their customers. This surcharge is comparatively smaller, ranking around third or fourth in size. As the ETS cost accounts for only a small portion of the net freight, there is overall acceptance from customers. However, as approximately 20% of their customers generate 80% of their revenues, the ETS expenses can be more significant for their largest clients with high volumes.

The issue of customer size was highlighted when questioned about potential difficulties in transferring all ETS costs, along with contract lengths. Long-term contracts, which are common for deep-sea RoRo shipping, can make it difficult to implement new surcharges during the contract period. Shorter contracts, or spot customers, are more common in container shipping and are more likely to accept new surcharges. Furthermore, larger customers have greater negotiation leverage, meaning that the carrier must sometimes adapt their ETS calculations to meet customer expectations, which might result in minor losses. Although some customers have refused to accept the ETS surcharge due to contract terms or their high volumes, the overall financial impact remains unsignificant compared to their revenues.

RoRo carrier 1 also notes that their ability to manage ETS costs is mainly due to their deep-sea services, and that short-sea RoRo carriers are more likely to face significant impact from

the ETS scheme. Additionally, the intended expansion of the ETS scope to 100% coverage in 2026 could further increase the impact on deep-sea voyages.

4.2.1 EU ETS costs in short sea RoRo shipping

RoRo carriers 2 and 3 exclusively operate intra-European RoRo services, with daily departures from several European ports. Both carriers adopt a similar surcharge approach, passing their EUA purchasing costs to their customers. The surcharges are separate and not imbedded in the overall freight rates. Currently, the surcharge attributed to ETS accounts for approximately 3-5% of the total freight cost, which is a significant increase in an industry characterized by tight margins.

RoRo Carrier 2 explains that their surcharge calculations are based on forecasted cargo volumes, actual CO_2 emissions and EUA market prices. The surcharge is then structured per lane meter and ranged between 3-4 Euros at the time of the interviews, corresponding to 30-40 Euros per trailer, depending on routing. Given that RoRo customers ship multiple trailers at the same time, the cumulative surcharge becomes substantial. However, the carrier explains that all customers have accepted this surcharge due to a lack of realistic transport alternatives and fuels. The carrier has made great efforts to maintain transparency and proactive communications, to prevent any disputes.

While customer acceptance has not presented a major concern, RoRo carrier 2 reveals that the greater challenge lies in meeting the targeted and assumed volume utilization, which the surcharge calculations are based on. When actual volume utilization falls short of expectations, the cost per lane meter increases, causing the carrier to absorb part of the ETS-related expenses. While they can adjust future surcharge levels to account for such discrepancies, these under-recoveries are described as a commercial risk inherent to carriers.

RoRo carrier 3 similarly bases their ETS surcharges on emission volumes and EUA market prices, adjusting the rates quarterly. Since they operate ConRo vessels, they apply a uniform surcharge structure across both containerized and RoRo cargo, enabling some risk sharing between the cargo types. As they face strong competition from land transportation modes, they reveal that their freight rates must remain competitive overall. When the ETS surcharge increases significantly, they might be forced to lower their net freight to maintain competitiveness, and thereby negatively affect their profit margins. This dynamic is particularly critical for low-margin cargo types, such as forestry cargo, where transport costs account for a considerable portion of the total end cost. In contrast, high and heavy cargo or high-value cargo, such as heavy machinery, are less sensitive.

RoRo carrier 2 and 3 both highlight that customers with longer contracts and volumes possess greater negotiating leverage, making it more difficult to fully pass the ETS surcharges to them. Consequently, the economic exposure is higher for RoRo operators with high dependency on a few key accounts.

Finally, both carriers have implemented slow steaming as a measure to decrease CO_2 emissions, and thereby their EUA requirements. Although this approach contributes to mitigate the rate of customer surcharges, it has met some customer discontent. However, the carriers explain that this measure does not affect the transit times, only the scheduled departures, but do agree that it might lessen their negotiation leverage. Another measure to

decrease their emissions is by providing the customers with the choice of using renewable fuel for their transport, similar to other carriers. Nonetheless, they reveal that this option is more costly than ETS surcharges, and the demand for alternative fuels is therefore limited. Only a small percentage of RoRo carrier 3 customer base have chosen this option.

4.2.2 RoRo transport buyer perspective on EU ETS

The transport buyers' experience of ETS surcharges from their container shipments and RoRo shipments mostly align with the responses provided by the carriers. As mentioned, their container shipments involve long-distance trade, which makes ETS surcharges more manageable and widely accepted. When discussing RoRo shipments, however, both buyers agree that the ETS surcharge is significantly more substantial. Transport buyer 2 states that ETS surcharges on RoRo shipments have become a major challenge, especially considering cost predictability and long-term budgeting. While the additional costs are still being managed, there is a concern that future expansions of the ETS coverage could pose significant difficulties in transport models.

Both buyers emphasize that transparency and accuracy of surcharge calculations is critical, as they require detailed and predictable cost breakdowns to integrate the expenses into their internal logistics and financial planning. Transport buyer 1 particularly highlights that the cost calculation of RoRo shipments is more complex than container shipments, due to the multimodal nature of the transport chain.

Both buyers agree that the future expansion of ETS scope to 100% coverage will challenge the current ability to absorb costs, where freight margins are tighter and transport chains more complex. RoRo transporters face greater risk of competitive pressure from alternative routes, until 2027 when EU ETS expands to road transport.

4.3 Comparison of EU ETS impact on cost structure

Among both RoRo and container deep-sea carriers, the cost impact of EU ETS is relatively minor, due to the long distances traveled and the high volume of transported units. However, according to interviews with container carrier 2 and RoRo carrier 1, the container carriers are generally more successful in transferring the ETS surcharges. This is facilitated by the highly competitive nature of container shipping, the use of spot markets, and the industries accustomed response to freight volatility. Consequently, the introduction of an additional surcharge is not unusual and does not face major resistance from customers. In contrast, the deep-sea RoRo carrier face negotiation pressure when implementing surcharges, due to their long-term contracts with major industrial clients. This results in occasional cost absorption. However, the interview suggests that the cost is minor in comparison to the overall operation cost and profitability.

In SSS, more distinct differences emerge between the segments. For SSS container transport, the impact of ETS is moderate, as container shipping markers apply consistent practices globally, using similar calculations and formulas. SSS Roro carriers, on the other hand, face distinctive challenges. They compete directly with road transport modes, which currently do not face equivalent carbon pricing legislation. This competitive pressure constrains RoRo carriers' ability to increase net freight, even when ETS expenses rise. Additionally, SSS RoRo carriers use different approaches to calculate their ETS surcharges, which can be

complicated due to their complex pattern of frequent port calls, variable cargo types and higher CO_2 emissions per transport work.

Although both segments can face miscalculation of surcharges, SSS RoRo carriers are subject to higher losses than container carriers. There are two primary reasons: RoRo shipping emits more CO_2 per transport work, and RoRo vessels carry fewer units compared to containerships. Each miscalculated unit might impact more, particularly since 100% of their voyages are in the scope of ETS. In contrast, SSS container operators have either first or last mile services on behalf of mainliners. Therefore, their customers range from 15 – 20 deep-sea container carriers which operate on the same terms, thus minimizing disputes and making cost recovery more predictable.

4.4 Volume shifts between RoRo and Container

This section presents the finding regarding potential volume shifts between the container and RoRo segment as a result of EU ETS, based on the interviews conducted with the respondents listed in table 1. As container shipping generally incurs lower ETS costs than RoRo carriers, the objective is to examine whether RoRo cargo could shift toward container shipping.

A common experience among all respondents is that no significant volume shifts have occurred thus far as a direct consequence of EU ETS costs. Although some volume adjustments have been reported due to factors such as capacity shortage, port congestion, and other operational disruptions, EU ETS has not caused customers to change transport mode, according to all respondents.

The primary identified is that EU ETS related surcharges is not sufficient enough to pressure customers to forgo the fast transit times and door-to-door services offered by RoRo transports. According to terminal 1 and transport buyer 1, many customers are reluctant to change their logistical solutions as long as the costs are considered acceptable. Furthermore, although ETS surcharges are higher for RoRo SSS, it often remains the most cost-effective alternative when considering the entire transport chain. Container shipping includes additional costs related to stuffing and unstuffing, crane operations and handling, whereas trailers enable easier transfer between road and sea, reaching final destinations through trucks. If the cost of RoRo transport were to become excessive, it is more likely that customers would shift toward road transport rather than container shipping.

Regarding high value cargo, such as newly manufactured cars, there is hardly any incentive for a modal shift to containerized shipping, as a result of EU ETS. Both transport buyer 2 and RoRo carrier 2 highlight that, while second-hand vehicles are sometimes shipped in containers to other regions, newly manufactured cars are unlikely to shift due to the operational challenges and risks associated with loading and transporting in containers. It is both time consuming and the potential of damage is higher than loading it onboard RoRo vessels. Instead, the focus will be on more sustainable transport and pushing shipping companies to use greener fuels to reduce EU ETS costs. While this still results in higher costs, it will be more reasonable than opting for container transport to mitigate expenses.

A significant share of RoRo cargo consists of forestry goods, which are defined by low value but high volumes. RoRo solutions offer fast and efficient handling of such cargo, which is

highly valued by customers. However, due to their low value, these goods are more sensitive to increased transport costs. Several respondents, including RoRo carrier 2 and 3, highlight that if ETS costs continuously increase, there is a possibility that certain volumes of forestry products could shift toward container transport, given that container transport offer lower surcharges.

When discussing the ability to shift from trailers or cassettes to containers, terminal 1 explains that the terminal infrastructure is well adapted to support such operations. In fact, the respondent reveals that they have experienced higher volumes of goods which they restuff to containers and transport to the container terminal. However, it remains unclear whether this increase in volume is connected directly to the implementation of EU ETS. In contrast, terminal 2 reports that volumes have remained as before, with no changes.

To conclude, the interviews do not reveal that any volume shifts have occurred in response to higher ETS costs. However, if the EU ETS cost continues to increase and reaches a level which disrupts the logistic chain, some low-value and non-time sensitive cargo might switch to container traffic.

5. DISCUSSION

In this section of the report, the insights of the study will be analyzed in relation to previous research. The presented results will be examined in light of the research question, with further reflections from both environmental and technical perspectives. Finally, the methodology and its implications will be further discussed in section 5.3.

5.1 The implementation of EU ETS and its impacts on Container and RoRo shipping

This study offers a nuanced insight of how the EU ETS both in the container and RoRo segments, focusing on two primary dimensions: changes in cost structure and the potential of volume shifts between the segments. As for the first dimension, the findings indicate that no immediate transformations have occurred. Instead, the finding points to an early stage of adaptation, where all carriers have been able to pass on their costs without significant obstacles. However, when comparing the segments based on trade routes, the dynamics become more nuanced. Short sea RoRo carriers face more difficulties due to their expose, while deep-sea RoRo experience minimal impact. This distinction is significant, especially in comparison to previous research, as this kind of detailed observation is not included. While it is stated that RoRo segment will face greater challenges due to their fuel consumption, it is important to take their exposure into consideration. In that case, the impact of EU ETS is more nuanced due to these differences, as well as other impacting factors such as competition with road transport. Nevertheless, the overall insights still support the fact that RoRo carriers still face higher EUA costs than container transport, which is supported by Christodoulou et al. (2021) in the theory.

Subsequent findings suggest a further nuanced relationship between market demand and the carrier's ability to transfer ETS surcharges. As outlined in the results, the level of cost transfer is closely related to supply and demand dynamics. Carriers benefit the most when customer demand exceeds supply (vessel capacity), as this increases their leverage to impose higher freight rates and surcharges. While this applies to both RoRo and container markets, Institute of Chartered Shipbrokers (2018) and the results suggest that the container market is significantly more volatile. This is particularly evident in rate fluctuations between main- and backhaul routes, as net freight can vary by thousands depending on direction and capacity utilization. This also applies to empty container repositioning, as containers are occasionally shipped empty to ensure availability at other ports. These imbalances in freight and demand show that the ETS surcharge can constitute different proportions of total freight costs depending on the specific context. On high demand routes, the ETS surcharge may account for a relatively small share of the total cost. On the other hand, low-demand routes such as Europe – Southeast Asia backhaul, the surcharge may constitute a much larger share of the freight, in some cases even exceeding it.

Such uneven terms can result in both strategic flexibility and risk. For premium cargo on demanded trades, the surcharge may be absorbed without friction. In contrast, price-sensitive cargo on low-demanded routes is more affected, and introduces potential risk of cargo

diversion and route restructuring. This finding is particularly relevant in the context of this study, as it shows how regulations such as EU ETS must be viewed through a broader lens of pricing dynamics and the constraints of supply chains, that together determine the response to these costs.

5.1.1 The objective of EU ETS

As mentioned by European Commission (n.d.-d), EU ETS was implemented in the maritime sector as part of the EU's broader effort to mitigate greenhouse gas emission from transportation. This study is designed to determine the practical implications of this regulatory measure on two segments in liner shipping to assess whether the intended environmental effect is being accomplished. The results indicate that both segments are required to purchase EUAs and primarily transfer the costs to their customers. However, it is suggested that the overall impact appears to be limited at this stage. As the results point out, global container carriers report that the surcharges are too marginal to influence customer demand for sustainable fuels. The same applies for RoRo operators, particularly short sea shipping, where road transport is a viable alternative as they are not yet subject to EU ETS. The results indicate that shippers and cargo owners are faced with a decision between increasingly expensive and slower RoRo transports, and road transportation, which remains outside of the regulation despite being more emission intensive.

From an environmental perspective, these findings raise concerns. The current structure of EU ETS can unintentionally encourage modal shifts toward road transportation within Europe. RoRo shipping, which is generally more energy efficient than road transport, is put at a competitive disadvantage, which aligns with the previous findings by researchers, such as Flodén et al. (2024).

As for alternative fuels, such as LNG, the results reveal that the demand remains low. Although these fuels reduce emissions, and consequently surcharges, customers prefer to pay for ETS rather than paying a higher freight rate for greener fuels. This can be explained by the current cost difference, as the surcharge imposed by ETS is still lower than the cost of operating on renewable fuels.

5.1.2 Cost effective measures as a result of EU ETS

Due to the limited customer demand for alternative fuels, the results reveal other measures which carriers implement to mitigate their emissions and associated costs. The findings show that short sea RoRo carriers slow down their sailing speed as a respond to ETS expenses. While sailing speeds are reduced, the transit times have not increased according to the result. This suggests that while the vessel is longer at sea, the terminals are expected to compensate by reducing port call times to maintain their scheduled service interval. This puts additional pressure on terminal operators to work more efficiently, as any delays could force the vessel to fail their schedule or increase their sailing speed again. Additionally, previous research by Sun et al. (2024), indicated that there is a threshold for slow steaming, where sailing speed below 8-10 knots can lead to higher fuel consumption and increased CO_2 emissions. Therefore, speed reduction as a strategy is only effective up to a certain point.

In the container segment, vessels already operate at slow sailing speed due to longstanding fuel optimization practices, therefore, carriers explore other strategies. As highlighted in the

result, some container carriers can offer transshipment options in evasion ports, such as North America, since they most likely already have services there. In doing so, fewer EU port calls are needed, which reduces ETS exposure. While this lowers costs, it undermines the hub-and-spoke design that mainliners rely on and introduces new operational challenges. The transshipment hubs outside of the EU must have sufficient infrastructure to handle a potential increase in volume. Otherwise, issues such as congestion can be exacerbated. Moreover, shifting transshipment hubs outside of the EU and thus relocating emissions does not align with the purpose of EU ETS, which is to decarbonize shipping. Consequently, while these measures may offer some economic relief, they risk leading to operational disruptions and undermining the environmental goals of the EU.

5.2 Volume shifts in between the segments

The second dimension of this study includes the insight of potential volume shifts between the container and RoRo segment as a result of the imposed ETS surcharges. Due to the findings showing that RoRo has lower fuel efficiency and thus higher ETS costs, the objective is to analyze if RoRo customers might choose container shipments as they lower economies of scale.

Similar to the insight regarding the limited customer demand for alternative fuels, the current level of ETS surcharges appears insufficient to influence shifts in trade patterns. Transport buyers are generally unwilling to redesign their supply chains based on the surcharges, as their existing logistical solutions remain the most cost-efficient when considering the entire transport chain. This insight is important as it shows a broader reluctance among certain industries to adjust established routines, particularly where RoRo solutions offer competitive advantages.

As highlighted by Christodoulou & Woxenius (2020) and supported by the interview results, RoRo shipments are prioritized for their high departure frequency and fast, door-to-door solutions. This allows customers to minimize the time which their capital is tied-up during transit, which is important for high-value goods or those requiring rapid turnover. Additionally, using trailers in RoRo shipping provides smoother intramodality and can be transferred between road and sea without complex handling procedures. In contrast, containerized logistics, especially in intra-Europe trade, face further challenges such as high costs and complexity associated with modal transfers, repeated terminal fees and logistical difficulties of repositioning empty containers. While container operations offer significant intermodal advantages on global trade routes, intra-Europe transports experience this benefit to a lesser extent, especially considering the last-mile delivery planning. Empty container repositioning adds to the complexity, as shippers and carriers prefer filled units to avoid any profit loss. This issue can be avoided by trailer operators, as empty trailers are more flexible to handle and require no crane operations, resulting in easier integration into supply chains. For this reason, these benefits outweigh the current ETS surcharges.

The findings suggest that one category of cargo that may be sensitive enough to increasing costs to consider a shift from RoRo to container is forestry products. Due to their lower margins, the cargo is particularly vulnerable to rising transport costs, such as ETS surcharges. Given that forestry products are moved in larger volumes and often through regions with rail infrastructure, a shift to containerized logistics is already feasible. With rising ETS costs, it could become economically feasible to implement a modal shift, as the necessary

infrastructure already exists. However, as previously highlighted, such a shift is less likely to occur during current ETS pricing.

As noted in previous research by Flodén et al. (2024), a modal shift from RoRo to road transportation is more probable than a shift between RoRo and container transports. This trend can be linked to a current regulatory imbalance, as road transport is not included in EU ETS as of yet. As a result, in some cases, road freight operators are required to purchase EUAs, the competition between the modes might become more balanced. At the same time, this could present new challenges for RoRo based transportation. Door-to-door trailer transport including sea and road transport would be subject to ETS through the entire chain. This may raise concerns for industries relying heavily on unaccompanied trailer services.

The EU´s aim with the EU ETS is to charge the vessel operators for their emissions, with the intention to use this revenue to invest in greener and more sustainable transport solutions. By regulating the maritime sector through EUA´s, the EU is increasing operational costs for polluting activities. However, since the road transport, especially road haulage, is not yet included in the ETS, the implementation of ETS to the maritime sector may lead to consequences that were unintended. As explained in Flodén et al. (2024), and highlighted in the interviews, the modal shifts are a risk that can be expected due to the delayed inclusion of road transport in the ETS, which could potentially make the road transport more cost efficient than the maritime alternatives. Road haulage is generally less energy efficient compared to RoRo, which makes it less beneficial in terms of emission per transport work. The unintended consequences may lead to an opposite effect in the climate and the ethical objectives in the ETS.

5.3 Method discussion

The methods applied in the study were carefully chosen to analyze the impact of the two dimensions: changes in cost structure and the potential of volume shifts between the segments. Denscombe (2018), explains that a qualitative method collects data through the engagement of the stakeholders. The qualitative approach was used because of the lack of prior research studies, and to be able to understand how the logistic stakeholders act on behalf of the newly implemented regulation of the EU, and in order to collect reliable and in-depth data.

Using interviews as the primary source of data collection is a good alternative in order to gain insights in real-life perceptive. The interviews were used as a data collection method due to the limited availability of prior research on the topic. However, a risk associated with interviews is that the participants present insights that reflect what they want the researchers to collect. In order to avoid misguidance and biased insight, the conducted interviews were carefully chosen to include all parts of the logistics chain. This enabled a more nuanced set of findings with the possibility of analyzing them from different perspectives.

5.3.1 Interviews

Prior to the interviews, the participants received a document which they were required to sign. The document informed about the ethical guidelines and conditions of the study. By signing the contract, the participants consented the researchers to use the collected data from the interviews, given that the participants remain anonymous.

The interviews were conducted through semi-structured interviews, which allowed for further adjustments depending on the stakeholder. Although this adjustability enabled more appropriate approach to each respondent and in-depth questioning, there is a risk of inconsistency and out-of-scope answers. A consequence of the semi-structured interviews was the extended time, with some recordings lasting up to 75 minutes. This resulted in both a time-consuming transcription process and complicated the analysis of multiple interviews during the given time frame. While useful and applicable data was collected, additional inapplicable and irrelevant data was also transcribed, which required detailed filtering.

Furthermore, given the wide range research of this study, additional participants are required to get a realistic and accurate result. While the participated respondents in this study are major companies in their respective area, the data can be single sided since 2-3 representatives from each sector was chosen. Additional carriers, transport buyers and terminals might have other important insights, which could further elaborate the result. Nonetheless, given the respondents are major corporations with leading roles in their markets, their given data is valuable and represents the broader scope of the current market.

5.3.2 Sampling method

The chosen sampling method was convenience sampling, aiming to gain insights from stakeholders within the researched area, given that the stakeholders interviewed have operations in greater Gothenburg. The convenience method is an approach that relies on the companies that we have successfully contacted, without any replies, this thesis would not have been possible. It is also worth noting that companies within the maritime sector in the Gothenburg region are open to participate in university research projects, which enabled the sampling process. However, a key delimitation of the study was the focus on companies operating within the Gothenburg area, which limited the sample size. Furthermore, the EU ETS is a newly implemented regulation from the EU, prior research is limited. Ideally, the study would be achieving more accuracy with a greater sample size and a wider geographical range.

Moreover, to broaden the range of perspectives the respondents were asked to provide recommendations on additional companies to interview. In cases where respondents had limited experience or insight on certain topics, they would refer the question to a more knowledgeable stakeholder. As a result, the snowball method was applied, which provided additional perspective and helped complete the picture.

6. CONCLUSION

This study sets out to assess the impact of EU ETS on the cost structure of the RoRo and container shipping segments, and to analyze if this impact could lead to potential modal shifts between the segments. The analysis is based on interviews with stakeholders across the RoRo and container supply chain.

The study has identified that the costs related to purchasing EUAs have not had a significant impact on either segment at the current pricing level. In both cases, ETS costs are transferred to customers through precalculated surcharges, designed to reflect the actual costs, without generating loss or profit. The study reveals that while all carriers apply this strategy, the ability to implement it varies depending on segment characteristics and geographical exposure. Global container carriers have found that ETS surcharges are widely accepted by their customers, and they have not faced any notable financial impact. Their economies of scale, diversified customer base and partial exposure to ETS contribute to this outcome. Likewise, global RoRo carriers have limited impact. However, due to their smaller customer base and long-term contracts, the surcharges are not as easy to transfer as with container carriers, which has led to minor cost absorption. Nevertheless, the general conclusion is that the current level of EU ETS has not significantly altered the financial landscape of the global carriers. The system has so far functioned more as an administrative cost mechanism, rather than a transformative driver of change.

The challenge regarding geographical exposure highlights the difference between global and intra-European carriers, as the latter is subject to 100% ETS exposure. These operators have lower cargo volumes, and their vessels make multiple port calls within the EU during a single voyage. As a result, the expenses are higher per EU port which increases their total EUA obligation. However, as intra-European container traffic often operates as first or last leg of intercontinental routes, as part of the hub-and-spoke design, their primary customers are mainliners. The mainliners, in turn, transfer on the ETS surcharge to their own customers maintaining the same pricing logic. Consequently, feeder operators can pass on their ETS expenses relatively easily, without absorbing significant losses.

In contrast, intra-European RoRo carriers experience a more constrained and complex situation, as a result of higher speeds, lower capacity utilization and competition with road freight. RoRo operators apply alternative strategies, often calculating ETS cost per lane meter. However, due to variations in volume and utilization, there is a potential of miscalculating the surcharges, forcing the carriers to absorb some of the cost. At the same time, the carriers can be pressured to reduce their net freight in order to remain competitive with road transport, which further impacts margins. Together, these factors result in greater overall impact of EU ETS on the cost structure of intra-European RoRo traffic, compared to container carriers, as their surcharge levels are higher and more volatile. Nevertheless, the impacts are manageable at the current state of ETS pricing. Though, the planned expansion of EU ETS to 100% emission coverage may intensify the effects, with several carriers expressing concern that increased costs might introduce new financial challenges.

Given the current state of EU ETS, this study reveals no current volume shifts between the RoRo and container segments, and the potential for future shifts remains limited. Although both segments operate in liner shipping, they serve distinct roles in the logistical system.

Their structural system and operational characteristics are beneficial for different types of cargo. RoRo operators offer speed, high frequency and door-to-door efficiency which continues to be the preferred solution for high-value and time sensitive cargo, such as automobiles. Despite their higher emissions and ETS costs, container shipping is rarely a feasible alternative for these goods. However, cargo with lower values and less time sensitivity, increasing ETS costs may become more influential in time. Such products include forestry and industrial in high volumes. The cost differentials could eventually pressure customers toward alternative solutions, provided that containerization is possible.

7. RECOMMENDATIONS FOR FURTHER RESEARCH

Given the findings of this study, future research is recommended to explore the continuous development and expansion of the EU ETS, especially its effects on the cost structure of shipping segments. As the ETS regulation is planned to extend its scope in the coming years, gradually increasing the coverage to 100% of emissions, it will be essential to evaluate and explore how the increasing costs may influence shipping segments. Attention should also be given to the full scope of emissions beyond CO_2, to determine its effect on the strategies of operators, including choice of fuel and investments in greener technologies.

Furthermore, additional research should be undertaken to explore the inclusion of road transport in the EU ETS, and its potential implications of shipping. Given the competitive nature among modal choices, the current exclusion of road transportation gives SSS RoRo cost disadvantages. Therefore, it is highly relevant to assess how future inclusions of ETS, and higher costs for both transport modes, might impact on the competitive dynamics, trade patterns and cost structures.

Finally, a natural progression for future research would be to expand the scope of respondents within each segment. This would provide a broader perspective on the impact of EU ETS and enable for a multifaceted analytical approach.

REFERENCES

Adamopoulos, A. (2021). *Shipping's 'big three' account for almost 80% of CO2 emissions*. Https://Www.Lloydslist.Com/LL1136035/Shippings-Big-Three-Account-for-Almost-80-of-CO2-Emissions.

Christodoulou, A., Dalaklis, D., Ölçer, A. I., & Ghaforian Masodzadeh, P. (2021). Inclusion of shipping in the eu-ets: Assessing the direct costs for the maritime sector using the mrv data. *Energies*, *14*. https://doi.org/10.3390/en14133915

Christodoulou, A., & Kappelin, H. (2020). Determinant factors for the development of maritime supply chains: The case of the Swedish forest industry. *Case Studies on Transport Policy*, *8*, 711–720. https://doi.org/10.1016/j.cstp.2020.07.008

Christodoulou, A., Raza, Z., & Woxenius, J. (2019). The integration of RoRo shipping in sustainable intermodal transport chains: The case of a North European RoRo service. *Sustainability (Switzerland)*, *11*. https://doi.org/10.3390/su11082422

Christodoulou, A., & Woxenius, J. (2020). Short-distance maritime geographies: Short sea shipping, RoRo, feeder and inter-island transport. In *Geographies of Maritime Transport: Transport, Mobilities and Spatial Change* (pp. 134–148). Edward Elgar Publishing Ltd. https://doi.org/10.4337/9781788976640.00013

Denscombe, M. (2018). *Forskningshandboken : för småskaliga forskningsprojekt inom samhällsvetenskaperna* (Fjärde upplagan). Studentlittertur. https://eds.s.ebscohost.com/eds/detail/detail?vid=10&sid=1dfbe0dc-2687-4e7d-a93a-d2196a3b3912%40redis&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=clpc.oai.edge.chalmers.folio.ebsco.com.fs00001000.e4f0013a.bbcb.4e44.9d3c.4f76299f01a6&db=cat09075a

Elgohary, M. M., Seddiek, I. S., & Salem, A. M. (2015). Overview of alternative fuels with emphasis on the potential of liquefied natural gas as future marine fuel. *Proceedings of the Institution of Mechanical Engineers Part M: Journal of Engineering for the Maritime Environment*, *229*, 365–375. https://doi.org/10.1177/1475090214522778

Elsevier. (n.d.). *Scopus AI - Research on the Go*. https://www.elsevier.com/products/scopus/scopus-ai/research-on-the-go

European Commission. (n.d.-a). *About the EU ETS - European Commission*. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/about-eu-ets_en#what-is-the-eu-ets

European Commission. (n.d.-b). *Delivering the European Green Deal*. Https://Commission.Europa.Eu/Strategy-and-Policy/Priorities-2019-2024/European-Green-Deal/Delivering-European-Green-Deal_en.

European Commission. (n.d.-c). *Development of EU ETS (2005-2020) - European Commission*. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/development-eu-ets-2005-2020_en

European Commission. (n.d.-d). *Development of EU ETS (2005-2020) - European Commission*. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/development-eu-ets-2005-2020_en

European Commission. (n.d.-e). *Reducing emissions from the shipping sector - European Commission*. https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en

Flodén, J., Zetterberg, L., Christodoulou, A., Parsmo, R., Fridell, E., Hansson, J., Rootzén, J., & Woxenius, J. (2024). Shipping in the EU emissions trading system: implications for mitigation, costs and modal split. *Climate Policy*, *24*(7), 969–987. https://doi.org/10.1080/14693062.2024.2309167

IMO. (n.d.). *Fourth Greenhouse Gas Study 2020*. Https://Www.Imo.Org/En/Ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.Aspx.

Institute of Chartered Shipbrokers. (2018). *Liner Trades* (P. Neylan, Ed.; 2018 edition). Institute of Chartered Shipbrokers.

Klang.ai. (n.d.). https://klang.ai/

Lagouvardou, S., & Psaraftis, H. N. (2022). Implications of the EU Emissions Trading System (ETS) on European container routes: A carbon leakage case study. *Maritime Transport Research*, *3*. https://doi.org/10.1016/j.martra.2022.100059

Lee, C. Y., & Song, D. P. (2017). Ocean container transport in global supply chains: Overview and research opportunities. In *Transportation Research Part B: Methodological* (Vol. 95, pp. 442–474). Elsevier Ltd. https://doi.org/10.1016/j.trb.2016.05.001

Notteboom, T. (2020). Roro shipping vs. trucking: revisiting the impact of low-sulphur marine fuel use on cost competitiveness of routing options in north Europe. *WMU Journal of Maritime Affairs*, *19*, 399–426. https://doi.org/10.1007/s13437-020-00221-z

Notteboom, T., Pallis, A., & Rodrigue, J.-P. (2021). Port Economics, Management and Policy. In *Port Economics, Management and Policy*. Routledge. https://doi.org/10.4324/9780429318184

Øvstebø, B. O., Hvattum, L. M., & Fagerholt, K. (2011). Optimization of stowage plans for RoRo ships. *Computers and Operations Research*, *38*, 1425–1434. https://doi.org/10.1016/j.cor.2011.01.004

Park, S., Lee, H., & Kim, D. (2024). Regulatory compliance and operational efficiency in maritime transport: Strategies and insights. *Transport Policy*, *155*, 161–177. https://doi.org/10.1016/j.tranpol.2024.06.024

Slack, B., & Gouvernal, E. (2011). Container freight rates and the role of surcharges. *Journal of Transport Geography*, *19*, 1482–1489. https://doi.org/10.1016/j.jtrangeo.2011.09.003

Stopford, M. (2009). *MARITIME ECONOMICS, Third edition* (3. ed). Routledge.

Sun, L., Wang, X., Hu, Z., & Ning, Z. (2024). Carbon and cost accounting for liner shipping under the European Union Emission Trading System. *Frontiers in Marine Science*, *11*. https://doi.org/10.3389/fmars.2024.1291968

Trading Economics. (n.d.). *EU Carbon Permits - Price - Chart - Historical Data - News*., https://tradingeconomics.com/commodity/carbon

Woxenius, J., & Bergqvist, R. (2011). Comparing maritime containers and semi-trailers in the context of hinterland transport by rail. *Journal of Transport Geography*, *19*, 680–688. https://doi.org/10.1016/j.jtrangeo.2010.08.009

Zheng, X. Bin, Kim, Y. S., & Shin, Y. R. (2021). Cost effectiveness analysis in short sea shipping: Evidence from northeast asian routes. *Journal of Marine Science and Engineering*, *9*. https://doi.org/10.3390/jmse9121340

DEPARTMENT OF MECHANICS AND MARITIME SCIENCES
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden
www.chalmers.se

CHALMERS