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The use of low sulphur fuel and its effect on shortsea shipping between the North Sea ports and Southern Europe

By

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Acknowledgements

Exhausted but at the same time satisfied and proud, I currently review my year at the MEL from the 46th floor in Manila. This is the reason and the feeling, this masters is a total fit with my personality; a great challenge with an international mind set.
Now that the thesis deadline is coming up, the end of a year, everyone considered as endless is coming. A feeling which is hard to describe as it simultaneously will be the start of a new phase in life.

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Abstract

The aim of this research is to analyse the impact of the Marpol Annex VI[1] amendment on (SSS) between the three major North Sea ports and Southern Europe. The transport network analysed in this research include the port of Antwerp, Hamburg, Rotterdam and their relation with France, Greece, Italy and Spain. The research is segmented using three modes of transport; SSS, road and rail transport.

The regulations imposed by the International Maritime Organization (IMO) limit the degree of sulphur content in fuel used by vessels. For the predefined Sulphur Emission Control Areas (SECA) are these sulphur content limits lower than compared to the average limit for the international waters. The SECA's include the North Sea, English Channel and Baltic Sea. Although the Mediterranean region is not yet subject to these regulations, it is can be assumed that this will change in the future to support an equal competitive maritime industry. (Panagakos et al, 2014) The relation between the European ports and the Mediterranean region for SSS is important with a share of 29% in the overall SSS throughput. (Eurostat, 2014)

Starting in January 2015, the sulphur limit for SECA's will be reduced from 1.0% to 0.1% per mass. (IMO, 2014) As a consequence, the currently used heavy fuel oil (HFO) is not allowed in the SECA areas anymore. Companies sailing in these areas should find an alternative for HFO, this research will review the impact of switching to low sulphur fuel oil (LSFO). The use of LSFO will increase the bunkering costs for the ship owners, who will in turn increase the freight rates of all maritime transport subject to this, to recover these costs. Based on related academic research and data, the methodological approach to estimate the impact will be a Global Simulation Model (GSIM).

The outcome of the model is in line with the reasoning of other researchers confirming a modal backshift from SSS to especially road transport. Remarkable is the result for Rotterdam, where a large modal backshift occurs. Furthermore the results indicate that the port of Hamburg will substitute the ports of Antwerp and Rotterdam. The decrease in SSS is variable within a range from -20 to 64% for the OD relations between the North Sea port and the Southern European countries.

Keywords; Short Sea Shipping, Modal back shift, North Sea ports, Southern Europe, Marpol Annex VI, SECA, GSIM, trade tariffs, elasticities

[1] Marpol 73/78 Annex VI; Regulations for the Prevention of Pollution from ships, International Maritime Organization, Marine Environment Protection Committee.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

EC	European Commission
EU	European Union
EU28	28 Member States of the EU
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
KM	Kilometres
MGO	Marine Gas Oil
MOS	Motorways of the Sea (EU Project)
OD	Origin Destination
ROW	Rest of the World
SCE	State Choice Experiment
SECA	Sulphur Emission Control Area
SSS	Shortsea Shipping
Tkm	Tonne-Kilometres

1. Introduction

The shipping industry is responsible for 85% of global transport. (DNV, 2008) It therefore is the key to success for the global economy. Notwithstanding, the shipping sector has a high influence on society and nature. Although the largest part of a maritime journey is operated on international waters and outside the critical eye of society, it is not unnoticed that shipping has a share of around 4-5% in the total of global emissions. (Acciaro et al, 2014) Especially air pollution is of serious concern and a hot topic on the agenda of the European Union (EU) and the International Maritime Organization (IMO). The new low sulphur regulations will have consequences for all members of the maritime industry, especially related to the routes in the North Sea, English Channel, Baltic Sea and the US, areas referred to as the Sulphur Emission Control Areas (SECA), where strict rules apply or will apply.

The IMO adopted Annex VI of Marpol 73/78 prescribing regulations in order to reduce air pollution from ships in 2008. It is divided in different levels of future sulphur limits and is therefore constantly challenging the maritime sector. The newest regulation stipulates the reduction of the sulphur limit in SECA's from 1.0% of maximum content in fuel to 0.1% starting in January 2015. This is currently a hot topic, because - although future prices of fuel are hard to predict - marine gas oil (MGO) with a sulphur limit of 0.1% is expected to be 70-90% more expensive when compared with the HFO used. (ENTEC, 2009) This will probably have far-reaching consequences for an industry highly dependent on bunkering.

After the crisis hit hard in 2008, times changed in the maritime world and the market was characterized by overcapacity and laid up vessels. Currently, six years after the start of the crisis, liner companies are still having tough times surviving while operating their vessels for competitive prices, sometimes only recovering the operating costs. The financial consequences of the new low sulphur fuel requirements are of high concern for the shipping companies.

The market of SSS is important in the EU as it is highly promoted by the European Commission (EC) to switch the large number of road transport to SSS. On the other hand with the new low sulphur regulations it is hard for the SSS industry to cope with the other modes of transport, therefore it is interesting to research the impact of this on a potential modal shift. Before overwhelming the reader with an in-depth analysis about the maritime world and the corresponding regulations, it is important to define one of the main concepts of this research; SSS; *"Shortsea shipping is transport by smaller vessels from the hub to the gateway ports having a coastline on the enclosed seas bordering Europe".* (European Commission, 2014) Further defined explanations will be discussed in chapter 2.

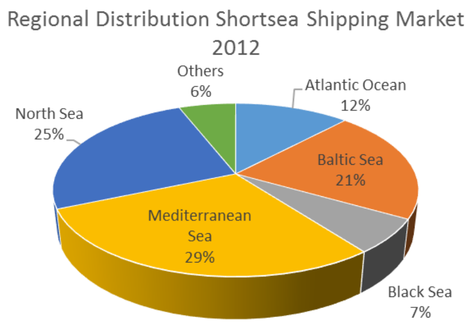
Due to the increased transport costs after the new regulations different stakeholders speculate about a 'modal backshift', a shift back from sea to land transport. The chance for a modal backshift is the highest in regions where well developed connections of different modes exist between hub and gateway ports. This research will focus on the trade route between the three largest North Sea ports; Rotterdam, Antwerp and Hamburg and their connection to Southern Europe; France, Greece, Italy and Spain.

The question aimed to be answered by this research is; what will be the impact of the use of low sulphur fuel (MGO) on the shortsea shipping route between the North Sea ports and Southern Europe?

1.1. Relevance

SSS is a well-developed mode of transport within the EU territory. There is an important SSS connection between the hub ports of Northern Europe and the gate ports of Southern Europe. The Mediterranean region was in 2012 the largest SSS region for the European ports with a share of 29%, as shown in Figure 1 below.

Figure 1. Regional distribution SSS market 2012



Source: Compiled by author, based on Eurostat (2014)

Although the Mediterranean Sea is not yet incorporated as a SECA, it is expected that this will change soon, according to Panagakos et al (2014), an assessment of this possible extension of the SECA is currently commissioned by the EC. The introduction of the Mediterranean Sea as a SECA has societal and environmental benefits of a reduction in this area and most important for the shipping industry a more equal playing field within the EU. (Schinas & Bani, 2012)

The SSS companies specialised on the route between the North Sea ports and Southern Europe, accounted in total for almost 1.8 billion tonnes of cargo in 2012. Their geographical orientation is focused on the SECA area and will be affected by the increased operating costs as a consequence of the amendment. (Eurostat, 2014) The share of bunker costs for an average shortsea vessel used in the North Sea is estimated to be between 26% and 48% of the overall costs, as a consequence the freight rates for shortsea shipping will on average increase between 8 and 13%. (Notteboom, 2010)

These companies have to decide whether they will bear the costs of these regulations on their own or let their client indirectly pay by increasing the freight rates with a chance of losing them. In general losses and financial increases in the maritime industry seem to concentrate at the end of the supply chain, in other words the ship owners themselves. (Wagelaar, 2012)

Based on the high level of trade between the North Sea ports and this region it is relevant to discuss the consequences of the low sulphur requirements. Several reports are conducted on the impact of the regulations between the North and Baltic

Sea trade, but minimal academic research is done on this trade route, forming the basis for a new challenge.

Finally, it is relevant to research the possibilities of a modal backshift as a consequence of the new regulations. The trade route from the three North Sea hub ports to the Southern European countries has a well-developed competing connection of shortsea, road and rail transport. Although SSS is actively promoted by the EU, the new low sulphur regulations change the decision making of transport modes by shippers. In short, the hot topic of current new low sulphur regulations and the competition of a well-developed road and rail network on this route give rise to an interesting and challenging research.

1.2. Methodological approach

The methodology used to support the aim of answering the critical question is the Global Simulation Model (GSIM). This quantitative model, established in 1997 by the academics Francois and Hall, focuses on the impact of changing trade tariffs on the bilateral trade between countries.

By slightly modifying this model it is possible to analyse the impact of changing freight rates on transport flows per transport mode on different trade routes. For the subject concerning the impact of the new low sulphur regulations, the GSIM will determine the effect of the new regulations and the possible modal backshift. The three modes considered are SSS, rail and road transport. Accurate data for the different modes on this trade route is limited, therefore it is decided to use Antwerp, Hamburg and Rotterdam to represent the North Sea hub ports. Furthermore, as the largest share of transport from these ports to the Mediterranean region is distributed over Spain, France, Italy and Greece, these countries will represent the Mediterranean region. The data used is based on sources of Eurostat, port authorities and the national statistics bureaus, the most accurate data or the year 2012 is used.

1.3. Structure

This research exclusively focuses on the trade routes for freight transport and does not include passenger transport. Further segmentation for cargo is not established due to a lack of accurate information on the distribution of cargo types for the three modes. However it can be assumed, based on common knowledge, that the international road transport is mainly containerized and rail and sea transport is a mix of container as well as bulk cargo. Although there is no distinction made in the type of cargo, it is indirectly taken into account when reviewing the average value of cargo per transport mode in order to monetise the throughput. This subject will be further discussed in the methodology in chapter 4.

Within the research, a literature review is conducted in chapters two and three. The first literature section discusses the trade routes and the relation of trade between these regions. Furthermore the different modes of transport used and a background on the decision making of shippers for different modes of transport is reviewed.

The second part of the literature review is dedicated to the regulations regarding the prevention of the air pollution of vessels. First of all, the current situation is reviewed and a summary of the different EU policies and the Marpol convention is provided.

Furthermore, a discussion on the new regulations and the adaptions necessary in the shipping industry is discussed. In the end a small qualitative analysis on the consequences of the implementation of low sulphur fuel requirements is established.

In the fourth chapter the methodology is covered, including the data collection and a thorough explanation of the GSIM. Important elements are the process of monetising the trade values for the OD relations and the assessment of tariffs and elasticities, this is partly explained and summarised in the appendices.

After this qualitative and quantitative research the results are presented in chapter five and the conclusion and discussion review the research in chapter six. This latter part also include a discussion on the shortcomings of this research, as well as the recommendations for further research.

2. The short sea trade market of the North Sea ports and Southern Europe

This chapter provides a background on the short sea trade routes between the major North Sea ports and Southern Europe including an assessment of the ports, modes of transport and the decision making behind the mode choices.

The research is focused on the bilateral transport of the North Sea ports of Antwerp, Rotterdam and Hamburg and the four largest countries of the Southern European region; France, Greece, Italy and Spain, the map including the locations is included in figure 2 below. France can be defined as Western as well as Southern European country due to its coastline which is connected to three different sea basins. This research is focused on the Southern European region and will for this reason only take the French Mediterranean sea basin into account. Based on the data available, the SSS throughput of Marseille will represent the French share in the research. The most important SSS related ports in the Southern European countries are Barcelona, Marseille, Genoa and Piraeus. (Grosso, Lynce, Silla, & Vaggelas, 2009) When globally compared, SSS is developed in Europe as 60-70% of the production takes place in areas near coastlines or inland waterways. According to Grosso et al (2009), the European network, can be considered as the extension or complementary part of deep sea shipping which mostly ends in the larger hub ports.

Figure 2. Locations of North Sea and Southern European ports.

Source: Compiled by author, based on GoogleMaps (2014)

2.1. Shortsea Shipping in Europe

Some authors compare SSS with cabotage; "…seaborne traffic between ports of the same country…" (Musso, Casaca, & Lynce, 2002), however this scope it too narrow. The definition closest to the SSS in Europe is that of Marlow et al. (1997) 'Shortsea shipping are seaborne trade flows of all kinds of freight performed by vessels of any flag, from EU member states to whichever destination within the territory embracing Europe, the Mediterranean and Black Sea non- EU countries'. According to Stopford (1997) SSS is defined as; "a maritime transport within a region, essentially serving port-to-port feeder traffic which can be in competition with land transport". This definition confirms the competition between different modes. From a technological point of view, some authors define SSS by vessel type, however this is not relevant in this research due to the lack of information providing the possibility to distinguish between vessel or cargo type.

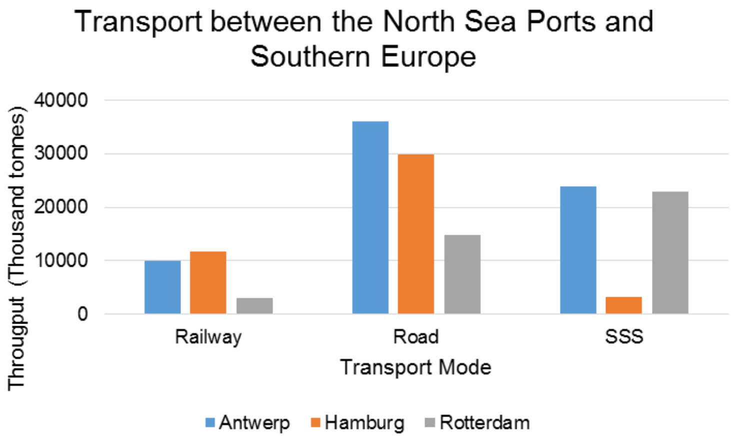
Currently, the European SSS industry is struggling in order to attract cargo, only 6% of the internal EU trade is carried by SSS, a small share compared to the 80% share of road transport. (Nitsopoulos & Psaraftis, 2008) The oversupply of tonnage has an impact on the freight rates, which are expected to be under pressure for the upcoming years. (Wagelaar, 2012)
Besides this, the renewed sulphur regulations will challenge the market and a solution is desirable. Wagelaar (2012) proposed the use of ship pooling in the SSS market as a solution for this. However he recognises the problems in pooling when considering the anti-monopolist laws in the EU. For this reason, he recommends shipping companies to involve the customers in this process by giving them a fair share of the benefits gained by pooling. According to Wagelaar (2012), pooling is necessary to secure the future of the market as asset light companies perform better compared to companies with large owned fleets. (Wagelaar, 2012) Considering the impact of the financial crisis and the consequences for SSS, Savy (2013) reports that the future is uncertain and overcapacity is likely to exist. He advises all stakeholders to integrate and improve their networks, without ruling out restructuring or concentrating operations.

In Europe a distinction for SSS in two different markets can be made; on the one hand the companies specialised in the maritime service and on the other hand the companies specialised in both the maritime as well as the hinterland transport, the door-to-door operators. Furthermore SSS can be categorized by cargo type and geographical area. (Systema, 1999) Related to this is the concern about the rate of competition between several modes, it is crucial to consider that SSS is a part of the intermodal transport network or a feeder service belonging to the deep sea service of the hub ports to serve the gateway ports. In other words is it a self-fulfilling market or an extension of the deep-sea network? (Musso, Casaca, & Lynce, 2002) The answer for this is dependent on the trade route.

Although SSS in general involves a lot of liquid and dry bulk, the trade relation between the North Sea ports and the Southern European countries is characterised by mainly container transport, due to the transit nature of the route. This means that the SSS between the North Sea ports and the Southern region involves mainly transporting containers that arrive in the larger North Sea hub ports. The next step is the transport of smaller lots to the gateway ports which act as consolidation points. According to Sytema (1999) and Musso et al (2002), these operators are therefore mainly focused on the maritime service belonging to the deep sea service. At the gateway ports, the containers are being unloaded and distributed further into the region by road transport to reach the final destination. The main shipping operators on this route are Unifeeder, Grimaldi, K'Line, APL, CMA CGM and CLdN. Due to a lack of transparency in this industry, there is unfortunately not more in depth information available on the type of products and the schedules of the sailings.

In order to get an overview of the distribution of the transport modes used on the trade route, figure 3 below can be reviewed.

Figure 3. Transport mode distribution between the North Sea ports and Southern Europe.



Source: Compiled by author, based on Eurostat (2014)

It can be concluded that road transport is the dominant transport mode used on the route from the three North Sea ports to the Southern region, with almost three times the throughput of rail transport. The rail transport is low compared to the other modes due to the capacity in railway connections to the Southern region, however, Hamburg is overall as well as on this route the most involved in railway transport compared to the other ports.
SSS is mostly developed in Rotterdam and Antwerp as important transfer ports to the Southern region and the geographical location, the SSS in Hamburg is mainly focused on the Baltic region. Although SSS is heavily promoted by the EU to promote the shift of containers from road to sea, it is still not the dominant mode.

The use of shipping has advantages over other modes, namely; environmental benefits, less accidents and economic benefits. The economic benefits are remarkable compared to other modes as SSS requires less investments in terms of infrastructure, the sea is the natural infrastructure. Furthermore, the level of transport congestion is reduced and SSS is important for the port competitiveness of ports in hinterland transport network. (Musso, Casaca, & Lynce, 2002)
However the reasons for not being the dominant transport mode can be found in the challenges faced by SSS. First of all, it is not a door-to-door mode of transport and is less reliable and flexible. Furthermore the average age of the European SSS fleet is very high. (Grosso, Lynce, Silla, & Vaggelas, 2009) The discussion on the average age of the SSS fleet and the necessity for renewal to support the market is discussed in the article written by Nitsopoulos and Psaraftis (2008).

2.2. The North Sea ports

The three North Sea ports of Antwerp, Hamburg and Rotterdam represent the Northern part of the trade route relevant for this research, and serve as hub ports for the deep-sea vessels. The Southern European countries are for a large share dependent on the cargo arriving in these hub ports and the transport to the region. This section will shortly discuss the focus and transport in the three ports.

Rotterdam, Hamburg and Antwerp are the three largest North-European ports of the global ports, respectively ranked as 11^{th}, 14^{th} and 15^{th}. In total these ports handle 12% of the global cargo. (European Commission, 2013) They form the basis for the intra-Europe modes of transport. SSS represents 60% of the total EU maritime transport of goods and accounts for 37% of the intra-EU trade (Tkm) in 2012. Furthermore, the shortsea freight volume was in 2012 the largest in the Mediterranean region, according to Eurostat (2014). With 577 million tonnes of cargo, this region accounts for 29% of the total shortsea freight volume of the EU ports.

As concluded in paragraph 2.1., the SSS to Southern Europe is mainly departing from Antwerp and Rotterdam, while Hamburg is more focused on the transport to the Baltic region. However, the competitive advantage for Germany is in land transport which is well connected due to its central location and advanced infrastructure.

The three port authorities are currently in consultation with the governments in order to actively promote SSS and to overcome the challenge of a lack of cooperation between SSS and intermodal connections to move from a port-to-port to a door-to-door service. For example, based on the projections of Lloyds (2008) the shortsea connection between Rotterdam and Algeciras will in 2016 account for over 18 million tonnes of cargo and be listed in the projected top 20 Mediterranean voyage/transit routes.

The geographical location of the port of Antwerp and Hamburg and their long sea leg land inwards, from the North Sea pose operational problems. However maritime transport is on average less expensive and therefore a positive side of this rather operational challenge for serving vessels in an efficient way is that it reduces the overall costs of transport due to the extended sea leg. (Savy, 2013)

Although Rotterdam and Antwerp are competitors, according to Savy (2013), they are also complementary as the large shipping companies are reducing their ports of call. For example, the total container trade between Rotterdam and Antwerp accounts for 622.000 TEU. However, due to overcapacity there is high competition which lowers the prices, the opening of the Maasvlakte 2 is assumed to have a serious impact in the Antwerp shortsea shipping as well.

2.3. The Southern European ports

Southern Europe and the corresponding four countries covered in this research as defined above, form a part of the Mediterranean region. The Mediterranean region is recognised by the natural boundary of the Straits of Gibraltar on the west side and the Suez Canal and the Bosporus on the east side. This maritime region is the most active region in global shipping, accounting for 15% of global shipping activity or 252.000 port calls. (Lloyds Marine Intelligence Unit, 2008) The largest share of cargo in intra-Mediterranean transport is liquid bulk, followed by dry bulk and general cargo. The average vessel size for port calls in the region is 15.000 DWT, indicating there is a high number of feeder vessels. (Lloyds Marine Intelligence Unit, 2008)

The region can, based on the maritime industry, be split in two submarkets; a) Western Mediterranean; large hub ports and on the other side; b) Eastern Mediterranean; equal sized and dynamic ports. (Grosso, Lynce, Silla, & Vaggelas, 2009) This research will mainly focus on the Western Mediterranean market. One exception is Greece, due to the economical and maritime relevance of Piraeus it will be included.

Another segmentation shows that container ports in the Mediterranean region are either transhipment hubs or gateway ports. The transhipment hub is specialised on the transport that is transhipped to another vessel, as an intermediate reload location for a journey. The gateway port, is specialised in handling containers which have a destination or the goods in it, to a location in the hinterland and are therefore fully offloaded from the vessel and mostly leave the terminal via the landside. Algeciras and Gioia Tauro are examples of hubs. Valencia, Genoa and Marseilles are gateway ports serving the national trade to the hinterland. (Lloyds Marine Intelligence Unit, 2008)

The Mediterranean Sea mostly acts as a transit route and is amongst the world's busiest waterways. (Lloyds Marine Intelligence Unit, 2008) Based on the EU SSS definition, Morocco can also be considered as part of the Mediterranean freight, however it will not be discussed in this research, as the road and rail transport possibilities from the EU are limited to this region.

Although the name suggests differently, SSS is also used for long haul transport and a good alternative for road transport. Five Spanish ports are part of the MoS in the Mediterranean region and particularly linked with Belgian ports. The SSS container transport in the Mediterranean region is for approximately 24% an alternative to road transport.

France handles a high amount of shortsea freight, especially in the Mediterranean region. It is currently under research if it would be economical to set up SSS network between Le Havre and Algeciras, this will likely affect the congested road transport on this route. (Savy, 2013) As explained in the introduction, the data used for France will be based on Marseille, representing almost one third of the total SSS throughput of the country. (Eurostat, 2014)

2.4. Factors influencing the choice of mode

The decision making of shippers in order to decide on the mode of transport on a specific OD relation is influenced by different factors, which will be discussed in this paragraph.

"Understanding mode choice decisions", written by Brooks et al. (2012) is a research article describing the decision making process behind modal choices of shippers in Australia. A set of variables mainly influencing this process include; transit time, frequency of departure, reliability and costs. Furthermore the environmental awareness nowadays also plays a crucial role in the process to switch to the most environmental friendly mode of transport; SSS. The key variable influencing the modal choice is freight distance, shortsea shipping turns out to be most attractive on the longer distance markets of over 1000 nautical miles. (Brooks, Puckett, Hensher, & Sammons, 2012)

According to Savy (2013) it is observed that distances and concentration of traffic on the corridors serving the major ports are beneficial to alternatives to road transport. This is in line with the reasoning according to Holmgren et al (2013) where they also refer to the impact of the length of the sea leg on a route for a modal choice, ship types, cargo categories and the availability of fuel and price forecasts.

Although different institutions are supporting the use of SSS, road transport remains the dominant transport mode in the EU and the modal shift has been lower than expected. Overall in the EU, road is perceived as the most reliable source of transport due to its flexibility. Compared to other modes where a time window is not even considered, SSS is considered reliable with a delay within 1 day, this indicates the level of reliability in the market. (Brooks, Puckett, Hensher, & Sammons, 2012)

The academic as well as maritime world agree that the price of fuel has a large impact on the industry due to the high share of fuel in the overall transport costs. Furthermore, the price of crude oil affects the shipping industry in a higher extend compared to the road transport, as a large share of the price of diesel fuel consists of taxes. (Notteboom, 2010) Furthermore, Notteboom et al (2010) conclude that trucking firms have much more flexibility in accepting and implementing fuel related regulations as the lifetime and therefore amortization period of trucks is around 3-4 years compared to 20-25 years for vessels.

3. Literature review: Background of the low sulphur fuel requirements in Marpol Annex VI

In order to cope with the business in the future, it is important to understand the background of the new low sulphur regulations and is discussed in this paragraph.
First of all, the shipping policies in the EU are reviewed after which the Marpol Annex VI convention will be discussed, summarising the specific requirements. Furthermore, the implications of the new regulations on the shipping companies will be discussed by reviewing the adaptions required to meet the new regulations. Finally, a qualitative discussion will conclude discussing the possibility of a modal backshift.

Although shipping is considered to be the cleanest mode of transport in terms of CO2 emissions, this is not the case in terms of sulphur and nitrogen oxides. Due to globalization, the international legislation on shipping has been strengthened and harmonized between the different nations. (Holmgren, Nikopoulou, Ramstedt, & Woxenius, 2014) An example of this is the adaption of Annex VI, Marpol 73/78 by the IMO, prescribing the limits regarding the sulphur content in fuel used in the SECA's. The need to reduce the sulphur content used in fuel is the high impact on the environment and more specifically on acid rains. (Notteboom, 2010)

The first convention came into practice in May 2006 applied to the Baltic Sea, in 2007 the North Sea and English Channel followed. In these areas, the limit for sulphur emissions was reduced to a maximum of 1.5% per mass. Vessels are currently allowed to use a fuel oil with a maximum of 3.5% sulphur content outside the SECA areas, 1.0% inside the SECA and 0.1% used by vessels moored in EU ports, or in the case of the latter one it is even preferred to switch to shore electricity. (IMO, 2014)

The new regulations prescribe the reduction of sulphur emission to a maximum of 0.1% per mass in the SECA's per January 2015. Outside the SECA areas the current sulphur limit is at 3.5% and will be lowered to 0.5%, this is expected to be done in 2020, but it is still under discussion. The SECA's cover approximately 0.3% of the world's water surface. (Notteboom, 2010)

As discussed in the introduction, it is currently reviewed by different institutions to incorporate the new amendments also for the Mediterranean Sea in order to equalize the international transport markets.

3.1. Transport policies of the European Commission

The EU forms a social as well as economic community, policymakers have to take various interests into account such as citizen health, controlling industry competition and consumer prices while at the same time promoting and securing a stable economic environment. (Holmgren, Nikopoulou, Ramstedt, & Woxenius, 2014) An example of the sometimes contradicting interests is the implementation of the Marpol Annex VI amendment. Implemented in order to reduce air pollution from shipping, but at the same time contradicting the objective of the EC to support SSS to shift the land transport to sea.
The mode dominance of road transport in the European transport system causes problems such as congestion and safety. According to different studies SSS is considered the less pollutant and safest mode of transport compared to other. The modal split in the European Union is imbalanced, therefore one of the reasons for the

promotion of SSS is to reduce road transport and rebalance the split. (Grosso, Lynce, Silla, & Vaggelas, 2009)

The support for SSS is especially focused on designing it as a door-to-door mode of transport limiting the road transport to a minimum due to environmental and congestion problems. Although these policies show promising rewards for the use of SSS, the gap between the present growth rate and the goals of policy makers is still large. (Musso, Casaca, & Lynce, 2002) This is because SSS is, due to the global economy which is characterized by just in time transport and supply chains, not a full substitution for road haulage.

Since 2001, the EC is active in promoting SSS as a substitutable mode of transport. These actions are separated in three types; Legislative, technical and operational. (Grosso, Lynce, Silla, & Vaggelas, 2009). Legislative support is provided in faster procedures in legislation for SSS. The technical as well as operational support are more linked to the infrastructure established and the daily operation. The EC for instance subsidises ports in order to establish a network.
This support for the use of sustainable transport connections is done by the Marco Polo Programme, including the Motorways of the Sea corridors (MOS), which focusses on SSS. A drawback is that non-EU ports are excluded from the subsidies in this program. On certain routes where a connection exists between a subsidized and a non-subsidized port, there might be serious consequences for the trade route. (Ng, Sauri, & Turro, 2013) An example is Greece. For the last years the country is especially involved in trade with Turkey, this is a problem as the support of the project is limited to only the Greek ports, compared to other trade lanes, this is unequal competition.

One of the most successful MoS projects is the SSS network between Zeebrugge, Belgium and Bilbao in Northern Spain. A subsidy of 6.8 million euros which is funded to the shipping companies and ports in the project, it is expected to incur a modal shift of 8.4 million tonnes of traffic from road to SSS. The aim of the project is to decrease congestion in Northern France, the environmental benefit accounts for 211 million euros. (Brooks, Puckett, Hensher, & Sammons, 2012) A drawback of the Marco Polo Programme is the five year commitment of shipping companies and the investment in port projects rather than vessels. (Savy & Burnham, 2013)
According to Brooks et al (2012, the most efficient and successful SSS projects supported by the European Union have on average shipping distances greater than a 1-day trucking distance. This corresponds to the longer distance relations between the North Sea ports and Southern Europe.

Different initiatives are proposed for developing competing land transport networks between the Northern and Southern EU as well. An example is The Mediterranean Corridor, as part of the TEN-T network project, it develops a railway network between the largest Spanish ports; Valencia, Barcelona and Algeciras and the Northern EU ports. (Barcelona Activa, 2011)

3.2. Adaptions in order to meet the requirements

In order to meet with the requirements for the low sulphur emissions in the SECA areas, a ship owner has a few options to adapt its vessel, this is reviewed in this chapter.

First of all it is possible to use the fuel changeover procedure from heavy sulphur fuel oil (HSFO) to low sulphur fuel oil (LSFO). However this changeover and therefore mixing of the fuels should be finished before entering the SECA. Changing of fuels should be recorded in a log book indicating the time, date and place of fuel change. The blending ratio should be as low as possible and be agreed on by a certified oil testing company. A possible adaption made to the bunkering installations should also first be approved by a certification company. (DNV, 2008) However, this is especially applicable to deep sea vessels, which are mostly crossing oceans and only sometimes enter a SECA. SSS on the route from the North Sea to the Mediterranean is constantly subject to the regulations and therefore switching of fuels is not applicable here.

Furthermore it is possible to make use of the scrubber technology. This process means cleaning the exhaustive gasses after burning the HFO. HFO can therefore still be used by the vessels. However as the technological developments and therefore the expected impact on the freight costs is not yet accurate enough, it is hard to draw expectations and incorporate the impact of scrubbers in a model. (Notteboom, 2010) Notteboom addresses that although the initial investment will be high, it is not yet exactly clear how high, this investment is expected to pay off its debt automatically due to less maintenance costs due the scrubbing and the savings on using the HFO.

Another adaption with lower initial costs but higher variable costs, is a total shift of fuel to alternatives with a content lower than 0.1% sulphur, as for instance LNG. This is different from the fuel changeover procedure, which is more applied for deep sea vessels, while the SSS vessels while change fuel totally. Furthermore, important to take into account when using the alternatives is the dependence on the refining industry's willingness to supply a sufficient level of distillate products. (Notteboom, 2010)

When LNG would be used as an alternative it would require high investments in a bunkering network in the SECA. Ports will sell licenses for these bunkering locations which will add to the investments for the LNG bunkering companies. On the customer side, ship owners have to incur high initial fixed investments while the use of LSFO increases the variable cost. Therefore it is dependent on the owner's decision whether to increase the fixed costs once or accepting the higher variable costs.

Although the impact of retrofitting the vessel or switching fuels is significant, Notteboom et al (2010) assume that the ship owner will eventually benefit from the use of low sulphur fuel as it is a distillate product causing less wear and tear to the engine and resulting in less sludge. This will decrease the costs in maintenance recovering a part of the increased costs of the fuel.

3.3. Possible consequences of the implementation of the low sulphur fuel requirements (qualitative)

The consequences of the implementation of the low sulphur regulations can be considered to have an economic impact, impact on the physical transport flow or an impact on assets (investments) used on the trade route. This respectively means the freight rates can increase (economic impact) which in turn switch the cargo to other modes of transport (transport flows). The first impact is on the assets due to the initial investment necessary to meet the requirements. These consequences are theoretically reviewed in this paragraph.

According to Grosso et al. (2009) SSS companies consider fuel as the most important element influencing the pricing policies. An increase in bunkering costs as a consequence of the new low sulphur regulations is therefore expected to have a large economic impact on these companies.

Notteboom et al (2010) summarizes four consequences for SSS after the implementation of the low sulphur regulations; a) disruption of the commercial dynamics of shipping in the SECA, b) considerable increase in vessel operating costs, c) lower competitiveness compared to other transport modes and d) a modal backshift from sea to road, contradicting the objective of the European Commission of promoting the use of SSS.

A number of studies is established on the impact of the low sulphur regulations, mostly commissioned by the EU, stakeholder organisations or the academic world. For instance the report; 'Competitiveness of European Shortsea Freight Shipping Compared with Road and Rail Transport' commissioned by the European Commission of Environment concludes that in a range varying from 1-7% the modal share of SSS will decrease. (Delhaye, et al., 2013) However this study does not draw conclusions on a shift to other modes and is only focused on the decrease of the modal share of SSS.

Another research, also referred to in this research is 'The impact of low sulphur fuel requirements in shipping on the competitiveness of RORO shipping in Northern Europe' commissioned by the European Community Ship owner's Association (ECSA). The conclusions in this report indicate modal backshift of up to 20% from SSS to road transport. (Notteboom, 2010)

Furthermore the SKEMA study reviewing the impact on the future requirements of MARPOL Annex VI is commissioned by the European Commission of Transport and Energy and shows that by making use of scrubbers, the benefits outweigh the costs and therefore a modal backshift is prevented. (Kehoe, Nikopoulou, & Liddane, 2010)

Although several studies refer to the possibility of a modal backshift, it will not be the first time that fuel costs rise steeply, for instance in 2001-2008, shipping did not cease operations when the price of crude oil increased eightfold. (UNCTAD, 2012) However, this increase in crude oil prices affected the overall transport sector, while the sulphur regulations is a tariff only for maritime transport. Furthermore, currently the shipping sector is in a financially challenging period.

According to Delhaye et al (2010) especially container and general cargo vessels will be affected by the new regulations due to the high share of fuel costs in these sectors. The regulations will have little impact for the container shipping on the short distances to 500 km. This research is however focused on the longer distance from the North Sea ports to the Southern region and will following this reasoning be affected.

There seems indeed to be a trade-off between the distance of the sea leg and the modal back shift based on the research of Notteboom et al (2010) and Kehoe et al (2010). The ISL study performed in 2010, researching the impact of the new low sulphur regulations on the trade between the North and the Baltic Sea supports this by concluding that the SSS container segment on the medium-long routes will be affected by around 27% in terms of cargo throughput.

4. Methodology

The methodology is the operational part of the research, the GSIM model will be used to answer the research question in a quantitative way; *What will be the impact of the use of low sulphur fuel (MGO) on the shortsea shipping route between the North Sea ports and Southern Europe?* This chapter will guide the reader through this process behind the results of the model.

First of all, different reports with a relation to the subject of the new low sulphur regulations and its consequences are reviewed to provide a background on the research models used.
After this, a theoretical introduction of the GSIM model and its application to this specific research question is discussed. Finally, the quantitative part is explained by the monetization of the trade values and the process behind the tariffs and their elasticities. This is a complex and time consuming process, therefore in order to keep this research relevant the smaller details behind the intermediate results used will be explained in the appendix.

4.1. Introduction research methods

It is important to use a model which can economically analyse the impact of the low sulphur regulations on SSS volumes between certain regions. Most studies reviewing the Marpol Annex VI regulations are focused on the impact of the regulations on the reduction of emissions, engine performance, use of alternative energy sources, mostly with a technical objective. Other research is focused on the social cost and benefits of the new regulations as for instance in the ENTEC study, commissioned by the UK. (ENTEC, 2009) These technical and social impacts are interesting and of crucial importance for reviewing, however it is outside the scope of this research.

In addition research is done on the potential modal backshift as a consequence of the Marpol Annex VI, some of these articles will be reviewed in this paragraph.

To continue on the subject raised in paragraph 3.3, the ECSA and SKEMA studies review the impact of a modal shift as a consequence of the new regulations. However these studies have another geographical scope, trade route. Another difference is the role of different transport modes, the SSS market is analysed by focusing on certain vessel types or not taking rail transport into account. These small research scopes are necessary to perform an accurate research but leave space for further research.

In the article of Brooks et al. (2012) the State Choice Experiment (SCE) is used to investigate a potential freight mode shift under carbon pricing by focusing on the decision making process of Australian shippers. Similar to the GSIM makes this method use of OD relations by three trade corridors. A drawback of the SCE model is the required data which is not available for the trade routes between the North Sea ports and Southern Europe and is therefore not the right model to investigate the potential modal shift in this research.

A recent study done by Panagakos et al (2014) focuses on the future extension of the SECA area to the Mediterranean. The objective of this research is to investigate a potential modal back shift on the route from Greece to Northern Europe. The logit model analyses the data which is gathered by interviews with small transport service companies. The results indicate a modal backshift by an increase in road transport of 5.2%. Remarkable is the narrowed scope of the research by the focus on Greece-Germany route as there is, according to Eurostat (2014), not a lot of SSS throughput. However the objective for this scope might be explained by the nationality of the authors.

The various interests of the EU and international organizations make it sometimes challenging to establish a common policy. Different commissioned studies are performed to review the implementation of the Marpol Annex VI amendment. Holmgren et al (2013) reviewed several of these studies as a basis for the analysis on the possibility of a modal backshift. Characterized with a geographical research scope on the OD relation between Lithuania and the UK, it differs from this research. The methodology used is the TAPAS (Transportation And Production Agent-Based Simulator) model, an agent based freight transport model, simulating the decision making and activities for transport and the consequences after the implementation of new regulations. (Holmgren, Nikopoulou, Ramstedt, & Woxenius, 2014) Another difference is that this study does not consider a modal backshift to rail transport and is narrow with a focus on three high value cargo types. The result indicates that a modal backshift to road transport is unlikely to occur.

Crucial for reviewing these research results is to notice the geographical focus of this research. This can provide insights on the results found in a specific research. An example is the result of no modal backshift on the route for Lithuania and Germany while on another corridor results might indicate something else.

In contrast to most studies is a constant elasticity of substitution (CES) used in the research by Delhaye et al (2010). This research is focused on OD relations between different continents with the SECA ports as entry/exit locations. The research is especially focused on the impact of the Marpol Annex VI amendment in relation to the port calls to these entry and exit ports. The conclusion is that the regulation will have a marginal effect on the overall costs compared to the deep sea transport. Due to the flexibility of SSS, it is not expected that deep sea vessels will extend their network of ports substituting SSS.

After reviewing the methodological approaches used in different studies it is decided to use the GSIM model due to the level of data required and the lack of data available for the specific trade route and sector. An important difference between the GSIM and other studies performed is the incorporation of proportions and elasticities in the model. The reason for this is that elasticities are route and segment specific as concluded by Notteboom et al. (2010) and therefore important to incorporate as it makes the research more representative and valid.

All research related to the topic of low sulphur regulations add to the overall academic research. However using the GSIM model to analyse the impact of the Marpol Annex VI amendment for the trade route between the North Sea ports and Southern Europe adds new and extra relevance.

4.2. Global Simulation Model (GSIM) applied to the subject

Using GSIM is relevant for this research as it can analyse the impact of a change in a trade tariff on bilateral trade, in this research in terms of transport values. The GSIM consists of three main tables containing data on trade values, the initial tariff and the final tariff.

First of all the origin-destination (OD) relationships should be determined and monetised for trade values. This matrix contains all trade values expressed in Euros between Antwerp, Hamburg, Rotterdam and France, Greece, Italy and Spain, segmented by SSS, rail and road transport. In order to support the reader, a print screen of this matrix is included in figure 4 below to visualise the structure

Figure 4. GSIM Matrix trade values

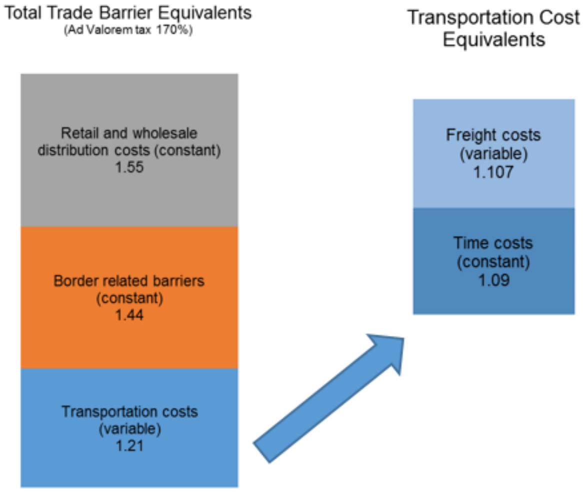
origin	destination				
	France	Greece	Italy	Spain	ROW
Antwerp Road	110314341171	470794025	4642482258	7895240978	610259831629
Antwerp Rail	2564610590	0	1876126778	113796203	14202034663
Antwerp SSS	2306107370	3898153841	12350592851	8282327684	62097178213
Hamburg Road	59966542483	1863617302	26667569179	13683457018	3663910685492
Hamburg Rail	671822534	5730200	4420588798	225561507	58253733625
Hamburg SSS	304439309	514612319	1630455721	1093386262	42906500028
Rotterdam Road	36922922695	893255587	5291016757	7546994646	1315828920867
Rotterdam Rail	200305798	676709	1162924035	338354	11367015697
Rotterdam SSS	2220749930	3753868959	11893452393	7975768547	153352181868
ROW Road	6675772670424	1368067331680	3806210040897	4217486054230	28042354068542
ROW Rail	36563491960	1031764930	32981997078	11613902216	631309001147
ROW SSS	49971564865	84469981784	267627804288	179471641485	1342890316689

Source: Compiled by author, based on Eurostat (2014).

The second matrix has the same structure but includes the initial total trade barrier between the OD relations per mode, this is based on the research of Anderson et al (2004) and explained in this paragraph. In order to determine the trade barriers it is assumed that for a developed industrialized country, the average Ad Valorem tax[2] of a good is 170%. This consists of a) retail and wholesale distribution costs, b) border related barriers and c) transportation costs. The focus of this research will be on the latter tariff equivalent, assuming the first two will be constant. The transportation tariff equivalent can in turn be segmented in a time cost and freight cost equivalent. (Anderson & Wincoop, 2004) It is furthermore assumed that the transport tariff equivalent 'time cost' is outside the scope of this research as the effect of the Marpol Annex IV is primarily about the freight cost. The values of the equivalents are summarized in figure 5 below.
In order to cross check these equivalents and the ad valorem tax, the following is done, multiplying the different total trade barrier equivalents gives the total of the Ad Valorem tax as can be seen in the following calculation;
$1.55 * 1.44 * 1.21 = 2.7\ (170\%)$

[2] Ad Valorem; 'According to value', a tax based on the value of the good

Figure 5. Trade barrier equivalents overview



Source: Compiled by author, based on Anderson et al (2004)

The process behind the third matrix, the final total trade barrier tariff, is similar to that of the initial trade barrier tariff. The difference is that it is adjusted for the impact of the new sulphur regulations affecting the trade values for SSS due to the increased operation costs.

The GSIM model makes use of three types of elasticities; a) composite demand elasticity, b) substitution elasticity and c) industry supply. (Francois & Hall, 2002) The assessment of the elasticities will be further discussed in the corresponding paragraph 4.6.

In order to run the GSIM model in excel it makes use of the indexes, variables, parameters and coefficients as summarized in table 1 below.

Table 1. GSIM Formula input

Indexes	
r, s	Exporting regions (North Sea ports)
v, w	Importing regions (Southern Europe)
i	Industry designation
Variables	
M	Imports (quantity)
X	Exports (quantity)
P	Composite price
Y	Total expenditure
$Pi, r*$	Export price on world market for transport
$P(i, v)r$	Internal price for same transport
$T(i, r), v$	Tariff barrier equivalent
Parameters	
$Em, (i, v)$	Aggregate import demand elasticity
$Ex, (i, r)$	Elasticity of export supply
Es	Elasticity of substitution
Calibrated Coefficients	

$N(i,v)(r,s)$	Cross price elasticity
$N(i,v)(r,r)$	Own price elasticity
$t(i,v)r$	Power of the tariff
$\theta(i,v)r$	Demand expenditure share
$\varphi(i,v)r$	Export quantity shares

Source: Compiled by author, based on Francois et al (2002)

First of all, the formulas for the calculation of the demand expenditure and export quantity shares will be summarized first.

(1) $\theta\ (i,v),r = \mathrm{M}(i,v),r\ \mathrm{T}(i,v),r/\sum \mathrm{M}(i,v),s\ \mathrm{T}(i,v),s$

(2) $\varphi(i,v),r = M(i,v),r/\sum M(i,w),r$

The cross price elasticity and own price elasticity formulas used for the different OD relations are respectively defined as;

(3) $N(i,v)(r,s) = \theta(i,v),s\ (Em + Es)$

(4) $N(i,v)(r,r) = \ \theta(i,v),r\ Em - \ \sum\theta(i,v),s\ Es = \theta(i,v),r\ Em - (1-\theta(i,v),r)Es$

In order to make the model sufficient to run, it is necessary to set the change in demand equal to the change in supply and define it in terms of world prices, this is accomplished by the incorporation of the next formula.

(5)

$$E_{X(i,r)}\hat{P}_{i,r}{}^{*} = \sum_{v} N_{(i,v),(r,r)}\hat{P}_{(i,v),r} + \sum_{v}\sum_{s\ r} N_{(i,v),(r,s)}\hat{P}_{(i,v),s}$$
$$= \sum_{v} N_{(i,v),(r,r)}[P_r{}^{*} + \hat{T}_{(i,v),r}] + \sum_{v}\sum_{s\ r} N_{(i,v),(r,s)}[\hat{P}_s{}^{*} + \hat{T}_{(i,v),s}]$$

The outcome of the GSIM model provides for this research an indication for the change in transport modes for the different OD relations as a consequence of the change in tariffs due to the implementation of the Marpol Annex VI amendment.

4.3. Data collection

Data is the input for running the GSIM model, it is important to gather accurate and relevant data for the subject, this process is explained in this paragraph.

The sources used are online databases of Eurostat, port authorities and related reports written by academics or commissioned by the EU. Unfortunately data is not provided by the port authorities as a first source of data, as the data was either not available or not possible to provide. Freight rates for shipping, road and rail transport are confidential, companies and brokers use an index exclusively for internal use. Due to this lack of common agreement the market works inefficiently, Wagelaar et al (2012) advise an implementation of a common index for the European SSS market.

The first step in the data collection is to determine the throughput on the trade routes from the three main North Sea ports to Southern Europe segmented by the three modes of transport. It is important to ensure the accuracy of the data, when comparing numbers it is beneficial to use one source, this is possible by using Eurostat. Eurostat provides data for maritime, rail and road transport. The maritime data is segmented in deep-sea, shortsea and inland shipping, this supports the accuracy of the data collection.
The datasets used in Eurostat are all in expressed in thousand tonnes, in the Maritime Transport paragraph the gross weight of goods handled on country and port level. This paragraph has a segment specialised in SSS, the throughput of SSS on country level and by sea region is extracted from this. From the Road Transport paragraph in Eurostat the annual road freight on country level and the loading and unloading data between countries is used. Finally, the Railway Transport segment gives insights in the total annual railway transport on country level as well as the loading and unloading data between countries.

Combining these different datasets of Eurostat enables to determine the OD relation values of SSS from the North Sea ports and Southern Europe. This is done in steps, first as data is available on both the SSS in the country as well as the throughput in the top 20 EU SSS ports, it is possible to determine the share of the North Sea ports in the country's throughput. This calculation is shown in figure 6 below, where the last table is the result of calculating the shares of the port throughput in the country level SSS throughput.

Figure 6. Port shares in SSS country throughput

Country throughput - gross weight of goods handled in all ports - [mar_mg_aa_cwh]

Country	Throughput (Thousand tonnes)
EU 28	3732638
Belgium	223987
Germany	298758
Netherlands	534247

Port throughput - gross weight of goods handled in each ports [mar_mg_aa_pwhd]

Ports	Throughput (Thousand tonnes)
EU 28 ports	3732638
Antwerp	164547
Hamburg	113531
Rotterdam	395597

Share of Port in Country Throughput — Source: Compiled by author

Port	Share (%)
Antwerp	73%
Hamburg	38%
Rotterdam	74%

Source: Compiled by author, based on Eurostat datasets.

Using another Eurostat dataset containing information of SSS trade from the Netherlands, Belgium and Germany to the Mediterranean region involves the first step of forming the OD relation. As the Mediterranean region, is the seabasin and not the specific countries which are relevant for the research, the OD has to be more specified to this.

This distribution of the South European countries in the Mediterranean region can be determined, by finding their shares in the region. Combining all these datasets, makes it possible to establish the OD relation between the North Sea ports and the Southern European countries, the result of this process is shown in figure 7 below.

Figure 7. OD Relations North Sea ports to Southern European countries

Port/ Country	France	Greece	Italy	Spain	ROW
Antwerp	2,243	3,792	12,013	8,056	60,399
Hamburg	296	501	1,586	1,063	41,733
Rotterdam	2,160	3,651	11,568	7,758	149,158
ROW	48,605	82,160	260,308	174,563	1,306,162

Source: Compiled by author, based on Eurostat datasets.

A note should be made concerning France, the country is characterized by three different coastlines, this research will focus on the Mediterranean coastline and therefore it is assumed that Marseille represents the SSS throughput for France.

As it is important to develop a trustworthy GSIM model it is necessary to decide on a Rest of the World column (ROW). Lacking this column would change the numbers of the OD relations between the North Sea ports and the Southern European countries as if there was no other trade than between these relations and therefore incur invalid changes after a final tariff barrier. For SSS, the selection of countries for the ROW is based on geographical transport boundaries. Therefore for SSS the ROW column includes the trade with the remaining EU28 countries as well as the trade with Norway and Turkey as these are realistic countries in the SSS network to take into account.

The ROW for rail transport is assumed to be the rest of the EU28 trade as well as Swiss, other countries are not included due to geographical and railway network boundaries.
Although road transport can in theory reach every part of the world connected by land or via a RoRo vessel, the ROW is assumed to be Norway and Swiss. This selection is also based on the data available in Eurostat. Monetizing the origin-destination relations.

4.4. Monetising the OD relations

The objective of the data collection is to find accurate data on the involved trade routes. In order to establish the GSIM, these values should not be in tonnes of cargo, as provided by Eurostat but be monetised to become trade values. This is necessary to show the proportions between the different OD relations. For this research for instance, the quantity of road transport may be higher but is it proportionally seen also more valuable or is the average cargo value maybe lower compared to the other transport modes? These are important considerations to take into account when evaluating different transport modes, it is therefore incorporated in the GSIM model.

In order to monetise a trade quantity it is necessary to calculate the average value of a ton of cargo transported. This calculation is based on the average trade value of intra-European imports and exports provided by Eurostat. By dividing the total value of trade by the quantity, it gives the value per thousand tonnes of cargo. Taking the average of imports and exports gives an outcome of the average value per thousand tonnes of European cargo expressed in euros. These numbers are shown in Table 2 below.

Table 2. Average trade value intra EU imports and exports

	Intra EU Imports	Intra EU Exports
Time frame	Jan-Dec. 2012	Jan.- Dec. 2012
Quantity (Thousand tonnes)	1,712,908	1,713,603
Total Value (€)	2,770,293,124,860	2,840,203,902,441
Value per thousand tonnes (€)	1,617,304	1,657,446
Average value of imports and exports (€) per thousand tonnes	1,637,375	

Source: Eurostat (2014). EU 28 Trade since 1988 by CN8 [DS - 016890]

Although it is hard to accurately determine the cargo value and therefore to differentiate between the trade values per mode, there is an indirect way to accomplish this. Savy et al (2013) review the difference in average freight value per transport mode in the book ‘Freight transport and the modern economy’. Based on this, freight cost proportions per mode can be established and applied to the average freight value in Europe of table 2. The proportions and corresponding values as outcome of this calculation are shown in table 3 below.

Table 3. Freight value proportions and final average value per mode

Transport mode	Average value density (Euros/Ton)	Proportion	Average Value (€/thousand tonnes)
Rail	400	0.27907	€ 456,942
Sea	900	0.62791	€ 1,028,119
Road	3,000	2.09302	€ 3,427,064
Average	1,433		

Source: Compiled by author, based on Savy M. & Burnham J. (2013) 'Freight Transport and the Modern Economy'

The conclusion by Savy et al. (2013) that road transport carries on average the highest value of cargo, corresponds with the findings of Brooks et al. (2012). In this research Brooks et al conclude that especially high value and perishable cargo need a reliable service due to the significant inventory carrying costs, this confirms the high average value density of cargo carried by road.

The final step for calculating the freight values for the OD relations is by combining the cargo throughput (thousand tonnes) with the average freight value (euros/thousand tonnes). The outcome is a set of transport values expressed in euros per thousand tonnes and represents the first matrix of the GSIM. The detailed table containing all freight values can be reviewed in Appendix A.

4.5. Tariffs and elasticities

This paragraph will discuss the process behind the calculation of the initial and final trade tariff barriers, the second and third matrices of the GSIM. A change in these barriers affects the trade values of the OD relations and will indicate a potential modal shift. Finally, the theory behind the elasticities, which are applied to both barriers will be discussed.

4.5.1. Initial trade tariff barrier

The second matrix of the GSIM is the initial trade tariff barrier, the second step in the data collection process, this barrier is the initial freight rate before implementation of the new low sulphur regulations.
In order to establish this freight rate, it is necessary to determine the influencing variables. Although it can be disputed whether freight rates should not diminish over distance, this is too complex to incorporate and therefore it is assumed that transport distance increases the freight rate, other variables are assumed to be constant.

Step 1: Determine the OD relations distance (km)

The basis of the tariff barrier are the OD relations expressed in distances (Km). The reference points in the Southern European countries used for calculating this, are the main SSS transport cities; Marseille, Piraeus, Genoa and Barcelona. The ROW location is assumed to be in the middle of the OD economic relation centre; Zurich, Swiss.
The road and rail transport distance are assumed to be equal, nautical distance of SSS is determined by making use of the nautical miles planner. (Ports.com, 2014)
The table stating the distances can be reviewed in Appendix B.

Step 2: Freight cost equivalent proportions

It is essential to determine the proportions of the distribution of the freight rate costs per mode. Table 4 below summarizes this distribution based on the tariffs as assumed in the COMPASS report of the EU by Delhaye et al (2013).

Table 4. Initial freight cost equivalent proportions

Transport mode	Initial tariff (€/ton km)	Proportions
Rail	0.008	0.195758564
Road	0.1046	2.55954323
SSS	0.01	0.244698206
Average	0.040866667	

Source: Compiled by author, based on Delhaye et al (2013).

Combining the matrices of the OD relation distances (Appendix B1) and the proportions of the freight cost, will form a proportional freight cost distribution for each OD relation individually, this can be reviewed in Appendix B2.

Step 3: Freight cost tariff barrier equivalent per OD relation

As discussed in paragraph 4.2, the article of Anderson et al (2004) is a good support in determining the trade tariff barrier and its equivalents.

Table 5 below, summarizes the barrier equivalents as used in the Excel file, as explained before, the objective of the research is about the freight costs, the remaining barrier equivalents are assumed to be constant.

Table 5. Trade tariff barrier equivalents

Trade tariff barrier equivalents	
Transportation costs, including;	1.21
1. Time costs (constant)	1.09
2. Freight Costs (variable	1.107
Border related barriers (constant)	1.44
Retail and wholesale distribution costs (constant)	1.55

Source: Compiled by author, based on Anderson et al (2004)

In step 2, the distances are adjusted to the freight cost proportions per mode, the next step is to calculate the freight cost tariff equivalent.

$$Freight\ cost\ tariff\ equivalent = \frac{Specific\ OD\ Freight\ Cost}{Average\ Freight\ Cost} * 0.107 + 1$$

This freight cost tariff equivalent is calculated for every OD relation individually, the average freight cost is based on all OD relations including the ROW columns and has an average value of 1589. The table including the outcome for every OD relation can be reviewed in Appendix B3.

Step 4: Total trade tariff barrier per OD relation

The next step is to determine the total initial trade barrier tariff, taking into account the constant equivalents of time costs, border related barriers and retail and wholesale distribution costs as summarized in table 4. The formula for changing the freight cost tariff equivalent to the total initial tariff barrier is summarized below;

$$\begin{aligned} Total\ initial\ trade\ barrier \\ &= time\ cost\ barrier * freight\ cost\ tariff\ equivalent \\ &* border\ related\ barrier * retail\ and\ wholesale\ distribution\ cost \\ &= 1.09 * freight\ cost\ tariff\ equivalent * 1.44 * 1.55 \end{aligned}$$

The total initial trade barrier represents the Ad Valorem tax, this means that all barriers for trading between two countries incur a cost of 170% of the average value of a product. The freight cost barrier is in this research the variable equivalent and therefore influences the total barrier. For this research specific, the total trade tariff barrier are the costs of transporting products by use one of the three modes from a destination to an origin. The freight cost is an equivalent of the transport cost and a part of this is the bunkering cost. After the low sulphur regulations, as is explained in the total final trade barrier, these bunkering costs will increase for SSS and therefore increase the overall initial trade tariff barrier for all SSS and change the trade values in these relations.
The table including the overview of the total initial trade tariff barrier for the OD relations individually can be found in Appendix B.

The last step before the initial trade barrier tariff is valid and can be included as the second matrix of the GSIM is the adjustment for mode and port specific elasticities. This is covered in the next paragraph.

4.5.2. Final trade tariff barrier

The third matrix in the GSIM model represents the final trade tariff barrier. It is calculated using the same steps as in paragraph 4.5.1. for the initial trade tariff barrier. The only difference is the freight cost proportions distribution in step 2, which is adjusted to the consequences of the increased fuel costs after the sulphur regulations. The assumptions regarding the adjustments are based on the article of Notteboom (2010). Notteboom concludes that the bunkering costs represent 47% of the total freight costs, after the implementation of the new low sulphur regulations, it is expected that these costs will increase by 166%. Based on the report by Delhaye et al (2013) it was assumed, as can be seen in table 3, that the freight cost for SSS was initially 0.01 euros/Tkm, adjusting this to the 166% increase of 47% of this cost, the increase will be 0.007802 euros/Tkm. Adding this increase to the initial tariff will give a new tariff for SSS of 0.017802 euros/Tkm, this enables to calculate the new proportions as can be seen in the last column of table 6 below.

Table 6. Adjusted freight cost proportions

Mode	New tariff (€/Tkm)	New proportion
Rail (constant)	0.0080	0.18
Road	0.1046	2.41
SSS	0.017802	0.41
Average	0.0435	
Adjustment	Increase (%)	Tariff increase (€/Tkm)
Total tariff increase in SSS		0.007802
Increase in bunker fuel	166%	
Bunker as percentage Freight	47%	

Source: Compiled by author, based on Notteboom (2010)

In order to calculate the final trade barrier tariff it is necessary to review the different steps as explained in paragraph 4.5.1. First of all, the first matrix consisting of the distances of the OD relations remains unchanged and the adjustment affects the outcomes from step 2 onwards, the changed tables can be reviewed in Appendix C. Similar to the last step of the initial trade tariff barrier should the total final trade tariff barrier also be adjusted to elasticities, this will be done in the next paragraph.

4.6. Assessing elasticities

In order to finalize the trade barriers it is necessary to adjust the total initial and final trade tariff barriers, calculated in paragraph 4.5.1 and 4.5.2, for the port and mode specific elasticities. These elasticities indicate the impact of a one percentage change in trade barrier tariff on the trade values of an OD relation, specific for port and mode. It is therefore important to incorporate it when assessing the impact of the increased freight costs as a consequence of the new regulations on the throughput per mode and port. The level of the elasticity indicates how sensitive the OD relation is for a change in trade barrier based on the level of competition of the port as well as the type of mode of transport.

The GSIM model is based on three types of elasticities; substitution, industry supply and composite demand elasticity. It is hard to establish a basis for the three types of elasticities required to run the GSIM, due to a lack of accurate data on the elasticities for transport modes. Freight elasticities are mostly not determined for different sectors, types of cargo or geographical orientation. (Beuthe, Jourquin, Geerts, & Koul a Ndjang' Ha, 2001) Therefore, the assessment of the elasticities is based on the conclusions drawn by other research done. Table 7 below, provides an overview of the process of calculating the port and mode specific elasticities.

Table 7. Port and mode specific elasticities

	Port	Road	Rail	SSS	Total
Antwerp– Port throughput (Thousand tonnes)	Three pretty equal modes	35985	9,967	23,860	69812.56
Share of mode in port (%)		52	14	34	
Specific Elasticity		-1.4	-1.4	-1.4	
Hamburg Port throughput (Thousand tonnes)	One dominant mode	29816	11,651	3,150	44616.56
Share of mode in port (%)		67	26	7	
Specific Elasticity		-1.1	-1.1	-1.1	
Rotterdam Port throughput (Thousand tonnes)	Two dominant modes	14781	2,986	22,977	40743.23
Share of mode in port (%)		36	7	0.56	
Specific Elasticity		-1.1	-0.5	-1.1	
	Total EU freight per transport mode	80582	24,604	49,987	155172

Source: Compiled by author, based on VanElswijk (2012)

In order to support the review of table 7 above an explanation is provided. First of all the table is separated in three sectors, the main North Sea ports on the vertical axis. The horizontal axis include the modes and total columns related to these three ports. In the second column it is noticed how the port is ranked in terms mode dominance, however in the research of VanElswijk (2012), also the port competition is taken into account, this is based on the economic nature of these three ports assumed to be constant. The level of dominance of a mode is determined by the share in the overall transport of the port. These shares are calculated by using the first row of a port; the port throughput, this sums up to a total throughput number in the last column. The result of the mode shares is shown in second row. The process of assigning the right elasticity to the relation of port and mode is explained in Appendix E. All information in table 6 is used in order to calculate the composite demand, which is explained next.

The composite demand elasticity is calculated based on the weighted average elasticities per mode of table 7. The first step is calculating these weighted average elasticity per mode by using the formula below. (VanElswijk, 2012);

$$\text{Weighted average elasticity per mode} = \sum \left(\frac{Freight\ per\ mode\ per\ port}{Total\ freight\ handled\ by\ this\ mode}\right) * Specific\ elasticity$$

The final step in the process of determining the composite demand is to weight these averages per mode compared to the total freight share of all modes. This is done using the formula below.

$$\begin{aligned} Total\ weighted\ composite\ demand\ elasticity &= weighted\ average\ elasticity\ road * \left(\frac{total\ road\ freight}{total\ freight}\right) \\ &+ weighted\ average\ elasticity\ rail * \left(\frac{total\ rail\ freight}{total\ freight}\right) \\ &+ weighted\ average\ elasticity\ SSS * \left(\frac{total\ SSS\ freight}{total\ freight}\right) \end{aligned}$$

The outcome of this formula is summarised in table 8 below and shows that the composite demand as will be used in the GSIM is; -1.22.

Table 8. Total weighted composite demand elasticity

Transport mode	Weighted elasticity results
Road	-0.640805113
Rail	-0.182139335
SSS	-0.400482236
Total composite demand elasticity	-1.223426685

Source: Compiled by author, based on VanElswijk (2012)

The outcome of the elasticity distributions for the different modes of transport is in line with the reasoning of Abdelwahab et al (1998), confirming that road transport is more elastic compared to other modes. Another validation can be found in the article of Notteboom et al (2010) stating that price elasticities of demand are close to -1. This indicates that a price increase in SSS with a specific percentage is expected to decrease the demand with the similar percentage, a composite demand elasticity of -1.22 is therefore close to this reasoning.

Based on the constant numbers used by Francois & Hall (2002) for the industry supply and substitution elasticity, it is assumed that these are respectively 1.5 and 10.
A validation for this assumption can be found in the article of Garcia-Menendez et al. (2004) concluding that for a discrete choice between road and shortsea transport, the industry supply elasticity of shipping is smaller than the substitution elasticity (1.5 to 10). It also concludes that an efficient substitution for an eco-tax would be a subsidy on SSS to decrease road transport, the largest polluter, to make up for the increased costs when shortsea shipping is subject to carbon fuel pricing.

5. Results

The aim of this chapter is to link the theoretical framework of the literature review with the GSIM model and review the outcome of the study.
Table 9 below, is one of the result tables of the GSIM indicating the percentage change in trade values of the OD relations as a consequence of the increased trade tariff barriers due to the low sulphur regulations under Marpol Annex VI.

Table 9. GSIM result, trade quantities; percentage change

	France	Greece	Italy	Spain	ROW
Antwerp Road	9.2	9.7	14.8	8.9	***-0.6***
Antwerp Rail	1.7	0.0	6.6	***-2.4***	***-2.3***
Antwerp SSS	***-22.0***	***-54.3***	***-20.0***	***-23.5***	6.4
Hamburg Road	10.6	13.1	15.4	10.8	0.4
Hamburg Rail	2.6	***-13.9***	7.5	***-1.3***	***-1.6***
Hamburg SSS	***-30.7***	***-64.1***	***-28.9***	***-31.9***	0.2
Rotterdam Road	12.8	7.3	14.8	13.1	0.5
Rotterdam Rail	2.7	***-14.9***	7.3	***-1.1***	***-1.8***
Rotterdam SSS	***-29.9***	***-62.0***	***-27.8***	***-31.4***	2.3
ROW Road	0.5	5.3	***-0.7***	1.6	1.7
ROW Rail	1.7	***-14.8***	6.1	***-2.1***	***-1.4***
ROW SSS	3.2	***-33.3***	11.3	***-4.5***	***-3.2***

Source: Author's Excel results GSIM

The structure of table 9 is similar to the GSIM input tables of trade tariff barriers and trade values. The percentage change is the change in trade values for a specific OD relation and mode used on the route compared to the initial trade values before the regulations. The negative numbers indicate a decrease of trade for a specific mode and port, for SSS this is the modal backshift as described before. This table is useful to support the reader in a quick glance on the impact of the low sulphur regulations.

Next to the percentage change outcome compared to the initial situation, results are also expressed in terms of real trade values, euros per thousand tonnes of cargo, this table is included in Appendix F. When dividing these numbers by the corresponding average trade values per thousand tonnes per mode as calculated in table 3 of paragraph 4.2, the change in throughput is calculated, these results are summarised in table 10 below. This is useful as most port performance data is mostly based on this parameter and it provides a more realistic overview when comparing the impact for different OD relations. The last two columns show the total of the OD relation throughput including and excluding the ROW respectively, the latter one is used when focused on the Southern European countries.

Table 10. GSIM result, trade quantities; thousand tonnes

Change in Throughput (Thousand tonnes)	France	Greece	Italy	Spain	ROW	Total	Total S-EU
Antwerp Road	3204	14	211	223	79	3732	3652
Antwerp Rail	61	0	247	-7	-900	-600	300
Antwerp SSS	-534	-2098	-2620	-2036	2372	-4918	-7290
Hamburg Road	1945	74	1246	452	9991	13708	3717
Hamburg Rail	29	-2	662	-9	-2842	-2162	680
Hamburg SSS	-94	-324	-477	-352	-596	-1842	-1247
Rotterdam Road	1464	21	240	306	4633	6663	2031
Rotterdam Rail	9	0	169	0	-588	-410	178
Rotterdam SSS	-675	-2290	-3376	-2539	471	-8409	-8880
ROW Road	27488	25118	2160	31698	212625	299090	86465
ROW Rail	895	-345	3926	-691	-26928	-23143	3785
ROW SSS	721	-28288	24745	-10622	-61784	-75227	-13444

Source: Author's Excel Calculations based on GSIM results

When reviewing table 9 and 10, it is clear that for almost all OD relations the trade values are decreased for SSS and increased for road transport.
Remarkable is the result for the port of Rotterdam compared to the other ports, when reviewing the GSIM result tables above. First of all in table 9 the range of percentage change is summarised varying from a decrease of 27 to 62% for SSS and for road transport from 0.5 to almost 15%. Table 10 in turn shows that the impact is the largest for SSS with the Southern European countries by a decrease of 8880 thousand tonnes of throughput. On the other hand the road transport to this area is increased by 2031 thousand tonnes, based on this, it can be concluded that a modal backshift is the consequence.
The port of Antwerp is in terms of percentage and trade quantities relatively similar to the result for the port of Rotterdam. The situation for the port of Hamburg is different where the increase in road transport outweighs the decrease in SSS and rail, a modal shift can be detected.

In order to gain a deeper understanding of the consequences of the regulations for the different ports and modes in total, table 11 and 12 below show the overall change in cargo throughput (Thousand tonnes) per port and mode respectively. The last two columns of table 11 have a similar meaning as that of table 9.

Table 11. GSIM Result, Change in cargo throughput per port (Thousand tonnes)

Change in throughput per port (Thousand tonnes)	Total	S-EU
Antwerp	-1786	-3337
Hamburg	9704	3151
Rotterdam	-2155	-6671
ROW	200719	76806

Source: Author’s Excel Calculations based on GSIM results

Table 11 confirms the negative impact of the regulations on the total port throughput to the Southern European countries especially for Rotterdam and also, but with less impact when taking the ROW into account in the ‘total’ column. On the other hand has also Hamburg a remarkable result, by adding up all throughput changes it can be concluded that the port has an increase in throughput. Reviewing table 9 and 10 provide insight and show that this is due to the high modal backshift, boasting the road transport throughput outweighing the decrease in rail and SSS.
Based on the decreased throughput for the port of Rotterdam and Antwerp and on the other hand the increase for Hamburg and the ROW ports, it can be assumed that cargo is shifted from the port of Rotterdam and Antwerp to Hamburg or other ports. This substitution effect is a consequence of the new low sulphur regulations.

Concerning the columns in table 12, the N-Sea ports columns include the OD relations between the three major North Sea ports and the total (incl. ROW) and Southern European countries. The last two ’Total -’ columns include next to this also the ROW as an origin.

Table 12. GSIM Result, Change in cargo throughput per transport mode (Thousand tonnes)

Change in throughput per mode (Thousand tonnes)	N-Sea ports - Total	N-Sea ports - S-EU	Total - total	Total - S-EU
Road	24103	9400	323193	95865
Rail	-3171	1159	-26315	4943
SSS	-15169	-17416	-90397	-30860

Source: Author's Excel Calculations based on GSIM results

Table 12 shows the importance of the in-depth review of the results as it confirms the modal backshift from SSS to road transport. Furthermore for the OD relations with the Southern European Countries there is also a modal shift to rail transport, however this is not the case when taking the ROW countries into account. In order to validate the result of the impact on the modes, evidence is found in the research by Brooks et al (2004) conclude that after comparing the mode specific constants, it turned out that, ceteris paribus, road is preferred to rail and shortsea shipping.

Although the focus is mainly on the Southern European countries as an area, it is interesting to review the impact for these countries individually, this is done in table 13 below. The 'Total' column includes the ROW as a relation and the last column is limited to the three main North Sea ports.

Table 13. GSIM Result, Change in cargo throughput per Southern European country (Thousand tonnes)

Change in throughput (Thousand tonnes)	Total	North Sea ports
France	34513	5408
Greece	-8120	-4605
Italy	27133	-3698
Spain	16423	-3963
ROW	136533	12621

Source: Author's Excel Calculations based on GSIM results

In relation to the three major North Sea ports, France is the only Southern European country that shows an increase in throughput by 5408 thousand tonnes. Reviewing table 10 this is especially a consequence of the increased road transport from the port of Antwerp. When comparing the different Southern European countries it can be assumed that France substitutes the other countries in the transport network as a consequence of the new low sulphur regulations.

6. Conclusion & Discussion

At the end of the reviewing and learning process on the consequences of the low sulphur regulations, all essentials are summarized in this concluding paragraph. Furthermore, along the way different challenges and shortcomings are detected and discussed in the corresponding paragraphs as well.

In order to determine the consequences of the implementation of Marpol Annex VI, the low sulphur regulations on the SSS industry between the North Sea ports and Southern Europe, a GSIM model is applied.

On the trade route from the main North Sea ports to the Southern region, road transport is the dominant mode of transport. Although the EC supports the use of SSS, the goals are not yet accomplished as road transport still has the advantage over SSS in terms of flexibility. This is an important element in the decision making of shippers next to the freight rates. The main SSS ports on the specific route are Antwerp and Rotterdam while Hamburg is more active in the rail transport. The SSS of the Port of Hamburg is due to its geographical location more focused on the Baltic region.

Different research is done on the subject from a technical and social point of view. The economic studies performed differ from this research in terms of geographical and shipping segment scope. Although these studies had sometimes different outcomes, most of them conclude on a modal backshift or at least a decrease of modal share for SSS after the implementation of the new low sulphur regulations.

For ship owners in order to meet the requirements of the new regulations, different options are available. First of all it is possible to use the technology of fuel changeover, however this is mostly done by deep sea vessels which do not sail so often in the SECA area. Another option is the use of scrubbers, although Kehoe et al (2010), concludes that the benefit of scrubbers will outweigh the high initial costs of installing them there is a lack of information on the use of scrubbers. The option reviewed in this research is the use of fuel distillates that have a sulphur content of less than 0.1%, these are referred to LSFO and include for instance LNG.

The methodology is based on OD relations between Antwerp, Hamburg, Rotterdam and France, Greece, Italy and Spain, the model is based on the transport by three modes; SSS, road and rail transport. The trade quantities are monetised to become trade values. As the new regulations require the use of alternative energy sources on board of vessels, it is assumed that bunkering costs will increase. The GSIM incorporates this by using an initial and an adjusted final trade tariff barrier and the assessment of elasticities in order to make the trade values representative of the real life industry

The result of the research indicates a modal backshift from SSS to mainly road transport in all three ports. However, the largest modal backshift is in Rotterdam with a total decrease of 8880 thousand tonnes of cargo transported by SSS to Southern Europe. Rail transport also gains from the consequences of the regulation however to a smaller extent than compared to road transport. This can be explained by the capacity constraints and infrastructural network of the railway in Europe.

Furthermore it is concluded that the port of Hamburg will substitute the port of Antwerp and Rotterdam. Especially the trade quantities to Greece are decreased while for France an increase occurred.

Overall was the outcome of the GSIM in line with the expectations in the maritime industry and reasoning of earlier research performed. The low sulphur regulations will negatively impact the SSS share on the route between the North Sea ports and Southern Europe and incur a modal backshift from sea to mainly road transport.

The EC should seriously take the predictions of the impact on SSS into account when supporting the mode in order to shift cargo from road to sea transport. In order to outweigh the costs of the costs of the new regulations either subsidies for ship owners or taxes on road transport should be reviewed.

6.1. Methodological Limitations

This paragraph shortly summarises some of the limitations of the research.
The main limitation was the lack of elasticities for transport modes. Furthermore, it was not possible to make a distinction in throughput by type of cargo, this would however be very valuable to indicate which markets will be mostly affected.

Although it is not the aim of the research to calculate the exact tonnes of cargo that will be subject to a potential modal shift, it would have been helpful to have more exact data about the OD relations. In the end it was possible to calculate everything indirectly in a reliable way, but first source would have been beneficial.

The scope of the research was due to the level of data narrowed. An interesting extension to this scope would for example be the port of Zeebrugge, Amsterdam, Duisburg.

6.2. Recommendations for further research

The recommendations for further research include the limitations experienced in this research as described in the paragraph above.
It would be interesting to incorporate the direction of freight; head- and backhaul, as these have other rates and requirements according to Brooks et al. (2012)

Another recommendation based on the article by Brooks et al (2012) is to review the willingness to pay of shippers (WTP) although indirectly taken into account in the elasticities it is an interesting concept for these regulations.

A valuable addition to the research would be to incorporate the economic effect of the different EU projects affecting the infrastructural network connecting the EU via land. This will certainly impact the elasticity and the modal backshift to road transport.

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8. Appendix

The appendix includes more extended however relevant information for this research. Especially the process behind the assessment of the elasticities for the GSIM is explained in this paragraph.

Appendix A. GSIM Matrix 1 – OD relation trade values

Table 14. Trade values of OD relations in Euros

OD trade values (Value (€))	France	Greece	Italy	Spain	ROW
Antwerp Road	110,314,341,171	470,794,025	4,642,482,258	7,895,240,978	610,259,831,629
Antwerp Rail	2,564,610,590	0	1,876,126,778	113,796,203	14,202,034,663
Antwerp SSS	2,306,107,370	3,898,153,841	12,350,592,851	8,282,327,684	62,097,178,213
Hamburg Road	59,966,542,483	1,863,617,302	26,667,569,179	13,683,457,018	3,663,910,685,492
Hamburg Rail	671,822,534	5,730,200	4,420,588,798	225,561,507	58,253,733,625
Hamburg SSS	304,439,309	514,612,319	1,630,455,721	1,093,386,262	42,906,500,028
Rotterdam Road	36,922,922,695	893,255,587	5,291,016,757	7,546,994,646	1,315,828,920,867
Rotterdam Rail	200,305,798	676,709	1,162,924,035	338,354	11,367,015,697
Rotterdam SSS	2,220,749,930	3,753,868,959	11,893,452,393	7,975,768,547	153,352,181,868
ROW Road	6,675,772,670,424	1,368,067,331,680	3,806,210,040,897	4,217,486,054,230	28,042,354,068,542
ROW Rail	36,563,491,960	1,031,764,930	32,981,997,078	11,613,902,216	631,309,001,147
ROW SSS	49,971,564,865	84,469,981,784	267,627,804,288	179,471,641,485	1,342,890,316,689

Source: Author’s Excel Calculations based on GSIM results

Appendix B. GSIM Matrix 2 process - Initial trade tariff barrier

Table 15. OD relation distance distribution

OD relation distance	France	Greece	Italy	Spain	ROW
Rdam Road	1,217	2,923	1,262	1,515	813
Rdam Rail	1,217	2,923	1,262	1,515	813
Rdam SSS	4,500	6,110	4,852	4,143	813
Antwerp Road	1,081	2,831	1,079	1,383	698
Antwerp Rail	1,081	2,831	1,079	1,383	698
Antwerp SSS	4,332	5,941	4,684	3,974	698
Hamburg Road	1,455	2,653	1,245	1,819	868
Hamburg Rail	1,455	2,653	1,245	1,819	868
Hamburg SSS	5,013	6,623	5,365	4,656	868
ROW Road	736	2,475	417	1,061	1,010
ROW Rail	736	2,475	417	1,061	1,010
ROW SSS	736	2,475	417	1,061	1,010

Source: Author's Excel Calculations based on GSIM results

Table 16. OD relation distance distribution adjusted for freight cost proportion per mode

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	3114.9641	7481.5449	3230.1436	3877.7080	2080.9086
Rdam Rail	238.2382	572.2023	247.0473	296.5742	159.1517
Rdam SSS	1101.1419	1495.1060	1187.2757	1013.7847	198.9396
Antwerp Road	2766.8662	7246.0669	2761.7471	3539.8483	1786.5612
Antwerp Rail	211.6150	554.1925	211.2235	270.7341	136.6395
Antwerp SSS	1060.0326	1453.7520	1146.1664	972.4307	170.7993
Hamburg Road	3724.1354	6790.4682	3186.6313	4655.8091	2221.6835
Hamburg Rail	284.8287	519.3475	243.7194	356.0848	169.9184
Hamburg SSS	1226.6721	1620.6362	1312.8059	1139.3148	212.3980
ROW Road	1883.8238	6334.8695	1067.3295	2715.6754	2584.4074
ROW Rail	144.0783	484.5024	81.6313	207.6998	197.6602
ROW SSS	180.0979	605.6281	102.0392	259.6248	247.0753

Source: Author’s Excel Calculations based on GSIM results

Table 17. **I**nitial freight cost tariff equivalent per OD relation

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	1.209746487	1.503770732	1.2175021	1.261105939	1.140118
Rdam Rail	1.016041796	1.03852931	1.016635	1.019969861	1.010716
Rdam SSS	1.074145525	1.100673147	1.0799454	1.068263314	1.013396
Antwerp Road	1.186307274	1.487914794	1.1859626	1.238356115	1.120298
Antwerp Rail	1.014249122	1.037316619	1.0142228	1.018229913	1.009201
Antwerp SSS	1.071377426	1.09788857	1.0771773	1.065478737	1.011501
Hamburg Road	1.25076511	1.457237001	1.2145722	1.313499474	1.149597
Hamburg Rail	1.019178976	1.034970325	1.0164109	1.023977015	1.011441
Hamburg SSS	1.082598115	1.109125737	1.0883979	1.076715904	1.014302
ROW Road	1.126847506	1.426559207	1.0718688	1.182860331	1.174021
ROW Rail	1.00970153	1.032624031	1.0054967	1.013985494	1.013309
ROW SSS	1.012126913	1.040780039	1.0068708	1.017481867	1.016637

Source: Author’s Excel Calculations based on GSIM results

Table 18. Total initial trade tariff barrier

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	2.943168033	3.65849374	2.962036531	3.068119417	2.773770855
Rdam Rail	2.471907765	2.526617189	2.473350863	2.481464277	2.458951958
Rdam SSS	2.613267166	2.677805685	2.627377451	2.598956451	2.465469948
Antwerp Road	2.886143241	3.619918145	2.885304641	3.012771824	2.725551362
Antwerp Rail	2.467546405	2.523666856	2.467482267	2.477231191	2.455264043
Antwerp SSS	2.606532712	2.671031145	2.620642996	2.59218191	2.460860054
Hamburg Road	3.04296142	3.545282754	2.954908432	3.1955866	2.796832352
Hamburg Rail	2.479540147	2.517958605	2.472805693	2.491213201	2.460715744
Hamburg SSS	2.633831303	2.698369822	2.647941588	2.619520587	2.46767468
ROW Road	2.74148476	3.470647364	2.607728077	2.877757242	2.856253145
ROW Rail	2.456482658	2.512250353	2.446252702	2.466905028	2.465260355
ROW SSS	2.462383323	2.532092941	2.449595877	2.475411285	2.473355444

Source: Author’s Excel Calculations based on GSIM results

Appendix C. GSIM Matrix 3 process – Final trade tariff barrier

Table 19. Freight cost tariff proportions

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	2928.5947	7033.9213	3036.8829	3645.7033	1956.4071
Rdam Rail	223.9843	537.9672	232.2664	278.8301	149.6296
Rdam SSS	1842.9702	2502.3440	1987.1314	1696.7612	332.9633
Antwerp Road	2601.3236	6812.5320	2596.5108	3328.0579	1679.6706
Antwerp Rail	198.9540	521.0350	198.5859	254.5360	128.4643
Antwerp SSS	1774.1660	2433.1302	1918.3272	1627.5475	285.8652
Hamburg Road	3501.3190	6384.1920	2995.9740	4377.2503	2088.7594
Hamburg Rail	267.7873	488.2747	229.1376	334.7801	159.7522
Hamburg SSS	2053.0688	2712.4426	2197.2300	1906.8598	355.4885
ROW Road	1771.1139	5955.8519	1003.4708	2553.1955	2429.7813
ROW Rail	135.4580	455.5145	76.7473	195.2731	185.8341
ROW SSS	301.4280	1013.6336	170.7819	434.5314	413.5274

Source: Author’s Excel Calculations based on GSIM results

Table 20. Final freight cost tariff equivalent for each OD relation

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	1.184521816	1.443185922	1.1913447	1.229704643	1.123267
Rdam Rail	1.014112567	1.033895673	1.0146344	1.017568233	1.009428
Rdam SSS	1.11611993	1.157665061	1.1252031	1.106907749	1.020979
Antwerp Road	1.163901465	1.429236861	1.1635982	1.209690773	1.105831
Antwerp Rail	1.012535485	1.032828823	1.0125123	1.016037535	1.008094
Antwerp SSS	1.111784786	1.153304113	1.1208679	1.102546801	1.018011
Hamburg Road	1.22060743	1.402248461	1.1887672	1.275797192	1.131606
Hamburg Rail	1.016872461	1.030764701	1.0144373	1.021093475	1.010065
Hamburg SSS	1.129357602	1.170902733	1.1384408	1.120145421	1.022398
ROW Road	1.111592487	1.375260061	1.0632256	1.16086906	1.153093
ROW Rail	1.008534798	1.028700578	1.0048356	1.012303561	1.011709
ROW SSS	1.01899206	1.063865962	1.0107604	1.027378499	1.026055

Source: Author’s Excel Calculations based on GSIM results

Table 21. Total final trade barrier tariff

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	2.881799435	3.511098166	2.898398757	2.991723832	2.732774413
Rdam Rail	2.467214182	2.515344104	2.468483729	2.475621402	2.455816475
Rdam SSS	2.715385856	2.816460174	2.737484092	2.692973725	2.483919391
Antwerp Road	2.831632596	3.477161775	2.830894848	2.943032488	2.690353924
Antwerp Rail	2.46337733	2.512748587	2.463320906	2.471897399	2.452572078
Antwerp SSS	2.704838971	2.805850509	2.726937207	2.682364061	2.476699797
Hamburg Road	2.969591403	3.411502235	2.892127902	3.103861472	2.753062473
Hamburg Rail	2.473928673	2.507726825	2.468004122	2.484197895	2.457368143
Hamburg SSS	2.747591524	2.848665841	2.76968976	2.725179393	2.487372241
ROW Road	2.704371129	3.345842696	2.586700382	2.824255119	2.805337162
ROW Rail	2.45364414	2.502705063	2.444644465	2.462813088	2.461366207
ROW SSS	2.479085402	2.588258221	2.459058876	2.499488603	2.496268933

Source: Author’s Excel Calculations based on GSIM results

Appendix D. Tariff adjusted for port & mode specific elasticities

Table 22. GSIM Matrix 2 - Total initial trade tariff barrier adjusted for port & mode specific elasticities

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	3.137484837	3.924343114	3.1582402	3.274931359	2.951148
Rdam Rail	1.735953883	1.763308594	1.7366754	1.740732138	1.729476
Rdam SSS	2.774593882	2.845586253	2.7901152	2.758852096	2.612017
Antwerp Road	3.640600537	4.667885403	3.6394265	3.817880554	3.415772
Antwerp Rail	3.054564966	3.133133599	3.0544752	3.068123668	3.03737
Antwerp SSS	3.249145796	3.339443603	3.2689002	3.229054674	3.045204
Hamburg Road	3.247257562	3.79981103	3.1503993	3.41514526	2.976516
Hamburg Rail	2.627494162	2.669754465	2.6200863	2.640334521	2.606787
Hamburg SSS	2.797214433	2.868206804	2.8127357	2.781472646	2.614442
ROW Road	3.438078663	4.45890631	3.2508193	3.628860139	3.598754
ROW Rail	3.039075722	3.117150494	3.0247538	3.053667039	3.051364
ROW SSS	3.047336652	3.144930118	3.0294342	3.065575799	3.062698

Source: Author’s Excel Calculations based on GSIM results

Table 23. GSIM Matrix 3 - Total final trade tariff barrier adjusted for port & mode specific elasticities

Port mode	France	Greece	Italy	Spain	ROW
Rdam Road	3.069979378	3.762207982	3.0882386	3.190896215	2.906052
Rdam Rail	1.733607091	1.757672052	1.7342419	1.737810701	1.727908
Rdam SSS	2.886924442	2.998106191	2.9112325	2.862271098	2.632311
Antwerp Road	3.564285634	4.468026485	3.5632528	3.720245484	3.366495
Antwerp Rail	3.048728263	3.117848022	3.0486493	3.060656358	3.033601
Antwerp SSS	3.386774559	3.528190713	3.4177121	3.355309685	3.06738
Hamburg Road	3.166550543	3.652652459	3.0813407	3.31424762	2.928369
Hamburg Rail	2.621321541	2.658499507	2.6148045	2.632617684	2.603105
Hamburg SSS	2.922350676	3.033532426	2.9466587	2.897697332	2.636109
ROW Road	3.386119581	4.284179774	3.2213805	3.553957167	3.527472
ROW Rail	3.035101796	3.103787088	3.0225023	3.047938323	3.045913
ROW SSS	3.070719563	3.223561509	3.0426824	3.099284044	3.094777

Source: Author’s Excel Calculations based on GSIM results

Appendix E. Elasticity Assessment

In this appendix, the process behind the elasticity assessment as discussed in chapter 4.6 will be explained. Composite demand elasticity is determined by the port and mode specific elasticities. (VanElswijk, 2012)

Applied to this research it is assumed that instead of three types of port competition, the port competition will be constant and assumed to be high due to the geographical orientation of the three North Sea ports in the HLH range.
For mode dominance holds that the higher the dependence of a port on a mode, the more inelastic this mode will be. With less competition it can be assumed that modes are substitutes and therefore elastic. Table 24 below summarises the decision making process behind the elasticity assessment based on the modal shares per port.

Table 24. The elasticities of demand (assumption high competition)

	Elasticity	Modal share
3 pretty equal modes		(sum of 2 modes > 41% share, 3rd mode >10% share)
All modes	-1.4	
2 dominant modes		(1 mode>40% difference, 2nd mode>30% share, 3rd mode<10% share)
Dominant modes	-1.1	
Less dominant mode	-0.5	
1 very dominant mode		(1mode>40% share difference)
Dominant mode	-1.1	
2 minor but subs	-1.1	
2 minor both not subs	-0.5	

Source: Compiled by author, based on VanElswijk (2012)

Based on the guidance of table 24 the specific elasticity per port and mode is determined by reviewing the modal shares per port. The final outcome is shown in table 6 in paragraph 4.6.

The process will be explained shortly by using the port of Antwerp as an example. As can be seen in table 20 below, road has a share of approximately 51%, rail of 14% and SSS of 34%. As there is no difference of more than 40% between the shares, there are no dominant modes in the port of Antwerp and the modes are assumed to be pretty equal, a specific elasticity of -1.4.

Table 25. Specific port and mode elasticity Antwerp.

	Port category	Road	Rail	SSS	Total
Antwerp– Port throughput (Thousand tonnes)	Three pretty equal modes	35985	9,967	23,860	69812.56
Percentage mode in port		0.515452	0.142774	0.341774	
Elasticity		-1.4	-1.4	-1.4	

Source: Compiled by author, based on table 7 in paragraph 4.6.

Appendix F. Results

Table 26. GSIM result; change in trade values; Euros/Thousand tonnes

	France	Greece	Italy	Spain	ROW
Antwerp Road	10979320259	49120708	722016199	765751514	272197861
Antwerp Rail	27832061	0	112808328	-3404154	-411243421
Antwerp SSS	-549263976	-2157397894	-2694175739	-2093651256	2438640149
Hamburg Road	6665325323	254018152	4270726419	1549618803	34240163867
Hamburg Rail	13245913	-827178	302594989	-4307000	-1298724368
Hamburg SSS	-96976541	-332914445	-490589641	-361409978	-612270296
Rotterdam Road	5016409726	71965244	822958257	1047856048	15876589001
Rotterdam Rail	4212910	-104192	77362002	-5851	-268598829
Rotterdam SSS	-693565487	-2354285138	-3471128928	-2610736066	484111945
ROW Road	94204380070	86079981555	7404159998	108632548638	728678695187
ROW Rail	408765168	-157669962	1794137550	-315813946	-12304644697
ROW SSS	741694454	-29083481194	25440436335	-10920225164	-63521195607

Source: Author's Excel Calculations based on GSIM results