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Economic and Trade Impact of Low Sulphur Fuel Requirements on the Ports in the Hamburg-Le Havre Range

by

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Acknowledgements

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Abstract

Dramatic decreases in the price of shipping services have led to an increased demand for shipping over the past decades (Cullinane & Bergqvist, 2014). The corresponding increases in shipping supply happened without too much consideration for the effect on the environment. Maritime transport is currently less regulated than land transport, although most of the shipping-related emissions take place at sea, and shipping pollutes densely populated coastal areas and causes negative health effects. The output of sulphur oxides by the shipping industry lies in the range of 5-10% of total global emissions, which exceeds the emissions of land transport by more than 2.7 times, and the emissions of air transport by more than 80 times due to the high sulphur content in heavy ship fuel.

In response to the sulphur emissions issue, international shipping legislation has stepped up (e.g. MARPOL Annex VI). It is not clear how the implementation of the new requirements will influence prices for shipping services, nor is it clear how the intermodal shares of sea, rail, road and inland waterways transport will be affected. This thesis assesses the economic and trade impact of the low sulphur fuel requirements on the ports in the Hamburg-Le Havre range. We use the Global Simulation (GSIM) Model – a trade model that allows for an analysis of tariff and transport-related regulatory measures in terms of trade and economic effects – for this assessment. We consider two types of shipping speeds in our scenario approach, distinguishing between traditional short sea shipping speeds (with low and high freight rate increases depending on the difference in price between heavy fuel oil and marine gas oil) and fast short-sea shipping speeds (also with low and high freight rate increases).

The low and high fuel price scenarios for traditional shipping and the low fuel price scenario for fast shipping showed little impact on trade flows, overall consumer prices, output, consumer and producer surplus and net economic welfare of the ports. However, the high fuel price scenario for fast shipping leads to considerable economic and trade effects. The high fuel price scenario for fast shipping proves to be significant for all four modes of transport. In terms of the intermodal split shares, short-sea shipping would be reduced by 7.1% on average. At the same time, road transport would benefit by 4.3% on average, while inland waterways and rail transport would benefit marginally (by 1.3% and 1.5% respectively). So we conclude that the value of the economic and trade impact of the low sulphur fuel regulations on the ports in the Hamburg-Le Havre range increases with the increase in price difference between heavy fuel oil and marine gas oil. When the impact of the directive is significant, we also witness a modal backshift as a result of the regulation. This would mean a decrease in SOx emissions (as intended) but also an increase in CO2 emissions, as the low sulphur fuel regulations cause a shift to more CO2 emitting modes of transport.

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List of Abbreviations

CES	Constant elasticity of substitution
CGE	Computable general equilibrium
CO2	Carbon dioxide
EC	European Commission
ECSA	European Community Shipowners' Associations
EEDI	Energy Efficiency Design Index
EMSA	European Maritime Safety Agency
ETS	Emissions Trading Scheme
EU	European Union
GSIM	Global Simulation Model
HFO	Heavy fuel oil
IMO	International Maritime Organization
LNG	Liquefied natural gas
MGO	Marine gas oil
NOx	Nitrogen oxides
NRMM	Non-road mobile machinery
OPS	On shore power supply
PE	Partial Equilibrium
PM	Particular matters
ROW	Rest of the world
SECA	Sulphur Emission Control Area
SEEMP	Ship Energy Efficiency Management Plan
SOx	Sulphur oxides
TAPAS	Transportation and production agent-based simulator

1. Introduction

1.1. *Research background and problem statement*

The shipping industry played a huge role in the globalisation of trade which has occurred during the past few decades. Following a combination of ever-larger ships and the development of intermodal supply chains, the prices of shipping services dramatically decreased. This led to the increased demand for shipping. However, the corresponding increase in the shipping supply happened without too much consideration of the consequences for the environment. Maritime transport is currently less regulated than land transport. This is partly due to the fact that the maritime regulations are difficult to agree upon because the shipping industry is more a matter of international nature. At the same time, it is also due to the fact that much of the environmental impact takes place at sea, and it is traditionally perceived that pollution from shipping does not reach land so much and has less immediate impact on the population (Holmgren, et al., 2014; Merk, 2014; Cullinane & Bergqvist, 2014).

Even though shipping is considered to be a relatively clean transport mode, it has its own challenges. While shipping is favourable in terms of carbon dioxide (CO2) emissions being around 2-3% of total global emissions, the air emissions from shipping are considerable (Merk, 2014). The output of sulphur oxides (SOx) by shipping is in the range of 5-10% of total global emissions, which exceeds the emissions of land transport by a factor of 1.6 to 2.7 (Friedrich, et al., 2007). According to Eyring et al. (2005), international shipping produces approximately 80 times more SOx emissions than aviation due to the high sulphur content in the ship fuel (Eyring, et al., 2005).

The vast majority of the world's shipping fleet uses diesel which is usually referred to as bunker oil. Bunker fuel is of much lower quality than the oil used in land vehicles. It is much cheaper as it is a waste product of the standard oil refining process. It is literally situated at the bottom of the barrel and is very thick for land vehicles. Due to these facts, even the most modern engines produce higher emissions than land diesel engines (Corbett & Farrell, 2002; Cullinane & Bergqvist, 2014).

Shipping-related emissions increased a lot over the last decades and are expected to increase in the future. Eyring et al. (2005) illustrate that SOx, CO2, nitrogen oxides (NOx) and particular matters (PM) emissions increased with a factor of around 4 during 1950-2001, while the number of ships during the same period only tripled (Eyring, et al., 2005). At the same time, the International Maritime Organization (IMO) expects an increase of the CO2 emissions related to shipping by a factor of 2 to 3 till 2050 (International Maritime Organization (b), 2015).

Moreover, although most of the shipping-related emissions take place at sea, shipping pollutes densely populated coastal areas and causes significant health effects. The most directly visible effect of these emissions happens in the port areas and port-cities. SOx emissions in ports are generally associated with respiratory issues and premature births.

They are also co-responsible for increased mortality rates, for instance, in the coastal areas of Europe and North America (Merk, 2014; Holmgren, et al., 2014; German Nature and Biodiversity Conservation Union, 2014).

Thus, as a part of globalisation, international shipping legislation is strengthened and harmonised among different nations. A recent example of such severe regulation is the implementation of MARPOL Annex VI. In April 2008, the IMO decided to introduce stronger requirements for airborne emissions of SOx from the sea transport. It set the global limits on the sulphur content of the bunker fuel, as well as the specific limits in the Sulphur Emission Control Areas (SECA). The global limits now include a reduction of 3.5% effective as of 1 January, 2012; a reduction of 0.5% effective as of 1 January, 2020 but subject to a review which is to be completed by 2018 (in case of the negative review, the effective date shifts to 1 January, 2025). Coming to SECA, the European part of SECA consists of the Baltic Sea, the North Sea and the English Channel. The SECA limits include a reduction of 1% effective from 1 March, 2010; and a reduction of 0.1% effective as of 1 January, 2015. Additionally, the new version of Annex VI reinforces the EU Marine Fuel Directive by requiring a sulphur limit of 0.1% at berth within the European Union (EU) (Cullinane & Bergqvist, 2014).

Now EU legislation encompasses both the global SOx regulations and the SECA limits of the IMO. Shipowners can use various strategies to meet these new requirements including: 1) using 0.1% marine gas oil (MGO) which is more expensive; 2) switching to cleaner energy sources, liquefied natural gas (LNG), for instance; 3) using scrubbers. In the short term perspective, all strategies lead to increased costs for the sea transport. In our study we will focus on the first option. At the same time, shippers can also use different strategies including: 1) changing route and/or mode; and 2) moving production facilities (in the long run perspective). It is important to mention that the modal shift from sea to land is called a modal backshift. The reason is that the main goal of the EU's White Book is to shift long distance land transport to more environmentally friendly transport, while the modal shift described above works in the opposite direction. In this respect, we will again focus on the first option (European Commission, 2011).

However, it is not clear how the implementation of new requirements will influence the prices for shipping services and trade flows, nor is it clear how the modal shift from sea to rail and road will change. Possible effects of the new regulations for sulphur emissions in SECA were studied, especially in the most affected countries and big companies, as supported by the following quote:

“The topic which poses the greatest challenge to Maersk, in particular Maersk Line and Maersk Tankers, and of course to our industry peers, is the new SOx rules, which took effect in Emission Control Areas from 1 January 2015, and later globally from 2020 or 2025. The SOx rules, as laid down in MARPOL Annex VI, are by far the most costly piece of regulation which has ever come out of the International Maritime Organisation. The global cap in 2020 (or 2025) may cost the shipping industry as much as 50+ billion USD – per year, based on the presently very low oil prices. By 2020 or 2025 that figure may be much larger. Maersk Line has estimated that SOx requirements will add USD 200 mill annually to their fuel cost.” (The Maersk Group website, 2016)

But relatively little is said about the economic and trade impact of low sulphur fuel requirements on ports. We decided to scope our research to the ports in the Hamburg-Le Havre range, as they are situated in the SECA region of the North Sea and the English Channel. Figure 1 shows that all 11 ports in this range serve the same hinterland consisting of many industrial and economic zones generally known as the banana shape and Central Europe (Herrera, 1999). Based on the high level of trade conducted through the ports in the Hamburg-Le Havre range, it is relevant to discuss the economic and trade impact of the low sulphur fuel requirements on these ports.

Figure 1. Blue Banana Area and Ports in the Hamburg-Le Have Range

Source: Cushman & Wakefield LLP, 2009

Finally, it is relevant to research the possibilities of the modal backshift caused by new regulations. The trade routes going through the ports in the Hamburg-Le Havre range have well-developed connections of sea, road, rail and inland waterways transport competing with each other. The new regulations may influence the decision-making process of the shippers.

1.2. Research questions and methodological approach

Based on the situation described in the previous section, this thesis assesses the economic and trade impact of the new sulphur regulations and possible modal backshift of nine ports in the Hamburg-Le Havre range. The results will show whether the sulphur regulations contribute to the modal backshift, and indicate a concentration or spread of cargo flows across these ports. The research question is therefore identified as follows:

What is the expected economic and trade impact of the low sulphur fuel requirements on the ports in the Hamburg-Le Havre range?

The outcome of the assessment will show whether there is a (significant) shift in trade flows between the transport modes of short-sea shipping, rail, road and inland waterways, as well as an overview of the change in the freight transport patterns across the ports in the Hamburg-Le Havre range.

The research question will be answered by using the (partial equilibrium) Global Simulation Model (GSIM). GSIM is developed in 1997 by J.F. Francois and H.K. Hall to model global trade policy changes in partial equilibrium. These policy changes are translated into tariff equivalents which result in a change in the bilateral trade flows between countries. In this thesis, the method is applied at a larger scale than in the original model. The developers initially applied the model at the country scale of 25x25. However, this thesis assesses a total of nine ports with four modes of transport (short-sea shipping, inland waterways, rail and road), which equals to 36 points of origin or supply. At the same time, there will be 29 points of destination or demand: the 28 EU member states and the rest of the world (ROW). Therefore, a GSIM model with dimensions of 36x29 is applied in this thesis. This requires an Excel Solver with a high capacity and the scaling up of the available GSIM model.

It is also important that the original model consists of the three following components: value of trade flows, initial and final import tariff equivalents. In this thesis, however, the following components will be included: port hinterland value of cargo flows per mode, initial tariff equivalents and final tariff equivalents after the implementation of new sulphur regulations. The overall GSIM process is visualised in Figure 2.

Therefore, the three main components of the model stated above will help to obtain the results of the analysis. Moreover, in order to support the research process, the following sub-questions will be answered in the thesis:

1. *What is the existing regulatory system of sulphur emissions from ships in the EU?* Here we will describe the existing regulatory system of sulphur emissions from ships in the EU, and also the new regulation which is the core for this master thesis (Chapter 2, sections 2.2 to 2.4).
    1.1. *What are the sources of sulphur emissions and related modes of transport?* Here the sources of sulphur emissions will be discussed in relation to the modes of transport. Special focus will be on the modes of transport in the ports (Chapter 2, section 2.1).

1.2. *Will the regulation hurt some of the modes more than others?* In this part we will illustrate the implications of regulations on different modes of transport and answer the question of whether the new regulation is going to hurt some modes more than others (Chapter 2, section 2.6; Chapter 3; chapter 4, section 4.3.2.4; chapter 5, section 5.4).

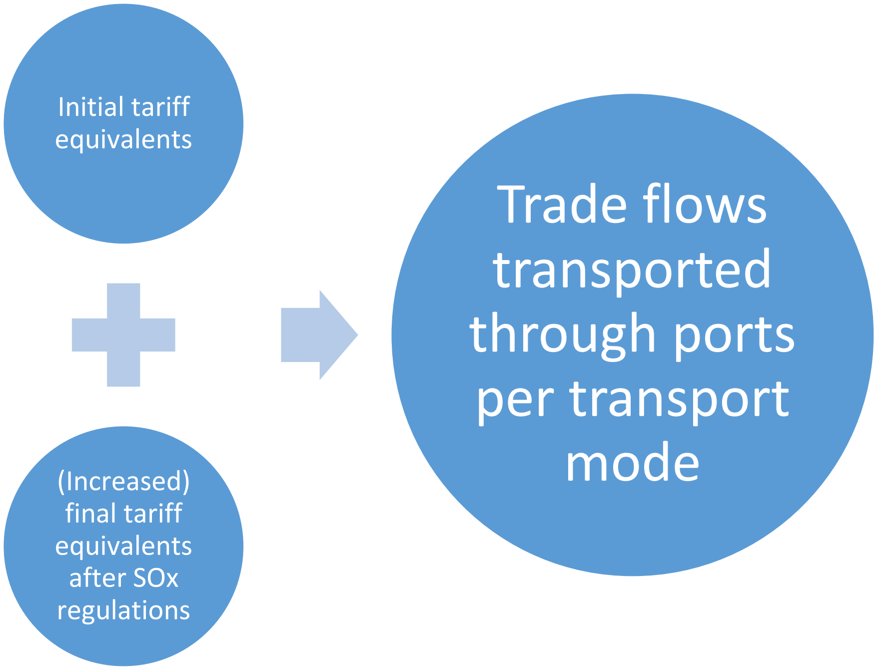

Figure 2. The GSIM Process Applied for Assessment of SOx Regulations in Ports in Hamburg-Le Havre Range

Source: own compilation

2. *How the ports in the Hamburg-Le Havre range deal with the sulphur content?* Here we will show how the ports in the Hamburg-Le Havre range are currently dealing with the sulphur content and what is their general approach to this issue (Chapter 2, section 2.5).
3. *What is the modal split in these ports and what will change about it after the regulations are in place*? Here we will answer the question of what the existing modal split is in these ports (Chapter 4, section 4.3.1), and what will change about it after the regulations are in place (Chapter 3; Chapter 5, section 5.4). This will help us analyse the current situation, and further compare our expectations with the GSIM model results.
4. *What are the regulation ambitions? What are the possible future scenarios?* In this part we will discuss ambitions of the new regulations (Chapter 1, section 1.1), and also formulate the possible future policy scenarios (Chapter 4, section 4.3.2.3).
5. *What model and data can we best use to analyse the economic and trade impact of low sulphur fuel regulation on the ports in the Hamburg-Le Havre range?* Here we will illustrate different available methods that we can use to analyse the economic and trade impact of low sulphur fuel regulation on the ports in the Hamburg-Le Havre

range (Chapter 4, section 4.1). Based on these findings, we will come up with the best method to be used in our paper. Then we will describe the chosen method in detail and demonstrate how it works (Chapter 4, section 4.2). Afterwards, the data collection process will be described. We will need to obtain trade data in value terms, initial fuel tariffs and non-tariff barriers (for instance, shipper surcharges for sales in the SECA regions), as well as price elasticities as inputs for the GSIM model (Chapter 4, section 4.3, subsections 4.3.2.1 and 4.3.2.2).

6. *How can we estimate additional costs for sulphur guidelines?* Here the calculations of the additional costs for the new regulations for sulphur emissions in SECA will be discussed. These calculations will help us get the final tariff barrier equivalents (Chapter 4, section 4.3.2.4).
7. *How will the economic and trade situation change after the new phase of the low sulphur fuel requirements?* Here the main outcomes of the literature review and the GSIM model will be stated. Changes in economic and trade situation after the new phase of the low sulphur fuel requirements in the Hamburg-Le Havre will be revealed, namely: changes in prices in percentages and euros, changes in consumer (cargo owners) and producer (shipping companies) surplus in percentages and euros, impact of the regulation on net economic welfare in percentages and euros, and changes in output (trade flows) in percentages and euros. Then these outcomes will be interpreted in terms of individual model outputs for four different scenarios (Chapter 5).
    - 7.1. *What are the changes in prices?* The GSIM model will help us estimate the possible price changes on the macro-economic level. We will then interpret these estimates (Chapter 5, sections 5.1 to 5.3).
    - 7.2. *What would be the impact of the regulation on net economic welfare?* The GSIM model will help us estimate the possible changes in net economic welfare on the macro-economic level. We will interpret these estimates (Chapter 5, sections 5.1 to 5.3).
    - 7.3. *What are the changes in consumer (cargo owners) and producer (shipping companies) surplus?* The GSIM model will help us estimate the possible changes in consumer (cargo owners) and producer (shipping companies) surplus on the macro-economic level. We will interpret these estimates (Chapter 5, sections 5.1 to 5.3).
    - 7.4. *What are the changes in output (trade flows)?* The GSIM model will help us estimate the possible changes in output (trade flows) on the macro-economic level. We will interpret these estimates (Chapter 5, sections 5.1 to 5.3).

According to the process described above, expected results will take the form of the absolute and relative changes in freight flows per mode and per combination of a port and a country. Afterwards, we apply four possible future scenarios to cover sub-question 4. These scenarios are developed based on the bunker share in the freight costs. Consequently, the new low sulphur fuel regulations influence the bunker cost, which in its turn influences the freight rates. The four scenarios are as follows:

a. Low fuel price scenario for the traditional short-sea shipping with 10.5% freight tariff increase,
b. High fuel price scenario for the traditional short-sea shipping with 20% freight tariff increase,

c. Low fuel price scenario for the fast short-sea shipping with 25% freight tariff increase,
d. High fuel price scenario for the fast short-sea shipping with 40% freight tariff increase.

Because of the research scope, this thesis will be based on as many existing studies and data as possible. The secondary data is primarily used due to the time limitations of the master thesis.

1.3. Structure outline

Given the above mentioned questions, the structure of the paper is as follows.

First, we provide the theoretical background of the new sulphur regulations in Chapter 2, focusing on the existing regulatory systems, alternative options of the ports to deal with the sulphur content, and the modal split in the ports. Chapter 3 contains a detailed literature review on the sulphur regulations impact and modal shifts. Both academic literature and industry reports are discussed. Chapter 4 describes the Global Simulation (GSIM) methodology used in the paper, including development of possible future scenarios and options to estimate additional costs of the regulations. It also includes the methods and data used to calculate the initial and final trade tariff equivalents. Chapter 5 illustrates the results of the analysis, their interpretation, and also highlights the most important findings. Chapter 6 concludes the paper answering the research questions stated above. This chapter also presents policy recommendations, research limitations and suggestions for future research.

1.4. Definitions

Following definitions have been outlined in the framework of this research:

- *Economic impact:* The effect of the low sulphur fuel regulations on the economies of the ports in the Hamburg-Le Havre range, the EU member states and the rest of the world in terms of welfare, including consumer and producer surplus, output (production) and consumer and producer prices.

- *Modal backshift:* The modal shift from sea to land.

- *Non-tariff barrier:* Non-tariff barriers are the devices to restrict trade where barriers to trade are set up and take a form other than a tariff.

- *Ports in the Hamburg-Le Havre range:* We focus on 9 of the 11 existing ports in the Hamburg-le Havre range. The eleven ports are:

    - In Belgium: Port of Antwerp, Port of Zeebrugge and Port of Ghent;

- In France: Port of Dunkerque and Port of Le Havre;
- In Germany: Port of Bremerhaven, Port of Hamburg and Port of Wilhelmshaven;
- In the Netherlands: Port of Amsterdam, Port of Rotterdam and Zeeland Seaports.

However, due to the fact that data on the Port of Ghent in Belgium and Zeeland Seaports in the Netherlands are not available, we will focus our research on the nine remaining ports.

- *Trade impact:* The effect of the low sulphur fuel regulations on the trade flows across the ports in the Hamburg-Le Havre range, the EU member states and the rest of world in terms of changes in the volume and quantity of trade flows.

2. Theoretical Background

2.1. Sulphur emissions sources and transport modes in ports

There are many sources of air pollution in ports. At the same time, various emitters have different shares of pollution in every specific port. German Nature and Biodiversity Conservation Union in their Working Paper on clean air in ports categorizes these emitters into two groups: 1) emitters belonging to immediate port business, 2) emitters other than belonging to immediate port business. The turnover business may be given as an example of the latter but it falls outside the scope of our research; while the former can be further divided into the three following groups:

a. Water transport including seagoing vessels,
b. Non-road mobile machinery (NRMM) including Automated Guided Vehicles, reach stackers, forklifts, electric machinery (ship to shore cranes, rail mounted gantry cranes, automated stacking cranes), van carriers and construction machinery, but also inland vessels and trains, locomotives and wagons,
c. Road transport including cars and trucks (German Nature and Biodiversity Conservation Union, 2014).

However, when we look at the modes of transport related to these emitters, we can see the major differences in how ports register their total throughput. Usually the majority of ports report the throughput of their maritime transport only. So, when we state that the Port of Antwerp handled 180 million tonnes in 2014 (Eurostat, 2016), that is purely maritime based, i.e. the deep-sea and short-sea modes, incoming and outgoing freight. This means that the hinterland transport is not included in that number, as long as the hinterland transport modes are road, rail and inland waterways. These hinterland modes of transport serve to take the freight to and from the ports, and, at the same time, they are used as the alternative options to the short-sea and deep-sea shipping modes. Hence, we will focus on the following transport modes in our research:

a. Short-sea shipping
b. Rail
c. Road
d. Inland waterways

It should be noted that in the past major online databases, such as Eurostat included the inland waterways mode into the short-sea shipping maritime transport. Nowadays, this approach changed, and these two modes of transport should not be mixed anymore. For example, according to the Maritime and Coastguard Agency in the UK, "'inland waters' include any area of water not categorised as 'sea' – e.g. canals, tidal and non-tidal rivers, lakes, and some estuarial waters (an arm of sea that extends inland to meet the mouth of a river)" (Maritime and Coastguard Agency, 2014).

Also, due to the literature review results, the deep-sea shipping is out of the scope of our research. Even though the absolute impact of the regulations on this mode is quite big, the deep-sea shipping does not have much alternatives to switch to other modes of transport. As a result, we do not expect major changes in this transport mode compared to others.

Additionally, the air mode is available as a transport mode too. In this case, the cargo can be transported in the specialised cargo aircraft or in the passenger aircraft together with passengers' baggage. It is the fastest mode of transport when it comes to long distances (Wikipedia, 2016). Nevertheless, being the most expensive one, it is not used very often, compared to the freight transportation to ports. It can be used only in special circumstances, and that is why, we will not include it into the scope of our research.

Finally, intermodal transport mode which means shipments involving more than one transport mode (Wikipedia, 2016) is also not in the scope of our research, due to the lack of specific data for this mode.

2.2. Global IMO regulations: MARPOL Annex VI

The IMO is a United Nations body that develops a set of rules to cover marine emissions including pollution by oil, noxious substances in bulk, sewage, refuse and discharges of noxious liquid substances. In 1997 during the conference in London it was agreed on the new Annex VI called “Regulations for the prevention of air pollution from ships”. Later it was added to the International Convention for the Prevention of Pollution from Ships, MARPOL 73/78. Based on this, the Baltic Sea was declared SECA with the sulphur content limits for the marine fuel oil of 1.5% or better.

Annex VI also defined the limits of the sulphur content in bunker fuels to be 4.5% on the global level. However, according to Cullen (1997), the specified limit would have no or little effect on the average sulphur content because only 0.02% of fuel used globally had more than 4.5% sulphur content in 1996 (Cullen, 1997). At the same time, in 1997 it was proposed to declare the North Sea and the Irish Sea SECAs too. Nevertheless, Per Kågeson states in his report in 1999 that it was not expected that the MARPOL Convention would have any major effect on reducing emissions from shipping (Kågeson, 1999).

Annex VI came into force only in 2005, however it was amended in September 2007 by the member states of MARPOL. The next SECA was declared also in 2005 – the North Sea and the English Channel. Having 72 signatories, Annex VI covers 94.3% of the world tonnage representing the international standards. Regulation 14 of Annex VI dedicated to SOx limits of all emission control systems to 6 g SOx per kWh.

Moreover, the fuel sulphur content should not surpass the 3.5% rate on the global level. In the designated SECA in the North Sea and in the English Channel, the fuel sulphur content should not surpass the 1% rate. Every fuel supplier is legally obliged to verify the sulphur content of his fuel by providing the supporting documents. It was expected that from the beginning of 2015 a further reduction in SECA would be implemented, this time to 0.1%. At the same time, starting from 2020 (or 2025, depending on the review) a new limit of 0.5% sulphur content is expected in the fuel used worldwide (Clean North Sea Shipping, 2014; International Maritime Organization, 2016; International Maritime Organization (a), 2016).

Table 1 below illustrates all the existing SECA regions at the moment:

Table 1. Annex VI: Prevention of air pollution by ships (SECA)

Special Areas	Emission Type	Adopted	Came into Force
Baltica Sea	SOx	1997	2005
North Sea & English Channel	SOx	2005	2006
North American	SOx, NOx, PM	2010	2011
United States & Caribbean Sea	SOx, NOx, PM	2011	2013

Source: Breuch-Moritz & Abromeit, 2015

Figure 3 shows SECA including the ports in the Hamburg-Le Havre range researched in this thesis.

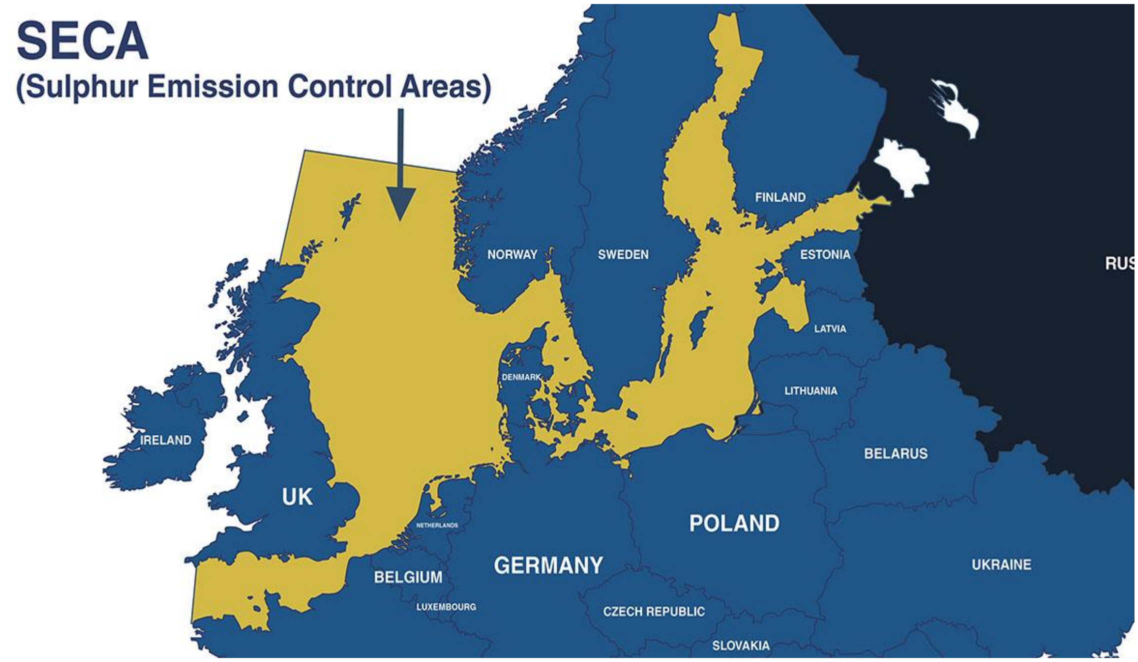

Figure 3. The North Sea and the English Channel SECA and the Ports in the Hamburg-Le Havre Range

Source: Knights of Old Group, 2014

Furthermore, Chapter four of Annex VI defines two energy efficiency regulations for ships, namely the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). The EEDI is mandatory for all newly built ships and is considered as the most important technical measure by the IMO. For different types of ships this measure assumes a minimum energy efficiency level. The EEDI is also a measure of the emissions from ships under particular operating conditions. The SEEMP, on the other hand, is an operational measure to reduce further emissions. The SEEMP provides every ship with a management plan to ensure energy efficiency on board (Clean North Sea Shipping, 2014; ForschungsInformationsSystem, 2016).

2.3. Regulatory system of sulphur emissions in EU ports

According to the Thematic Strategy on Air Pollution published by the EU Commission in September 2005, the annual number of premature deaths because of air pollution should be cut by 2020 by 40% in comparison with the 2000 level. Emissions of sulphur dioxide should be reduced by 82% compared to their 2000 level. There are two most important European directives with respect to air pollutants. The Ambient Air Quality directive 2008/50/EC limits, among others, the SO2 emission values. The National Emission Ceilings directive 2001/81/EC limits, among others, the sulphur dioxides emission values. It should be noted that the European limit values are legally binding (German Nature and Biodiversity Conservation Union, 2014; Commission of the European Communities, 2005).

Additionally, the EU Regulation 95/21 defines a common practice for all member states within the scope of Port State Control. It aims at improving and unifying the inspection process, where unsafe vessels are put on a black list. It also aims at removing substandard ships from operations. This regulation in general contributes to the compliance of MARPOL convention standards (Clean North Sea Shipping, 2014).

The Regulation 2005/33/EG is based on the strategy to improve air quality and aims at reducing sulphur content. Even though it was designed to implement MARPOL Annex VI, it sets even tighter emission limits for ships in the EU ports than the IMO regulations. According to this regulation, effective as of January 2010, the ship fuel sulphur content must be 0.1% or better. It should be noted that this regulation is not applicable to ships at berth in the EU ports for less than two hours (Clean North Sea Shipping, 2014; Breuch-Moritz & Abromeit, 2015).

The European Commission (EC) also adopted another Recommendation 2006/339/EG in May 2006. This recommendation encourages the shipowners to use the land-based electricity in ports. The shipowners are also provided various tax concessions if they use alternative energy sources in ports (Clean North Sea Shipping, 2014).

Moreover, there are specific EU directives designed for the single emitters in the EU ports defining various limits of SOx emissions. Based on their relevance to different modes of transport in the ports, we group these directives into three main categories as described below.

Sea mode: The European directive 2012/33/EU for the sulphur content of marine fuels. This directive limits the sulphur content of marine fuels for ships in SECAs to 1.5% sulphur fuel or better, including the Baltic Sea (since May 2006), the North Sea and the English Channel (since autumn 2007). Ships in the EU ports should use 0.1% sulphur fuel or better when at berth for two or more hours (since 2010).

Moreover, this directive states that ships can use other technical abatement technologies which lead to the same or higher level of reductions of emissions (for instance, scrubbers). But these technologies should not negatively affect the marine environment. It should be also stated that ships are subject to the EU Emissions Trading Scheme (ETS) till now (German Nature and Biodiversity Conservation Union, 2014).

Rail mode: Directive 97/68/EC and Directive 2012/46/EU are both limiting emissions from the NRMM. They affect, for instance, port equipment and machineries, inland vessels and trains, and other objects included in the NRMM terms. However, the different limit values apply for different engines, which complicates emission reduction process a lot. There are currently some talks about alignment of NRMM limit values with the norms of the EURO VI dedicated to cars and trucks (German Nature and Biodiversity Conservation Union, 2014).

Road mode: Directive 715/2007/EC defines emission limits for cars and light commercial vehicles. Directive 2005/78/EC and Directive 2005/55/EC are limiting emissions from trucks depending on the year they were built. At the same time, the new trucks have to satisfy the EURO VI standard effective as of 1 January 2013. These directives are quite ambitious, however due to the slow turnover of the fleet, there are still many vehicles with high sulphur emissions in the ports (German Nature and Biodiversity Conservation Union, 2014).

2.4. Major regulatory systems of sulphur emissions in the EU

Figure 4 below illustrates the comparison of different fuel sulphur limits in parts per million (ppm) on the global and European levels and in SECAs. It should be stated that 45,000 ppm for IMO global marine fuel limit in the figure represent 4.5% sulphur content and 10 ppm for road transport and inland shipping fuels represent 0.001% sulphur content. This is the result of the fact that land-based air pollution emissions are gradually decreasing, while air pollution emissions from ships are continuously increasing.

According to the German Nature and Biodiversity Conservation Union (2014), if nothing changes, by 2020 shipping will become the biggest single emitter of air pollution in Europe, exceeding the air pollution emissions from all land-based sources.

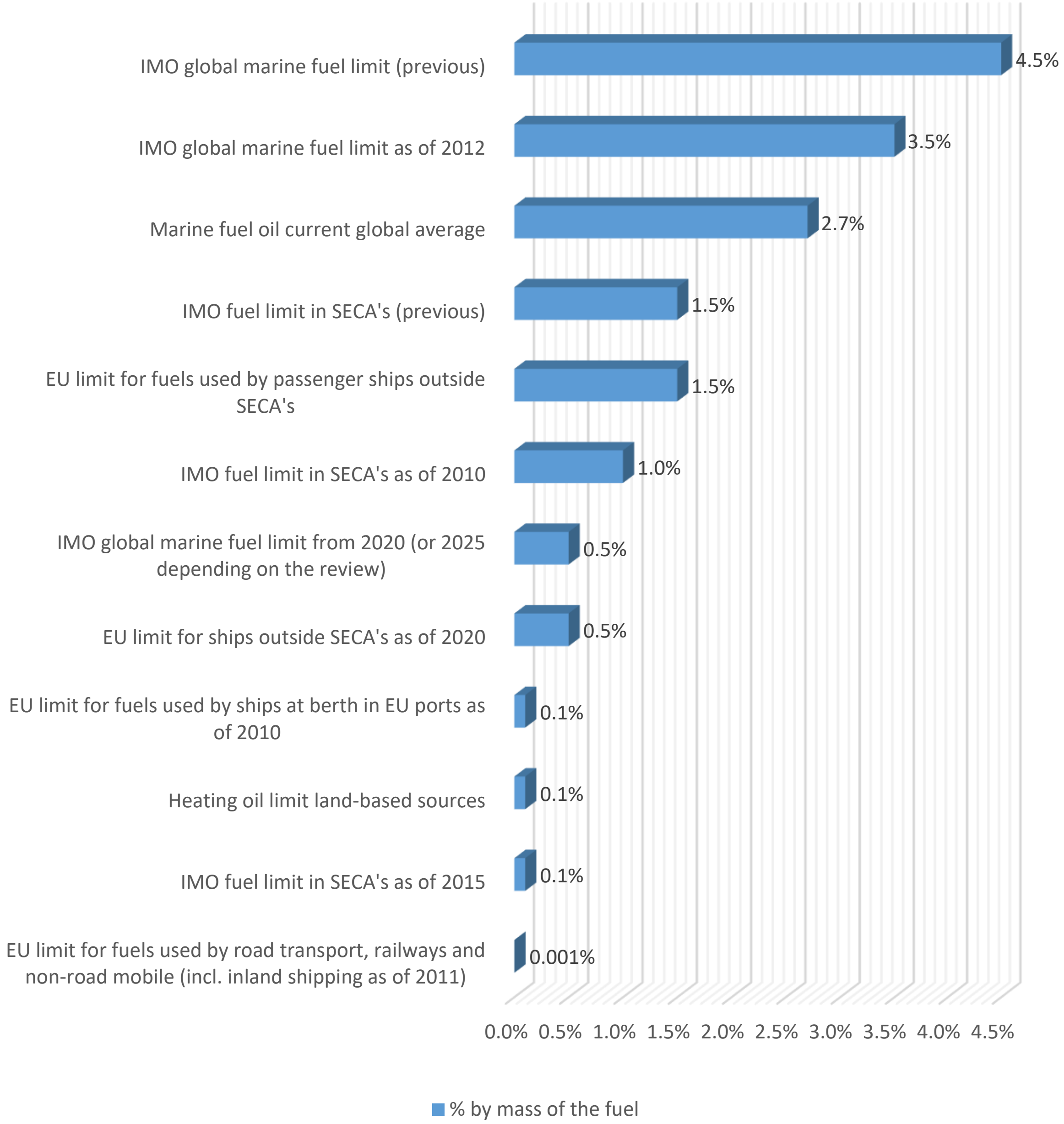

Figure 4. Sulphur fuel content: comparison in percentages

Source: own compilation based on data from Air Pollution & Climate Secretariat, 2015; European Environment Agency, 2013

Furthermore, Table 2 introduces the comparison between the limits of sulphur content values in fuel for SECAs and non-SECAs, and also for the passenger ships and for the ships at berth (for the period of two or more hours) as regulated by the IMO and the EU.

Table 2. Comparison between IMO and EU sulphur regulations

Maximum Sulphur Content in Fuel	IMO			EU		
	2012	2015	2020	2012	2015	2020
Non SECA	3.5%	3.5%	0.5%	3.5%	3.5%	0.5%
SECA	1%	0.1%	0.1%	1%	0.1%	0.1%
Passenger Ships	-	-	-	1.5%	1.5%	0.1%
At berth	-	-	-	0.1%	0.1%	0.1%

Source: German Nature and Biodiversity Conservation Union, 2014

It should be stated separately that the IMO providing important regulations for the shipping industry, does not have a centrally managed authority to enforce the aforementioned regulations, nor can it impose any penalties. At the same time, the EU is trying to bind the IMO regulations to the EC laws to be able to exercise its authority to enforce the regulations. Moreover, the European Court of Justice may also impose financial penalties (Clean North Sea Shipping, 2014).

According to Prof. Dr. Stefan Krüger of the Verband Deutscher Reeder, the new regulations enforced in the SECAs will become a key consideration for the shipowners operating exclusively in the North Sea. He states that even though the distances which the ships cover in the North Sea are small in comparison with the whole journey through the international waters; the shipowners will get additional high costs. The traffic existing in the North Sea cannot operate anywhere else. It means that higher fuel costs are unavoidable, and it is assumed that the shipowners are going to bear the major burden. However, the economic and trade consequences following the implementation of the regulations for the EU ports still remain unclear (Krüger, 2013) (Clean North Sea Shipping, 2014).

Finally, the comparison of the major regulatory systems of sulphur emissions in the EU leads us to the new phase which consists of the maximum sulphur content in the marine fuel of 0.1%. Figure 4 above illustrates that the road transport and inland shipping fuel limits are already much less than 0.1%. This percentage will serve as a basis in formulating the future possible scenario.

2.5. Ports in the Hamburg-Le Havre range and sulphur content

There are several measures developed for ports in order to reduce the sulphur emissions. The following measures can be specified for the ports in the Hamburg-Le Havre range:

Energy management systems: they include professional monitoring and control, and can help decrease energy consumption. For example, Eurogate (one of the terminals in the Port of Hamburg) reduced the energy demand by 13.5% per container handled from 2008 to 2014 (German Nature and Biodiversity Conservation Union, 2014).

Raising awareness and training employees: all the people working in ports - for companies doing business there, for the port authorities or for the shipping companies- can contribute to saving energy by raising awareness and by being trained about air pollution measures in their specific field of work. Eurogate and Hamburger Hafen und Logistik AG, for instance, run such trainings (German Nature and Biodiversity Conservation Union, 2014).

Low Emission Zones (LEZ): including ports into LEZs could mean stricter regulations for diesel engines, such as EURO V truck standard or NRMM filter requirements. It implies a reduction in commitments through monitoring stations. For example, the Port of Antwerp did a feasibility study on LEZ implementation for trucks in the ports (German Nature and Biodiversity Conservation Union, 2014).

Changing port-owned vehicles and equipment: by using energy from alternative sources such as electricity. The Port of Antwerp uses bicycles for commuting and for service. They also decided to replace most of the diesel powered cars by alternative energy powered ones. Hamburger Hafen und Logistik AG had the highest number of electric cars within northern range ports in 2014 (German Nature and Biodiversity Conservation Union, 2014).

Passive houses: port buildings can be erected in passive house standard, because a passive house does not use energy at all. For example, the Hamburg Port Authority used this technology in 2013 for one of their office buildings (German Nature and Biodiversity Conservation Union, 2014).

Alternative sources for general power supply: such as wind turbines and solar panels. For instance, some of the Hamburger Hafen und Logistik AG buildings have solar panels which produced more than 550,000 kWh electricity in 2012 (German Nature and Biodiversity Conservation Union, 2014).

And finally, *on shore power supply (OPS): cold ironing* is one of the methods here. It supplies ships with electricity at berth so that they can shut down their engines. The Antwerp Port Authority has the first OPS in Europe for ocean going vessels. It also supplied all 21 tug boats with OPS in 2014. Ports of Antwerp, Hamburg and Rotterdam run OPS systems for ferry and cargo ships. Port of Amsterdam currently does the feasibility study of the OPS Sea Cruise Europe project. *Shore-side/barge-side electricity supply from LNG* is another method of OPS when the energy is produced from LNG on shore or on a barge, and then delivered to ships allowing them to shut down their engines. An LNG fired power supply barge works at the Hafen City Cruise Terminal in the Port of Hamburg as of 2015 (German Nature and Biodiversity Conservation Union, 2014).

Moreover, special port policies and policies among ports exist in order to deal with the sulphur content. Some policies and examples of ports are provided below:

Developing general emission reduction strategies: some ports develop their own air quality strategies. First, the emissions from different sources are calculated; then a reduction plan is developed and a monitoring system is established. For example, the work of Hamburger Hafen und Logistik AG on a zero emission terminal was awarded the Hanse Globe 2011, a sustainability prize for their Zero Emission pilot project. They designed the environmentally friendly battery operated AGVs to be used at one of their terminals in the future (German Nature and Biodiversity Conservation Union, 2014; Green Port, 2011).

Different ship indices: in many ports ships with the *Environmental Ship Index* above average can get reduced harbour fees, as the Port of Antwerp, for example, granted 500,000 euro in 2012. The *Clean Shipping Index* provides real-time, quantified insights into the environmental performance of single ships based on the indicators of CO2, NOx, SOx and PM emissions, and also chemicals, on board wastes, sewage and ballast water. Then the logistic companies can evaluate the chosen shipping service providers. Additionally, the *EEDI* is the first globally-binding standard approved in 2011 by the IMO. This index requires new ships to be more energy efficient, taking into account that the standard will be increasingly stricter in future. The companies will be free to use the most cost-efficient options to comply with the regulations to make sure that the required energy efficiency level is achieved (German Nature and Biodiversity Conservation Union, 2014).

2.6. Possible implications of regulations on different modes

Substantial increase in sea transportation costs caused by the new sulphur regulations may decrease the competitiveness of the maritime transport. As a result, short sea shipping will not be as cost-effective as it is now. This may cause the modal backshift from sea to road. Furthermore, this may change the future cargo flows' directions in Europe to avoid SECAs (Rozmarynowska & Ołdakowski, 2012). Looking at the transport modes observed by different studies, sea transport is usually compared to the road transport for various routes on which each study is focused. According to Holmgren, et al. (2014), even though some studies (Delhaye, et al. (2010), Swedish Maritime Administration (2009) and Malmqvist & Aldén (2013)) cover also the comparison to the rail transport, Kehoe , et al. (2010) and theInstitute of Shipping Economics and Logistics (2010) do not cover the rail transport because of the capacity limitations.

Several studies consider the issue of the potential modal shift related to the new sulphur regulations. COMPASS is one of them. It shows the major corridors where the possible modal shifts may occur. These corridors are: Germany/Denmark – Sweden, the UK through the English Channel to the continental Europe, West Europe – Baltic States and Portugal/Spain – southern part of the North Sea. (Delhaye, et al., 2010) Another study conducted by the European Community Shipowners' Associations (ECSA) also focuses on similar corridors (Notteboom, et al., 2010). Hence, we may accept them as the corridors that are most sensitive to the modal shift from the short sea shipping to the land transport. Figure 5 below illustrates these sensitive corridors.

Figure 5. Internal freight corridors where modal shift may occur

Source: Delhaye, et al., 2010

Both of the studies mentioned above bring different conclusions. The COMPASS study states that the sailing from and to the European ports turns out to be marginally more expensive. Explicit costs cause a risk for the short sea shipping, but other factors such as opportunity costs, flexibility and load factors may significantly moderate this. The authors of COMPASS are not expecting any major modal shifts. They expect only minor cost increase for the end user prices due to the new legislation, as they find that both the maritime services cost increase and the maritime services share in the end user prices are marginal (Delhaye, et al., 2010). However, the ECSA study concludes that the 0.5% sulphur content limit does not lead to a modal shift, while the 0.1% sulphur content limit leads to approximately 20% of the modal shift. The authors emphasize that the modal shift might lead to traffic losses for the sea leg in favor of trucking or the shorter sea leg (Notteboom, et al., 2010).

According to Holmgren, et al. (2014), the implementation of the new sulphur regulations will result in the increased voyage costs, which in its turn will lead to the increased freight rates. They also state that for some shipping segments the increased elasticity to freight rates may lead to the modal shift. Moreover, the authors find that a combination of different external factors may cause a strengthening or limiting of the modal shift to the road transport. However, they study transportation of relatively high-valued containerised goods from Lithuania to the British Midlands and conclude that the modal backshift to the road transport is unlikely to occur. At the same time, in the authors' opinion, the new regulations may challenge some shipping segments in the North Sea and the English Channel. But they emphasize the temporary character of the upcoming changes to be aligned with the evolution of the involved actors that can address the new regulatory context (Holmgren, et al., 2014; Cullinane & Bergqvist, 2014).

Another interesting study conducted by Notteboom (2011) examines the low and high fuel price scenarios with their corresponding impact on different sailing distances of 0-125, 125-400, 400-750 and more than 750 kilometres. The low scenario indicates the expected freight rate increase to be in a range of 15 to 25%, with the highest increase on the longer routes. The volume losses here are to be 14.5%. On the other hand, the medium-distance routes of 400-750 kilometres are expected to be highly impacted with the volume losses of 21%. At the same time, the long-distance routes are expected to be less impacted. It should be mentioned that the high scenario indicates the significant impact with the freight rate increase of 60% and the volume losses of 50% and more. The medium-distance routes are expected to be highly impacted again (Notteboom, 2011).

In 2010 the Institute of Shipping Economics and Logistics conducted an impact study that also estimated the expected modal shift using different corridors to and from Germany (Institute of Shipping Economics and Logistics, 2010). The Swedish Maritime Administration (2009) performed an impact analysis for different corridors to and from Sweden. Moreover, the European research project SKEMA has studied the possible modal shift using different routes due to changes in regulations (Kehoe , et al., 2010)

Finally, in 2010 a review of six previously conducted impact studies was performed based on the request of the ship owners' associations from the Netherlands, Belgium, the UK, Germany, Finland and Sweden. Four of these studies including Notteboom, et al., (2010) and Kehoe et al. (2010) conclude that the implementation of the new IMO regulations will cause some modal shifts from sea to road and rail. The sea transport volumes are going to decrease by 3 to 50% depending on the particular route. There are also other factors such as availability of alternative routes, level of competition and the projected fuel costs which influence on the modal shift (ENTEC UK Limited, 2010).

3. Compilation of most relevant sources

There is a lot of literature on GHG and air pollution, however not many papers address the new sulphur requirements and their impact on shipping industry, and especially on ports. In this respect, the contribution of Psaraftis et al. in the field of marine air pollution, GHG emissions and its statistics, as well as the implications of the regulations leading to the opportunity costs is significant (Psaraftis & Kontovas, 2008; Psaraftis & Kontovas, 2009; Psaraftis & Kontovas, 2010). On the other hand, the case study based on estimating the cost of regulations (Schinas & Hartmann, 2010) adds data on differences of total operation cost of a ship within or out of a sensitive environmental area, before and after the implementation of the regulation. Substantial influence on research is attributed by the independent studies such as of Lloyd's Register, University College London and Det Norske Veritas AS (Lloyd's Register and University College London, 2014; Det Norske Veritas AS, 2012).

We have considered various sources of information for this research. Among others these are the following. First, papers about the consequences of low sulphur fuel requirements for costs and prices of short sea traffic and the modal split in the SECAs and their external costs (Notteboom, et al., 2010). Second research on the impacts of SECA on the maritime transport (Cullinane & Bergqvist, 2014). Third, work on the implications of the regulations on the future pattern of the trade flows in the Baltic region (Rozmarynowska & Ołdakowski, 2012). Fourth, papers on the impact of the new sulphur regulations on the competitiveness of roro shipping and implications of the regulations on different sailing distances based on the low and high fuel price scenarios (Notteboom, 2011). Fifth, research work on cost assessments of these regulations on the marine operators (Schinas & Stefanakos, 2012). Finally studies of the potential effect of sulphur regulations on the intermodal split (Kontovas, et al., 2016; Vierth, et al., 2015)

The compiled studies performed by Holmgren et al. (2014), ENTEC UK Limited (2010) and European Maritime Safety Agency (EMSA, 2010) are also used. Holmgren et al. collect the impact studies published before 2013 and discover that only few previous studies clearly focus on the modal shift. ENTEC compiles the impact studies published before 2010 and finds that the implementation of the new regulations together with some other important factors will cause some modal shifts from sea to road and rail with the sea transport volumes decreased by 3 to 50% (Vierth, et al., 2015). EMSA provides the assessment of available impact studies published before 2010 and comes to the following conclusions on the impact of the new regulations on the marine transportation in the SECA regions:

a. The marine diesel oil will be more expensive,
b. The modal shift changes are uncertain,
c. The medium-distance routes are expected to be impacted harder, as well as the general cargo and container ships (European Maritime Safety Agency, 2010; Hämäläinen, 2015).

All the studies mentioned above use different methods. The European research project SKEMA employs the NECL model (simulates the cost and duration of transporting a trailer on different routes) for ten competing routes on four corridors, and also the activity-based TAPAS (i.e. Transportation and Production Agent-based Simulator) model for five competing routes on a single corridor (Kehoe , et al., 2010) ECSA uses the stated preference approach and comparative cost analysis. (Notteboom, et al., 2010). The Institute of Shipping Economics and Logistics employs a logit model to estimate the risks sat by the modal shift (Institute of Shipping Economics and Logistics, 2010). COMPASS project used a CES (Constant Elasticity of Substitution) tree model to make a detailed cost analysis of the competing modes of transport (Delhaye, et al., 2010).

At the same time, new sulphur regulations are becoming more interesting for the ports as they realise that compliance will lead to changes within and between the ports. For example, Rozmarynowska and Ołdakowski (2012) in their regional report focus on the Baltic Sea Region and particularly on the ports in this area. They primarily cover the possible scenarios for fuel and freight rate changes, and also talk about a risk of shift from the sea transport to other transport modes.

There are also some studies focusing on the regulations and port incentives. Merk (2014) examines the shipping emissions in ports. Kågeson (1999) along with other important issues, focuses on the sulphur emissions, their sources, major regulations and measures for reducing. German Nature and Biodiversity Conservation Union (2014) and Clean North Sea Shipping (2014) cover similar issues extending their studies to the sulphur emitters in the ports, measures to be taken in the ports with the recent practical examples, and the port incentives.

Additionally, some authors analyse the changing nature of the role of the port authority as a result of the new sulphur regulations, such as energy management in ports (Acciaro, et al., 2014), alignment of environmental management with business strategy (Dinwoodie, et al., 2012), port state control (Bloor, et al., 2013), adaptation of new business strategies (Gritsenko & Yliskylä-Peuralahti, 2013), and port management tools (Lam & Notteboom, 2014).

However, majority of these research papers focus on ports that use qualitative methods and do not focus on the economic and trade impact or on the modal split related to sulphur content in ports. While several studies use quantitative methods and develop scenarios of changes in fuel prices and freight rates along with the modal shift implications, none of them focus on the ports in the Hamburg-Le Havre range. In this regard, the focal point of the current paper will be a quantitative estimation of the economic and trade impact of the new sulphur regulations (namely the changes in output, producer and consumer surplus, prices and net economic welfare) on the ports in the Hamburg-Le Havre range using the (partial equilibrium) GSIM model.

4. Methodology and Data

4.1. *Methods to model trade flows and modal choices in ports*

There are different methods that we can use to analyse the economic and trade impact of low sulphur fuel regulation on the ports in the Hamburg-Le Havre range. The main criterion here is the ability of the appropriate research model to incorporate the trade flows for the sea, road and rail transport.

One of the famous methods applicable to our case is the CES tree. It denotes a special type of the aggregator function combining more than one consumption types or more than one productive inputs types into an aggregate quantity. This aggregator function presents constant elasticity of substitution, as it can be seen from the method name, meaning that the production technology has a constant change in the proportions of the factors in terms of percentages. The COMPASS project built their cost analysis of the competing modes on the CES tree. Holmgren, et al. (2014) state that this method is realistic for modelling choices between mutually exclusive options. Though, the CES tree method is not fully suitable as it has constant elasticity of demand in terms of income. Also, focusing on the mutually exclusive options, it may bring possible misinterpretations among different modes and their variations (Delhaye, et al., 2010; Holmgren, et al., 2014).

Unlike the CES tree model, the TAPAS model used in the SKEMA project is based on the fragmented inclusion of elasticity in the short sea shipping in the SECA region. TAPAS is designed to simulate decision-making activity to assess the impact of different transport policies by simulating specific shipments in particular supplier-consumer relations, and further by calculating the logistical choices of the shipment size, route and mode. As a result, the TAPAS method may provide an alternative approach to the possible modal shifts caused by the regulations (Kehoe , et al., 2010; Holmgren, et al., 2014).

Another widely used model is the logit mode choice model. For instance, the study conducted by the Institute of Shipping Economics and Logistics (2010) uses the logit model to calculate the risks posed by the modal shift. Probability changes indicate the appropriate risk of the modal shift and create diverse trade flows, making this model a suitable choice for their study (Institute of Shipping Economics and Logistics, 2010).

At the same time, the World Container Model and the Western-European Container model represent different applications of the logit mode choice model. The former shows annual container flows on the major world shipping routes based on the data from more than 400 ports (Newton, et al., 2010), while the latter estimates the market shares of the Western-European hub-ports (Veldman & Bückmann, 2003).

However, the logit mode choice model and its applications are using a vast amount of input data, and according to Holmgren, et al. (2014), it does not necessarily produce more valid outcomes compared to other models (Holmgren, et al., 2014).

There is also a Computable General Equilibrium or CGE model. This model is designed to analyse economic impact of changes in trade, environmental policy and tax by examining the inter-sectoral and inter-institutional linkages as well as the inter-temporal dynamics due to the fact that policy changes in one sector affect other sectors too. Nevertheless, the CGE model generates too many possibilities that are not always necessary (HM Revenue & Customs, 2013).

Ultimately, we decided to make use of an alternative method that has not been used in the context of analysing economic and trade impact of the new sulphur regulations yet. This method is called the partial equilibrium (PE) Global Simulation or GSIM model. The GSIM model presents a simpler version of the CGE model. And while the CGE model provides only estimated aggregated effects, the GSIM model can also analyse the changes on the tariff level that demonstrates a broader picture of the policy changes.

Moreover, the GSIM model does not require many different inputs and complex computation requirements, but still generates a clear insight into the trade flows. Hence, the main advantage of this method is that it is very useful to conduct the research when the data availability is limited. Additionally, the GSIM model produces five different outputs, namely changes in output, producer surplus, consumer surplus, price and net welfare effect. These five outputs characterise the trade and economic impact of the policy changes which precisely meet the objective of our research. Therefore, the GSIM model is the most appropriate model for this study.

The general description of the model as well as its mathematical structure are demonstrated in the next section (Francois & Hall, 2003).

4.2. Global Simulation Model Methodology

The GSIM model is designed by Francois & Hall (2003) to assess the impact of trade policy at different levels (unilateral, regional, global) on the trade flows, welfare effects, output effects and price effects. It is broadly used in the recent literature on the impact of policy changes in terms of reducing transatlantic barriers to trade (Francois, et al., 2013; Felbermayr, et al., 2013; Love & Lattimore, 2009; European Commission, 2013) and non-tariff measures in the EU-US trade (Berden, et al., 2009; Messerlin, 2015). This approach is a partial equilibrium, with the industry focus yet global in scope. Unlike the general equilibrium models, the PE models do not take the numerous aspects into consideration. This leads to some practical limitations, but as long as they are kept in mind, useful conclusions can be made in terms of the multi-country trade policy changes performed at the industry level (Francois & Hall, 2003).

The GSIM model consists of three input matrices. Their sizes depend on the number of the origin and destination points, for example, the ports divided by the modes of transport and the states in our case. The most important part of work with the GSIM model is the input data. First of all, the initial trade flows between the ports in the Hamburg-Le Havre range, the 28 EU member states and the rest of the world are required. These data present the input for the first matrix of the model. Secondly, initial trade barriers are necessary to fill in the second matrix. And finally, the third matrix is filled in with the final trade barriers incorporating the effect of the sulphur regulations. Moreover, the price elasticity data consisting of the composite demand, industry supply and substitution should be added to the model. As soon as all data is collected, quantified and monetised, the GSIM model can be run.

We use the mathematical structure of the original model; however, we change the dimensions of the matrix. Instead of the countries of supply we use the 9 ports in the Hamburg-Le Havre range divided into the short-sea shipping, inland waterways, road and rail modes, resulting in 36 points of supply. The countries of import are presented by the 28 EU member states and the rest of the world (ROW). Then, trade flows are presented by the water, road and rail transport flows. And we also employ the initial and final import tariff equivalents as trade barriers between the ports and destination countries for each of the three transport modes.

The industry designation is not much relevant in our case, as the collected data consists of all types of goods going from the ports in the Hamburg-Le Havre range to the EU member states and ROW. Ultimately, the GSIM model can be broken down into a series of equations which are presented below.

The import demand is calculated as follows (Francois & Hall, 2003):

$$\text{(1)}\ M_{(i,v),r} = f(P_{(i,v),r}, P_{(i,v),s\neq r}, y_{(i,v)})$$

Where:

$M_{(i,v),r}$ = demand for product *i* from port *r* in country *v*
$Y_{(i,v)}$ = total expenditure on imports of product *i* in country *v*
$P_{(i,v),r}$ = internal price for goods from port *r* imported to country *v*
$P_{(i,v),s\neq r}$ = price of other varieties

Then the following two equations are used to define composite demand for national supply functions and national product varieties (Francois & Hall, 2003):

$$\text{(2)}\ P_{(i,v),r} = \left(1 + t_{(i,v),r}\right)P_{(i,r)} * = T_{(i,v),r}P_{(i,r)} *$$

Where:

$P_{(i,v),r}$ = internal price for goods from port *r* imported to country *v*
$P_{(i,r)}*$ = export price received by exporter *r* on world markets
$T_{(i,v),r}$ = proportional price mark-up achieved by tariff *t*

$$\text{(3)}\ X_{i,r} = ks_{i,r}(P_{(i,r)} *)^{es_{(i,r)}}$$

Where:

$X_{i,r}$ = export supply of product *i* from port *r* to world markets

ks = constant term
es = elasticity of supply

Now the composite demand can be defined as a constant function of elasticity as follows (Francois & Hall, 2003):

$$(4)\ E_{i,v} = ka_{i,v} P_v^{NA_v+1}$$

Where:

$E_{i,v}$ = composite demand
$ka_{i,v}$ = demand equation constant set in calibration
P_v^{NAv+1} = composite elasticity function of the regional composite price index

Furthermore, the GSIM model computes the welfare effects. Producer surplus is calculated as shown in the next equation (Francois & Hall, 2003):

$$(5)\ \Delta PS_{i,r} = R^0_{i,r} \times \hat{P}^*_{i,r} + \frac{1}{2} R^0_{i,r} \times \hat{P}^*_{i,r} \times \hat{X}_{i,r}$$

Where $R^0_{i,r}$ presents the benchmark export revenues valued at world prices.

At the same time, the two equations below are used to define the consumer surplus. The composite good function can be calculated as follows (Francois & Hall, 2003):

$$(6)\ Q_{i,v} = A_v \left[\sum_{i=1}^{r} \gamma_{(i,v),r} M^{\rho}_{(i,v),r}\right]^{1/\rho}$$

Keeping in mind that the benchmark equilibrium defines the price of the composite good as 1, the proportional change in Q's price can be determined as follows (Francois & Hall, 2003):

$$(7)\ \hat{P} = \frac{dP}{P} = \sum_{i=1}^{r} \theta_{(i,v),r} \times \hat{P}_{(i,v),r}$$

Where $\theta_{(I,v),r}$ represents the demand expenditure share at internal prices. Hence, this equation is used as the composite price equation.

Ultimately, consumer surplus is calculated as shown in the next equation (Francois & Hall, 2003):

$$(8)\ \Delta CS_{i,r} = (\textstyle\sum_r R^0_{(i,v),r} \times T^0_{(i,v),r}) \times (\frac{1}{2} E_{M,(i,v)} \hat{P}^2_{i,v} \times sign(\hat{P}_{i,v}) - \hat{P}_{i,v}$$

Where we use this formula for $\hat{P}_{i,v}$ (Francois & Hall, 2003):

$$(9)\ \hat{P}_{i,v} = \textstyle\sum_r \theta_{(i,v),r} \hat{P}^*_r + \hat{T}_{(i,v),r}$$

Additionally, the five calibrated coefficients can be produced based on the following formulas. Table 3 below provides the model notation for these calibrated coefficients.

Table 3. GSIM model notation for five calibrated coefficients

Indexes	
r,s	Ports of supply per each transport mode
v,w	Importing 28 EU member states and ROW
I	Designated industry/type of goods
Parameters	
$\mathbf{E_s}$	Elasticity of substitution
$\mathbf{E_{m(i,v)}}$	Aggregate import demand elasticity
$\mathbf{E_{x(i,r)}}$	Elasticity of export supply
Calibrated coefficients	
$\mathbf{N_{(i,v)(r,r)}}$	Own price demand elasticity
$\mathbf{N(_{i,v)(r,s)}}$	Cross-price elasticity
$\mathbf{T_{(i,v),r}}$	The power of the trade barrier, where T = 1 + t
$\mathbf{\theta_{(i,v),r}}$	Demand expenditure share
$\mathbf{\Phi_{(i,v),r}}$	Export quantity share
Variables	
M	Imports (quantity) by the countries
X	Export (quantity) of goods from ports
P	Composite domestic price
$\mathbf{P^*_{(i,r)}}$	World price for goods exported from port r
$\mathbf{P_{(i,r),v}}$	Internal prices for goods from port r imported to country v
$\mathbf{t_{(i,r),v}}$	Trade barriers for goods from port r imported to country v

Source: Francois & Hall, 2003

The cross-price elasticity for each combination of port and country (Francois & Hall, 2003):

$$(10) N_{(i,v)(r,s)} = \theta_{(i,v),s} \, (E_m + E_s)$$

The own-price demand elasticity for each combination of port and country (Francois & Hall, 2003):

$$(11) \qquad N_{(i,v)(r,r)} = \theta_{(i,v),r} \, E_m - \textstyle\sum_{sr} \theta_{(i,v),s} \, E_s = \theta_{(i,v),r} \, E_m - (1 - \theta_{(i,v),r}) E_s$$

Demand expenditure share for the countries (Francois & Hall, 2003):

$$\theta_{(i,v),r} = \frac{M_{(i,v),r}\, T_{(i,v),r}}{\sum_s M_{(i,v),s}\, T_{(i,v),s}} \tag{12}$$

Export quantity share from the ports (Francois & Hall, 2003):

$$\varphi_{(i,v),r} = \frac{M_{(i,v),r}}{\sum_w M_{(i,w),r}} \tag{13}$$

Finally, the market clearing condition $\check{X}_{i,r} = \breve{M}_{i,r}$ (the change in demand $\breve{M}_{i,r}$ should be the same as the change in supply $\check{X}_{i,r}$ of the goods) is established as follows (Francois & Hall, 2003):

$$E_{X(i,r)}\hat{P}_{i,r} * = \sum_v N_{(i,v)(r,r)}\hat{P}_{(i,v),r} + \sum_v \sum_{sr} N_{(i,v)(r,s)}\hat{P}_{(i,v),s} = \tag{14}$$

$$\sum_v N_{(i,v)(r,r)}\left[P_r * + \hat{T}_{(i,v),r}\right] + \sum_v \sum_{sr} N_{(i,v)(r,s)}\left[\hat{P}_s * + \hat{T}_{(i,v),s}\right]$$

4.3. Data collection

We use the combination of several datasets available on Eurostat and some port statistics. Table 4 below demonstrates the major annual datasets employed in this thesis. All the data presented in the table is from the year 2014 as it was the most recent data available for each matrix of the model.

Table 4. Overview of datasets employed to determine port related trade flows per each transport mode

Data Type	Year	Source
International annual road transport	2014	road_go_ia_lgtt, road_go_ta_tott (Eurostat (a), 2016)
International annual rail transport	2014	rail_go_intgong (Eurostat (a), 2016)
International inland waterway transport	2014	iww_go_atygofl, iww_go_atygo (Eurostat (a), 2016)
Incoming and outgoing freight per port in tonnes	2014	mar_go_aa (Eurostat (a), 2016)
Modal split per country	2014	tran_hv_frmod (Eurostat (a), 2016)
Modal split per port	2014	The PORTOPIA Project, 2016
Short-sea shipping per country	2014	mar_sg_am_cwd (Eurostat (a), 2016)
Short-sea shipping per port	2014	mar_sg_am_pw (Eurostat (a), 2016)

Source: own compilation

When using these data, we have to perform multiple calculations related to trade flows that go through each researched port to destination countries and ROW, distributed over the different modes of transport. These calculations are performed based on the assumptions made throughout the thesis. All assumptions are based on the outcomes of the literature review including different studies and research papers. Hence, using the assumptions we can overcome the challenges and produce credible inputs for the GSIM model.

However, freight cost components incorporated into the initial and final trade barriers presented below are limited to the distances, average freight rate proportions, and composite demand elasticity. Moreover, due to lack of availability of specific data, our analysis does not take into account some other factors that are as important as freight costs, such as specific port prices, incentives, specialised port facilities (infrastructure) and other port related indicators relevant to the cargo owners and shipping companies by transport mode. Finally, the deep-sea shipping and air modes are not considered in this research due to specificity of these modes, and also no data available.

4.3.1. Modal split in ports in the Hamburg-Le Havre range

We assume that freight incoming to the port is transported to Europe and ROW through three transport modes, namely inland waterway, road and rail. In order to get the estimated freight per port per mode, we multiply the incoming freight per port by its modal split figures. Additionally, we multiply it by the short-sea shipping share of the incoming freight that is calculated as shown in Table 5. We are using the short-sea shipping share here because we are not interested in the deep-sea shipping.

Table 5. Short-sea shipping share of the incoming freight per country (per relevant ports)

Belgium	**60.1%**
total sss incoming freight	75,781.0
total incoming freight	126,188.0
Germany	63.1%
total sss incoming freight	112,664.0
total incoming freight	178,446.0
France	**55.7%**
total sss incoming freight	114,210.0
total incoming freight	205,004.0
Netherlands	**50.0%**
total sss incoming freight	199,410.0
total incoming freight	398,688.0

Source: own compilation

It should be stated that due to the literature review results, the deep-sea shipping part is out of the scope of our research. Even though the absolute impact of the regulations on this mode is quite big, the deep-sea shipping does not have much alternatives to switch to other modes of transport. As a result, we do not expect major changes in this transport modes compared to others.

We compute this share by dividing the total short-sea shipping incoming freight per country by the total incoming freight per country. These data are available on Eurostat for the year 2014. Further we assume that these proportions hold for the short-sea shipping shares of incoming freight for the ports located in the appropriate countries.

Now we can insert these shares into the model along with the modal split percentages to find the incoming freight distribution per three hinterland modes of transport. Table 6 presents the results of these calculations.

Table 6. Outgoing freight 2013 statistics of ports per mode

Port	Total incoming freight (1000 tonnes)	Mode	Mode %	SSS part (%)	Goods (1000 tonnes)
Antwerp	86,066	IWW	42.71	60.05	22,074.26
		Road	50.00	60.05	25,843.03
		Rail	7.29	60.05	3,768.78
Zeebrugge	12,451	IWW	8.25	60.05	616.68
		Road	75.26	60.05	5,627.23
		Rail	16.49	60.05	1,233.37
Bremerhaven	23,714	IWW	2.00	63.14	299.44
		Road	59.00	63.14	8,833.55
		Rail	39.00	63.14	5,839.12
Hamburg	71,297	IWW	3.00	63.14	1,350.43
		Road	50.00	63.14	22,507.10
		Rail	47.00	63.14	21,156.68
Wilhelmshaven	23,060	IWW	10.31	63.14	1,501.05
		Road	70.30	63.14	10,235.12
		Rail	19.39	63.14	2,823.03
Dunkerque	27,522	IWW	4.00	55.71	613.31
		Road	86.00	55.71	13,186.22
		Rail	10.00	55.71	1,533.28
Le Havre	43,996	IWW	4.00	55.71	980.43
		Road	86.00	55.71	21,079.17
		Rail	10.00	55.71	2,451.07
Amsterdam	66,278	IWW	56.37	50.02	18,686.64
		Road	40.40	50.02	13,392.59
		Rail	3.23	50.02	1,070.74
Rotterdam	296,538	IWW	36.00	50.02	53,394.51
		Road	53.00	50.02	78,608.59
		Rail	11.00	50.02	16,314.99

Source: own compilation based on data from Eurostat (a, 2016) and The PORTOPIA Project (2016)

The modal split numbers for nine ports were obtained from the 2016 European Port Industry Sustainability Report (The PORTOPIA Project, 2016) and checked with the official port statistics available online for the Port of Hamburg, Port of Zeebrugge, Port of Amsterdam, Port of Rotterdam, and Port of Antwerp. Moreover, the ports of Zeebrugge and Antwerp have pipelines as the fourth mode of hinterland transport. Thus, a part of the outgoing freight related to the share of the pipelines was deducted for these two ports, and the modal split percentages were recalculated as shown in Table 6 above.

The next step is to divide the incoming freight per mode per port also by destination country, meaning across 28 EU member states and ROW. The following formula will help us derive the percentage of freight loaded in country X and unloaded in country Y from the international transport data available on Eurostat per mode of transport, for 28 EU member states (Van Elswijk, 2012). We assume that the international transport between countries X and Y is proportional to the international transport of the ports in country X.

$$\% \; of \; goods \; transported \; from \; X \; to \; Y = \frac{tonnes \; transported \; from \; X \; to \; Y}{total \; tonnes \; transported \; from \; X \; to \; EU28} \tag{15}$$

A calculation example from Germany to Austria, Belgium and Bulgaria is demonstrated in Table 7 below.

Table 7. Percentage of transport from Germany to Austria, Belgium and Bulgaria

Mode	Variable	Total outgoing freight per mode	Austria	Belgium	Bulgaria
water	thousand tonnes	49,393.00	456.00	14,668.00	19.00
	%	100.00	0.92	29.70	0.04
road	thousand tonnes	54,991.00	7,444.00	8,345.00	5.00
	%	100.00	13.54	15.18	0.01
rail	thousand tonnes	40,681.00	7,504.00	2,306.00	22.00
	%	100.00	18.45	5.67	0.05

Source: own compilation

Furthermore, we use the main statistical findings on maritime ports freight from Eurostat, showing that "most EU maritime freight transport is with extra-EU partners" (Eurostat (b), 2016). These statistical findings compiled for Belgium, France, Germany and the Netherlands can be found in Table 8.

Table 8. Main statistical findings on EU maritime freight transport

2014	**National**	**Intra EU-28**	**Extra EU-28**	**Unknown**
Belgium	1.2	31.2	67.2	0.4
Germany	1.2	38.2	60.2	0.4
France	6.0	32.0	58.0	4.0
Netherlands	0.4	25.0	74.0	0.6

Source: Eurostat (b), 2016

This table “estimates the seaborne transport of goods between the main European ports and their partner ports. As far as possible, double-counting of the same goods being reported as outward transport in one port and inward transport in another port is excluded in these figures” (Eurostat (b), 2016). We then recalculate these percentages deducting the unknown part.

On the other hand, as we are interested in the outgoing freight by short-sea shipping mode as well, it is required to make appropriate calculations for it too. First of all, the short-sea shipping share of the outgoing freight per port is to be found. We use the same way of reasoning as we did for the incoming freight: dividing the total short-sea shipping outgoing freight per country by the total outgoing freight per country, and assuming that these ratios hold for the ports located in these countries. The results are presented in Table 9 below:

Table 9. Short-sea shipping share of outgoing freight per country

Belgium	**52.5%**
total sss outgoing freight	58,630.0
total outgoing freight	111,664.0
Germany	53.7%
total sss outgoing freight	67,263.0
total outgoing freight	125,296.0
France	67.8%
total sss outgoing freight	66,409.0
total outgoing freight	97,904.0
Netherlands	42.4%
total sss outgoing freight	72,771.0
total outgoing freight	171,801.0

Source: own compilation

Eurostat similarly provides the data on the total short-sea shipping freight incoming to the European Union (28 countries), and the incoming short-sea shipping freight per country. These data can be used to calculate the ratios between these two figures to find out the distribution of the incoming short-sea shipping freight between the countries. We assume also that the same ratios hold for the freight going to the 28 EU member states through the ports by the short-sea shipping mode.

The small example of these calculations is shown in Table 10. It should be noted that the first row represents the total incoming freight to the 28 states by the short-sea shipping, and the incoming short-sea shipping freight to each country individually. During the calculations for any of the four countries in question, we deduct this country’s freight from the total EU freight to exclude this country and to make correct calculations.

Table 10. Short-sea shipping freight distribution over 28 EU member states

REP_MAR/TIME	European Union (28 countries)	Austria	Belgium	Bulgaria
2014	1,438,791	0	75,781	10,484
Belgium	1,363,010	0.00	0.00	0.77
Germany	1,326,127	0.00	5.71	0.79
France	1,324,581	0.00	5.72	0.79
Netherlands	1,239,381	0.00	6.11	0.85

Source: own compilation

As shown in the example, Austria, Czech Republic, Hungary, Luxembourg and Slovakia do not have direct access to short-sea shipping, and as a result have zero values in the short-sea shipping freight distribution table. We then use Table 8 (again) to be able to distribute the outgoing freight over all the 28 EU member states (including domestic freight) and the ROW column.

In the following step, with the help of statistics from Eurostat, freight distribution percentages between the 28 EU member states by hinterland modes and short-sea shipping, as well as modal split percentages per port can be determined. We can then distribute the short-sea shipping freight per mode per port over the 28 EU member states (including domestic freight) and Rest of World. Table 11 illustrates these calculations from the Port of Hamburg to Belgium.

Finally, we get the annual freight in thousand tonnes departing from the Port of Hamburg and arriving in Belgium as illustrated in Table 11. These calculations are repeated for all combinations of ports, 28 EU member states and ROW column.

Table 11. Distribution of freight from Port of Hamburg to Belgium per mode

Mode	Variable	Total outgoing freight	National	Intra EU-28	Extra EU-28	Belgium
Sss	per mode	29,368.51	29,368.51	29,368.51	29,368.51	11,263.83
	%		1.20	38.35	60.44	5.71
	1000 tonnes		353.84	11,263.83	17,750.85	643.67
Iww	per mode	1,350.43	1,350.43	1,350.43	1,350.43	517.93
	%		1.20	38.35	60.44	29.70
	1000 tonnes		16.27	517.93	816.22	153.81
Road	per mode	22,507.10	22,507.10	22,507.10	22,507.10	8,632.24
	%		1.20	38.35	60.44	15.18
	1000 tonnes		271.17	8,632.24	13,603.69	1,309.96
Rail	per mode	21,156.68	21,156.68	21,156.68	21,156.68	8,114.31
	%		1.20	38.35	60.44	5.67
	1000 tonnes		254.90	8,114.31	12,787.47	459.96

Source: own compilation

The next step is to monetize the obtained flows. Due to the data availability issue we cannot make estimation of the average value per tonne for every port and country combination. Hence, the aggregate values for all the 28 EU member states are used, based on the intra EU imports and exports figures. These calculations are demonstrated in Table 12 below:

Table 12. Value of trade for the period of January-December, 2014

	Intra-EU 28 Exports	**Intra-EU 28 Imports**
Value in EUR	2,932,245,591,734	2,854,086,980,133
Thousand tonnes	1,737,177	1,739,146
EUR/Thousand tonnes	1,687,938	1,641,085
Average of imports and exports	**1,664,511**	

Source: own compilation based on the data from Eurostat (a), 2016

So, €1,666,511 per thousand tonnes is applied on all derived transport flows.

Table 13 illustrates an example of the transport flows in value terms going from the Port of Hamburg to Austria, Belgium and Bulgaria[1]:

Table 13. Valuation of trade flows from Port of Hamburg to Austria, Belgium and Bulgaria

Mode	Austria	Belgium	Bulgaria
sss	-	1,071,390,741.59	148,222,648.62
iww	7,959,046.57	256,015,997.92	331,626.94
road	1,945,024,627.62	2,180,444,722.93	1,306,437.82
rail	2,491,376,803.28	765,606,997.38	7,304,143.08

Source: own compilation

4.3.2. Trade barriers between ports and the EU member states

Unlike the import tariff equivalent used in the original GSIM model, we determine the total trade barrier between the ports in the Hamburg-Le Havre range and the 28 EU member states. There are two trade barrier types to be determined in our thesis: the initial and final trade barriers. The initial trade barriers mean the barriers that currently exist between

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[1] Detailed calculation results are only provided in the entire Excel spreadsheet called Working File and are available upon request. The spreadsheet also covers all intermediate steps taken during the calculations.

the ports and the states. These barriers can be widely defined as a sum of all costs that emerge at any point in time or place in between the producer and the final customer. However, the marginal costs of production are not covered by this term.

Anderson and Van Wincoop compile several different studies dedicated to various components of the trade costs. According to the authors, the trade costs comprise of three major economically useful components (Anderson & Van Wincoop, 2004):

1. Local distribution costs consisting of retail costs and wholesale costs,
2. Border related barriers consisting of policy barriers (tariffs and non-tariff barriers), information costs, transaction costs, currency differences and language differences, legal and regulatory costs, contract enforcement costs,
3. Transportation costs consisting of both time costs and freight costs.

Border related barriers and transportation costs are also called by the authors international trade costs. These trade costs are usually reported with regard to their ad-valorem tax equivalent, where ad-valorem tax means the tax on the value of the goods.

According to Anderson & Van Wincoop (2004), “a rough estimate of the tax equivalent of representative trade costs for industrialized countries is 170 percent”. It includes 21% transportation costs, 44% border-related trade barriers and 55% local distribution costs. So, in total it comes to $1.21 \times 1.44 \times 1.55 = 2.70$; and after subtracting 1, we get 1.70 or 170%. The break-down of 170% is presented in Figure 6 below.

We use this division of trade barriers in our analysis. To calculate the total trade costs per mode per port and per country, the border related costs and the local distribution costs are kept constant as they are not in the scope of our research. The time costs are also set constant due to the same reason. As a result, we focus on the freight costs to calculate the initial trade barriers for the second matrix of the GSIM model.

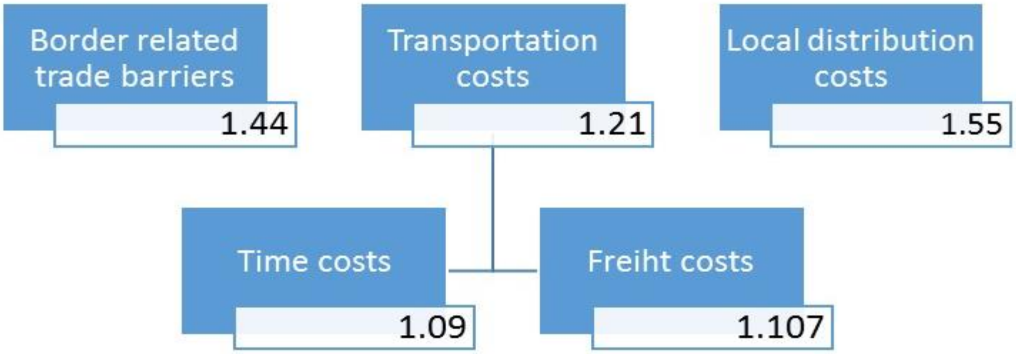


Figure 6. Overview of tariff equivalents

Source: own compilation based on Anderson & Van Wincoop (2004)

4.3.2.1. *Initial trade barriers*

We assume that the freight cost tariff equivalent in the first instance is based on the distances between the ports and countries to be reached by the hinterland modes and short-sea shipping. Longer distances will lead to bigger equivalents in our calculations, however in reality shorter distances sometimes become more expensive because of the selected route or types of goods, for example. But due to the fact that we have no data available to add these possible exceptions in our calculations, longer distances in our thesis will be associated with higher freight costs.

In the beginning we have to prepare a distance table for all combinations of 9 ports and 28 EU member states both for the hinterland modes and for the short-sea shipping. To do so, we consider, on the one hand, the distances between the ports in question and the capital cities for the hinterland connections, that can be explained by the assumption that the capital cities attract bigger freight volumes; and on the other hand, the distances between the ports in question and major ports reachable by short-sea shipping, assuming that major ports also attract bigger freight volumes. Figure 7 illustrates the distances that have to be collected for our further analysis.

Figure 7. Overview of ports in focus (red) and capital cities (blue)

Source: (Google Maps, 2016)

Coming to the distances, Google Maps has two types of distances that can be measured: straight line distance and driving distance. We use the driving distance and assume that the rail and inland waterways modes of the same ports have the same distance as the road transport due to a couple of reasons. First, most of the railways are parallel to roads and are never built in straight lines. Second, the inland waterways do not represent straight lines either, so it is more appropriate to use the driving distance as well. The short-sea shipping distances are obtained from Ports.com (2016).

In case of the Port of Amsterdam, an average distance into the country is used as Amsterdam is also a capital city. Table 14 represents an example of the derived distances between the Port of Hamburg and Austria, Belgium and Bulgaria. All impossible routes are marked as 1.

Table 14. Distances between Port of Antwerp and Austria, Belgium and Bulgaria

Mode	Austria	Belgium	Bulgaria
sss (km)	1	788.952	7809.884
iww (km)	907	592	1924
road (km)	907	592	1924
rail (km)	907	592	1924

Source: own compilation

After collecting all the distances, we apply the average tariff equivalent of 10.7% to the whole distances table using the following formula (Van Elswijk, 2012):

$$(16) \qquad (Freight\ cost\ tariff\ equivalent = \left(\frac{distance}{1868.993}\right) * 0.107 + 1\ ,$$

where 1,868.993 is an average distance based on all combinations of destinations. That is why this distance is represented by the 1.107 equivalent. Table 15 demonstrates an example of applying the average tariff equivalent to the distances.

Table 15. Freight cost tariff equivalents for Port of Hamburg and Austria, Belgium and Bulgaria

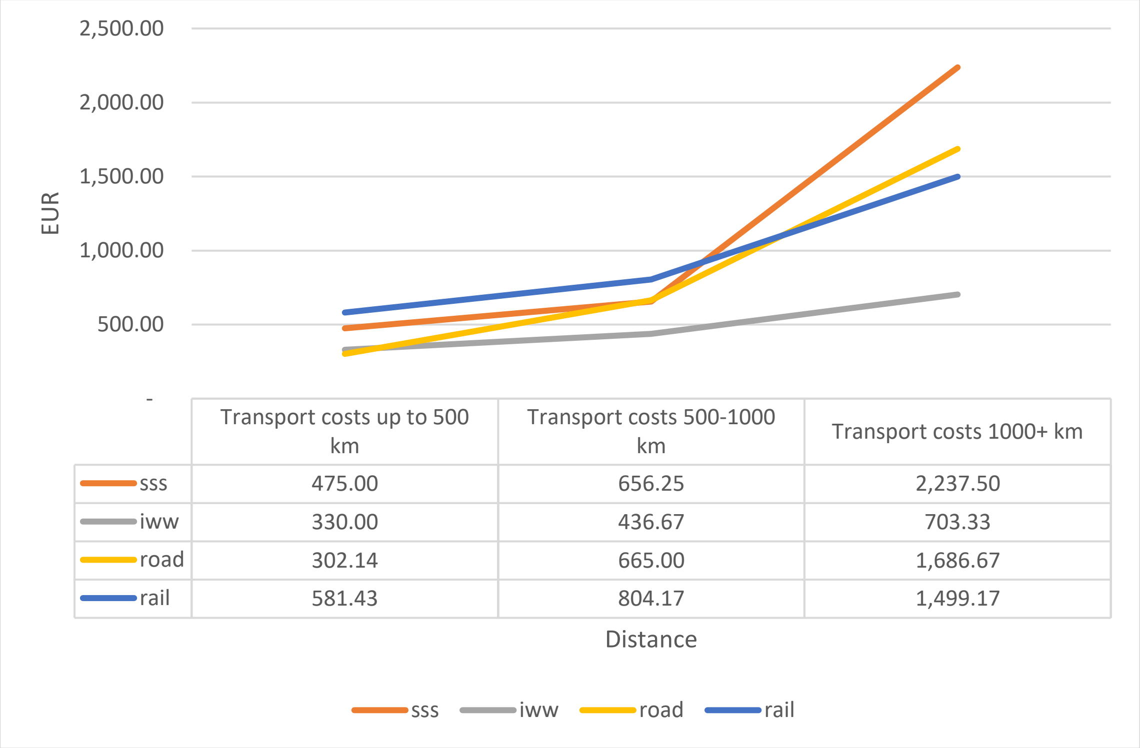
Mode	Austria	Belgium	Bulgaria
sss	1.000	1.045	1.447
iww	1.052	1.034	1.110
road	1.052	1.034	1.110
rail	1.052	1.034	1.110

Source: own compilation

According to Table 15, the freight costs of transporting goods from the Port of Hamburg to Bulgaria by the hinterland modes would be 11% of the value of the transported goods. And as we mentioned earlier, longer distances get higher tariff equivalents. Moreover, the barrier is equal to 1 for all impossible routes.

Now ROW column should be derived. Due to the fact that ROW consists of many countries, we use the average distance from the ports in question to the main non-EU countries. As we have to consider the short-sea shipping mode as well, we consider only those non-EU countries that are reachable by short-sea shipping. Table A1 in the Appendix represents selected non-EU countries and related distances. With the help of the formula (7) we get the freight cost tariff equivalents for the ROW column.

The following procedure includes defining the relative differences of the hinterland modes and short-sea shipping. Here we use the transport costs analysis per distance provided by the SEALS study. The authors of this study state that the relative attractiveness of different modes depends on the distances. (Meyer-Rühle, et al., 2008) Figure 8 shows the distribution of average freight costs in euros per distance per different mode of hinterland transport and short-sea shipping. Table A2 covers the exact numbers of cost-distribution based on a few routes described in the study.



	Transport costs up to 500 km	Transport costs 500-1000 km	Transport costs 1000+ km
sss	475.00	656.25	2,237.50
iww	330.00	436.67	703.33
road	302.14	665.00	1,686.67
rail	581.43	804.17	1,499.17

Figure 8. Distribution of average freight costs in euros per mode per distance

Source: own compilation based on Meyer-Rühle, et al. (2008)

Figure 8 shows that the relative costs per mode differ based on the distance class. The road transport is the cheapest one for shorter distances of up to 500 km (costs being only €302), while the inland waterway mode competes with it having freight costs of €330, only marginally higher than those for road transport. For distances between 500 and 1000 km, and also for distances over 1000 km the inland waterway mode is the cheapest one. The road transport becomes much more expensive, especially when it crosses the 1000 km limit. Rail never becomes the cheapest mode of transport, so only some other advantages of rail transport such as suitable transit times can make it attractive. Short-sea shipping is more attractive for the distances between 500 and 1000 km. However, we do not take into account the effect of economies of scale due to no data available. Hence, our conclusions are derived based on the freight costs increase for the same volume of goods transported over longer distances.

When adjusting the equivalents for the relative cost-attractiveness per individual mode of transport, we use an additional barrier of zero for the cheapest mode in the distance category. To assign additional tariff barriers for comparatively more expensive modes within the same distance category, we divide their average freight cost by the average freight cost of the cheapest mode in the same distance category. Table 16 demonstrates these additional tariff barrier equivalents for each mode within every distance category. The colours of different columns indicate the following: green cells refer to the distances up to 500 km, yellow colours to the distances between 500 and 1000 km, and red colours to the distances above 1000 km.

Table 16. Tariff equivalent coefficient for adjustment per mode per distance category

Mode	less than 500 km	500-1000 km	more than 1000 km
sss	1.572	1.503	3.181
iww	1.092	1.000	1.000
road	1.000	1.523	2.398
rail	1.924	1.842	2.132

Source: own compilation

When we finally adjust the initial tariff barrier equivalents for these relative costs, we use the following formula:

$$(17) \quad Adjusted\ tariff\ equivalent = (Freight\ cost\ tariff\ equivalent\ (Table\ 15) - 1) \times Tariff\ equivalent\ coefficient\ (Table\ 16)\ +\ 1$$

The coefficients in Table 16 are used for the appropriate distance categories as indicated by colours. The impossible routes are coloured white. Table 17 presents an example of adjusted freight cost tariff equivalents for the Port of Wilhelmshaven and Austria, Belgium and Bulgaria.

Table 17. Initial tariff equivalents adjusted for average freight cost per mode per distance category

Mode	Austria	Belgium	Bulgaria
sss	1.000	1.070	2.780
iww	1.065	1.039	1.146
road	1.100	1.036	1.349
rail	1.121	1.069	1.310

Source: Compiled by author

These calculations are repeated for all port, mode and country combination, including the ROW part. Now we need to compute the total initial trade barriers using Anderson & Van Wincoop approach stated above and represented by Figure 6. The local distribution costs, border related costs and time costs are set constant at 1.55, 1.44 and 1.09 respectively. Formula (18) is used to calculate the total initial trade barrier:

$$Total\ initial\ trade\ barrier = Freight\ costs\ barrier \times 1.55 \times 1.4 \times 1.09 \tag{18}$$

One more time, the impossible routes are bundled together. Table 18 represents an example of calculated total initial trade barriers for the Port of Hamburg and Austria, Belgium and Bulgaria.[2] The final step in calculating the initial tariff barriers will be made after determining the mode and port specific elasticities in the next section.

Table 18. Total tariff barrier equivalents for Port of Hamburg and Austria, Belgium and Bulgaria

Mode	Austria	Belgium	Bulgaria
sss	1.000	2.644	6.847
iww	2.594	2.538	2.775
road	2.678	2.593	3.253
rail	2.730	2.627	3.162

Source: own compilation

4.3.2.2. Elasticity calculations

As we stated earlier in this chapter, we need three types of elasticities for the GSIM model, namely elasticity of substitution, export supply elasticity and composite demand elasticity. We assume that the values of all elasticity types are equal for all modes, all countries and all years.

According to Francois & Hall (2003), the elasticity of substitution is 10 and the export supply elasticity is 1.5. For these two types of elasticity we will use the same values. Coming to the composite demand elasticity, it is specific in terms of ports and modes, and must be examined separately. Moreover, as we stated before, we will use the composite demand elasticity values to make the final corrections to the initial tariff barrier equivalents. This is done due to the fact that we have an asymmetric matrix with data, and it cannot integrate these specific values while computing the results.

As there is no data on the composite demand elasticities for ports, we use the technique adopted by Joey Van Elswijk in his work dedicated to the hinterland flows and modal split

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[2] The entire spreadsheet with all the calculations called Distances and Initial Tariffs is available upon request.

of the European Seaports. The author takes into consideration two effects (Van Elswijk, 2012):

a. mode dominance - if the dependency of the port on one specific mode is quite high, the demand for this mode is price inelastic, and vice versa,
b. port competition – if the dependency of the port on one specific mode is quite high, during the price increase for this mode the shippers will tend to choose another port (if any) competing with this one.

Table 19 shows the specific elasticities for nine ports in question per each mode.

Table 19. Overview of specific elasticities per port per mode

	sss	iww	Road	rail
Antwerp	-1.4	-1.4	-1.4	-1.4
Zeebrugge	-1.1	-0.5	-1.1	-1.1
Bremerhaven	-1.1	-0.5	-1.1	-1.1
Hamburg	-1.1	-0.5	-1.1	-1.1
Wilhelmshaven	-1.1	-1.1	-1.1	-1.1
Dunkerque	-1.1	-1.1	-1.1	-1.1
Le Havre	-1.1	-1.1	-1.1	-1.1
Amsterdam	-1.1	-1.1	-1.1	-1.1
Rotterdam	-1.4	-1.4	-1.4	-1.4

Source: own compilation based on Van Elswijk (2012)

Now we can estimate the composite demand elasticity. For this, we first compute the weighted elasticity following the formula presented below:

$$(19) \quad Weighted\ average\ elasticity\ per\ mode = \sum\left(\left(\frac{Freight\ per\ port\ per\ mode}{Total\ EU\ freight\ handled\ by\ this\ mode}\right) \times Specific\ elasticity\right) \text{ (Van Elswijk, 2012)}$$

Table 20 presents the results of these calculations.

Table 20. Weighted average elasticities per mode

Weighted elasticity	
sss	-1.262
iww	-1.314
road	-1.257
rail	-1.207

Source: own compilation

In our next step, we finally determine the composite demand elasticity using the formula:

$$(20)\quad Total\ composite\ demand\ elasticity = weighted\ sss\ average\ elasticity \times \left(\frac{total\ sss\ freight}{total\ EU\ outgoing\ freight}\right) + weighted\ iww\ average\ elasticity \times \left(\frac{total\ iw\ freight}{total\ EU\ incoming\ freight}\right) + weighted\ road\ average\ elasticity \times \left(\frac{total\ road\ freight}{total\ EU\ incoming\ freight}\right) + weighted\ rail\ average\ elasticity \times \left(\frac{total\ rail\ freight}{total\ EU\ incoming\ freight}\right)\ \text{(Van Elswijk, 2012)}$$

These calculations lead to the composite elasticity demand of -1.264, which indicates that the demand is slightly elastic. This value we will use in our GSIM model as an input.

Finally, we can correct the total initial tariff barrier equivalents calculated earlier by the specific elasticities per port per mode, using the following formula:

$$(21)\quad Total\ initial\ tariff\ barrier\ equivalent\ corrected\ for\ elasticity = ((Total\ initial\ tariff(Table\ 18) - 1) \times Specific\ elasticity(Table\ 19) \times (-1)) + 1\ \text{(Van Elswijk, 2012)}$$

Table 21 shows an example of the initial tariff barrier equivalents corrected for elasticities for the Port of Hamburg and Austria, Belgium and Bulgaria. [3]We will use these values to fill in the second matrix of our GSIM model.

Table 21. Initial tariff barrier equivalents corrected for elasticities for Port of Hamburg and Austria, Belgium and Bulgaria

Mode	Austria	Belgium	Bulgaria
sss	1.000	2.808	7.432
iww	1.797	1.769	1.887
road	2.846	2.752	3.478
rail	2.903	2.789	3.378

Source: own compilation

4.3.2.3. Future scenarios

While assessing the economic and trade impact of low sulphur fuel requirements on the ports in the Hamburg-Le Havre range, it is important to establish different scenarios according to which these requirements will cause changes (if any). The inputs of the third matrix of the GSIM model will depend on these scenarios.

New low sulphur fuel requirements bring the shift from the heavy fuel oil (HFO) to MGO. According to Notteboom (2011), “the bunker costs represent an important component in

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[3] The Excel spreadsheet called Distances and Initial Tariffs contains all the calculations and results of the initial tariff equivalents and is available upon request.

the total freight rate". HFO share in the freight rate is typically around 20-25%, reaching 50% when the prices for HFO are high. When shifting to MGO, this share will increase up to around 35-40%, reaching 64% with high prices on MGO. Using the work of Notteboom, we develop four different possible scenarios (Notteboom, 2011):

1. Low fuel price scenario for the traditional short-sea shipping. Here we assume that the vessels are sailing between the ports in the Hamburg-Le Havre range at 18.5 knots on average. An increase in the additional freight tariffs for the short-sea shipping mode is expected to be 10.5% following estimated relative freight rate changes of 10.5% calculated by Notteboom (2011).
2. High fuel price scenario for the traditional short-sea shipping. An increase in the additional freight tariffs for the short-sea shipping mode is expected to be 20% following estimated relative freight rate changes of 20% calculated by Notteboom (2011).
3. Low fuel price scenario for the fast short-sea shipping. Here we assume that the vessels are sailing between the ports in the Hamburg-Le Havre range at 25 knots on average. An increase in the additional freight tariffs for the short-sea shipping mode is expected to be 25% following estimated relative freight rate changes of 25% calculated by Notteboom (2011).
4. High fuel price scenario for the fast short-sea shipping. An increase in the additional freight tariffs for the short-sea shipping mode is expected to be 40% following estimated relative freight rate changes of 40% as presented by Notteboom (2011).

4.3.2.4. Final trade barriers

Now we can examine the final trade barriers which will be the inputs for the third matrix of our model. Here we follow exactly the same steps as for calculating the initial trade barriers. Only the average freight cost values for the short-sea shipping will be adjusted to the consequences of the new low sulphur fuel regulations in accordance with the four scenarios developed in the previous sub-section.

Using low scenario for the traditional short-sea shipping, we increase the average freight costs for the short-sea shipping mode by 10.5%. Table 22 represents these corrected average freight costs.

Table 22. Average freight costs for short-sea shipping corrected for low scenario for traditional short-sea shipping

Mode	Transport costs up to 500 km	Transport costs 500-1000 km	Transport costs 1000+ km
sss	524.88	725.16	2,472.44

Source: own compilation

Then we get the updated additional freight tariffs as shown in Table 23 below:

Table 23. Freight tariff coefficients for short-sea shipping adjusted for 10.5% freight cost increase

Mode	less than 500 km	500-1000 km	more than 1000km
sss	1.737	1.661	3.515

Source: own compilation

The final tariff barriers based on the low scenario for the traditional short-sea shipping are presented in Table 24.

Table 24. Final tariff barriers based on low scenario for traditional short-sea shipping

Mode	Austria	Belgium	Bulgaria
sss	1.000	2.832	7.942
iww	1.797	1.769	1.887
road	2.846	2.752	3.478
rail	2.903	2.789	3.378

Source: own compilation

The remaining average freight cost for the short-sea shipping corrected for high scenario for the traditional short-sea shipping, and low and high scenarios for the fast short-sea shipping and the appropriate freight tariff coefficients are demonstrated in Tables A3, A4 and A5 in the Appendix.[4]

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[4] Results of all the calculations for the final tariff barriers for four developed scenarios can be found in the Excel spreadsheets called Final Trade Barriers – Low Scenario Traditional, Final Trade Barriers – High Scenario Traditional, Final Trade Barriers – Low Scenario Fast, and Final Trade Barriers – High Scenario Fast; they are available upon request.

5. Results and Analysis

The GSIM model helps us run four different scenarios to assess the economic and trade impact of low sulphur fuel requirements in the ports in the Hamburg-Le Havre range. Model outputs reveal changes in economic and trade situation in several forms: 1) impact of the regulation on the net economic welfare, 2) changes in consumer (cargo owners) and producer (shipping companies) surplus, 3) changes in output (trade flows), 4) changes in prices.

To run the GSIM model, it needs to be expanded as the original model developed by Francois & Hall has the dimension of only 25x25. In our case, 9 ports with 4 modes of transport per port, 28 EU member states and ROW column lead to the matrices of 36x29. This means 1,044 combinations in total. All formulas in the model are adjusted for the asymmetric matrices we have. In the following sub-sections, we will interpret the reached outcomes in terms of the individual model outputs.

5.1. Low fuel price scenario for traditional shipping

In Chapter four we examined the trade flow values between the nine ports in the Hamburg-Le Havre range and destinations, the initial trade barriers, the final trade barriers for the four different scenarios, as well as the composite demand elasticity required for the input for the GSIM model. We decided to interpret the major model outputs individually for each specific scenario developed in section 4.3.2.3.

Low fuel price scenario for the traditional short-sea shipping is characterised by the freight tariff equivalent increase of 10.5% due to the sulphur regulations. This 10.5% increase is entered into the final trade barriers of the model. Changes in consumer (cargo owners) and producer (shipping companies) surplus and net economic welfare are presented in Figure 9. These changes are grouped by port to show the impact of the new sulphur regulations on the ports in the Hamburg-Le Havre range.

So, the shipping lines get the positive producer surplus only in the port of Le Havre amounting to €744 million which is quite small. And the total producer surplus for the ports in the Hamburg-Le Havre range is negative, amounting to €5 billion. The consumer surplus is also negative and equals €86 billion meaning that the cargo owners will lose this money as a consequence of the new sulphur regulations which is much bigger than the loss of the shipping lines. Coming to tariff revenue, the increased costs for the short-sea shipping mean less trade that leads to a potential loss in tariff revenue. However, as the model calculates tariff revenue in another way, the tariff revenue values are set to zero, as we do operate with the tariff equivalents and not with tariffs. Yet, the net welfare effect which represents the sum of the producer and consumer surplus and tariff revenues is negative for all ports, being the highest for the ports of Rotterdam, Hamburg and Antwerp.

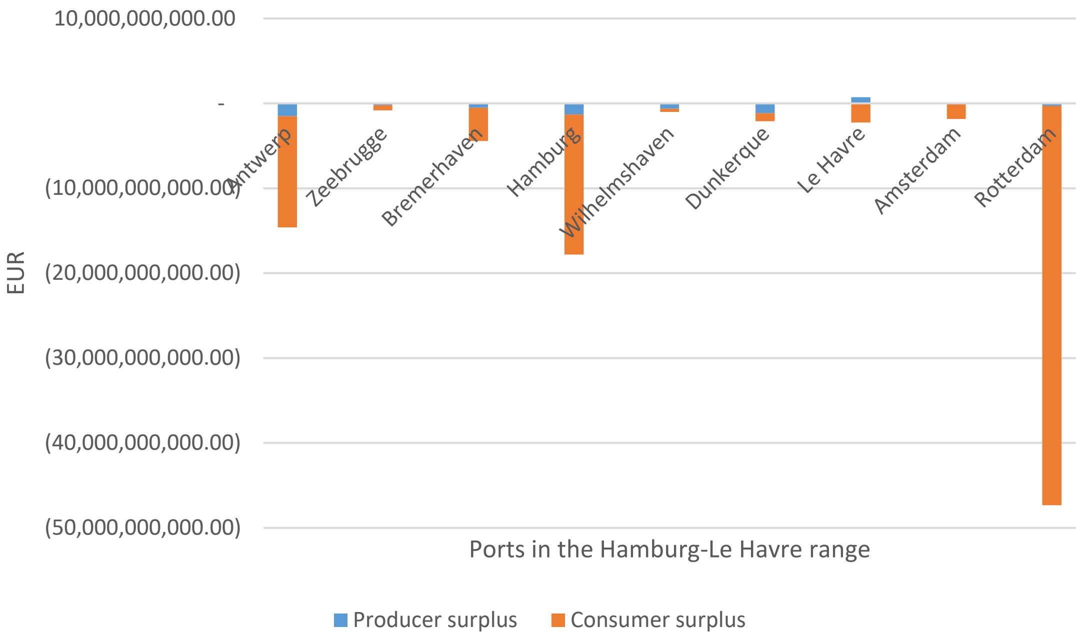

Figure 9. Changes in producer and consumer surplus and net economic welfare per port (low scenario for traditional shipping)

Figure 10 illustrates the absolute changes in trade flow values handled in the nine ports in question and transported through the hinterland modes and the short-sea shipping to the European countries and the rest of the world, per port. We can see from this figure that some ports benefit from the cargo transported through them from some countries, and some ports lose. For instance, the ports of Antwerp, Hamburg and Bremerhaven lose on the annual basis €3.8 billion, €1.7 billion and €1.3 billion respectively. The port of Wilhelmshaven is the only one that benefits after the new phase of sulphur regulations, gaining €493 million on the annual basis.

The biggest trade flow value changes are observed with Belgium, France, Germany, Italy, the Netherlands, Spain and the UK, as these are the countries having a higher share of the transport flows going through the ports, and with the new sulphur regulations they are expected to be more affected than the others. ROW constitutes the highest trade flow value changes, which is the result of the fact that “most EU maritime freight transport is with extra-EU partners” (Eurostat (b), 2016). Hence, ROW is affected the most.

Figure 11 presents the absolute changes in trade flow values per port per mode, giving us the chance to carry out a detailed analysis of the outcomes presented in Figure 10. Figure 11 shows a decrease for the short-sea shipping mode and increase for the hinterland modes in money value for all nine ports. For instance, the port of Rotterdam is losing €6.9 billion through short-sea shipping, which is the highest loss. At the same time, the port of Rotterdam also has the highest trade flow increase in absolute values via road transport which equals to €3.5 billion.

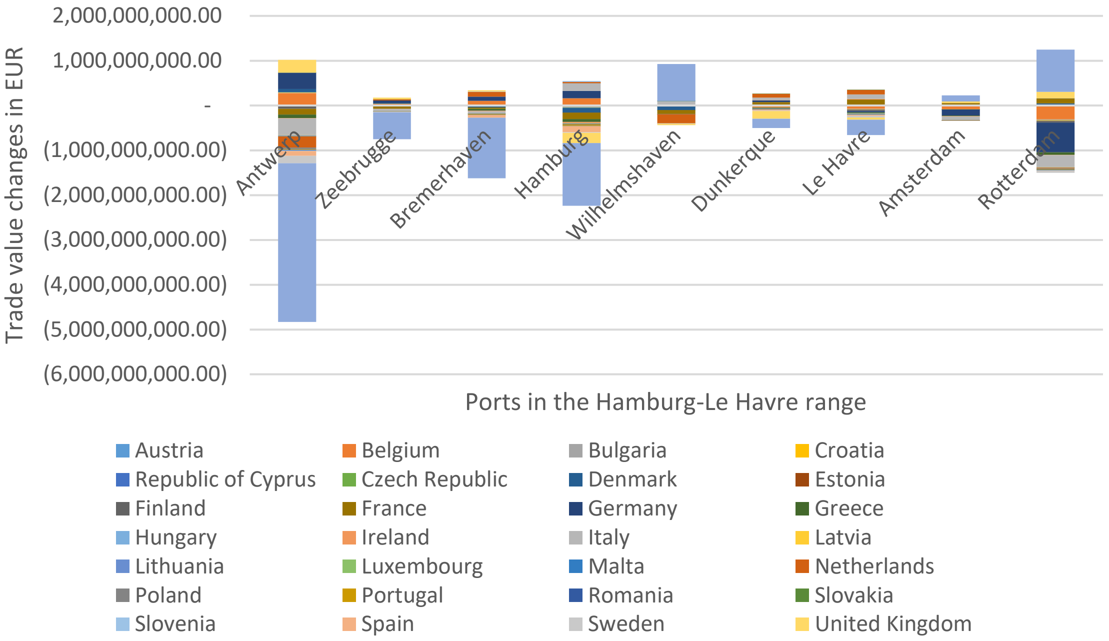

Figure 10. Trade flow value changes per port (low scenario for traditional shipping)

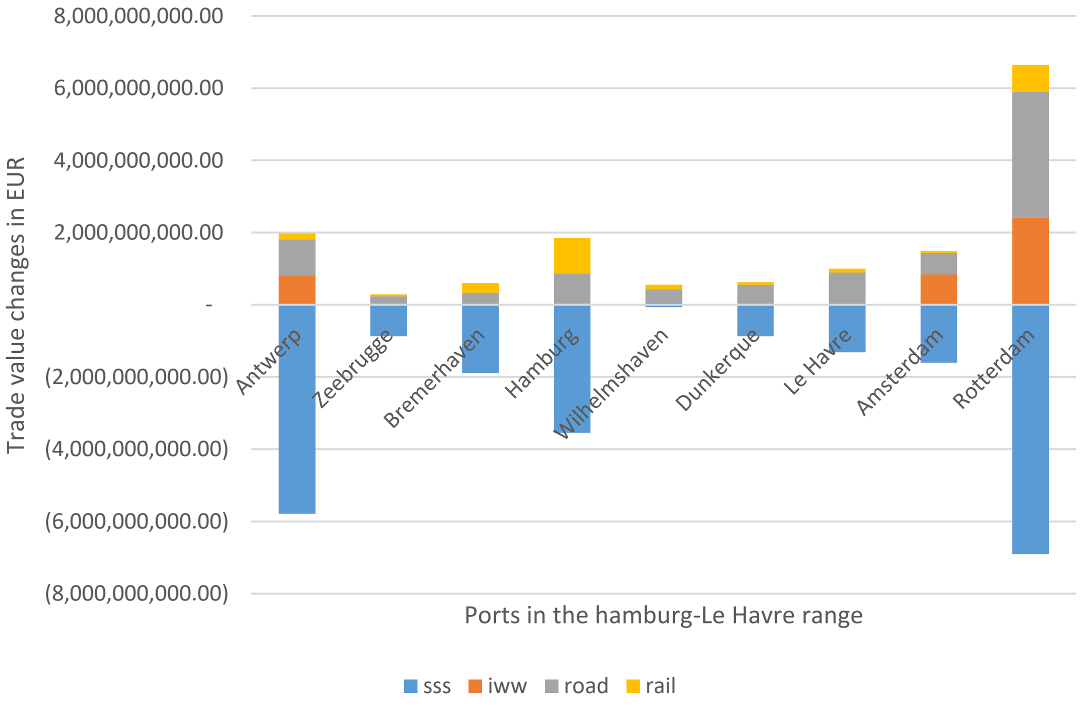

Figure 11. Trade flow value changes per port per mode (low scenario for traditional shipping)

Besides the port of Rotterdam, the ports of Zeebrugge, Wilhelmshaven, Dunkerque and Le Havre show a similar situation where the decrease in absolute values of the short-sea shipping is compensated by the increase of the trade flows transported by the road transport. The port of Amsterdam compensates this decrease by the increase in the trade flows transported by the inland waterways mode that can be explained by the fact that this mode of hinterland transport has the highest share in the modal split of the port (56.37%). The ports of Bremerhaven and Hamburg have almost equal increase in the trade flows transported both by road transport and rail transport. And the port of Antwerp has similar increase for the road and inland waterways modes.

As a result, the major modal backshift can be observed for the ports of Antwerp, Wilhelmshaven, Dunkerque, Le Havre and Rotterdam. The remaining ports also experience the modal backshift from the short-sea shipping to the road transport. However, some of them also get the increased trade flow values for the rail and inland waterways modes. However, when we examine the changes in trade flows in terms of percentages, we can observe a different picture. Figure 12 demonstrates changes in output (trade flows) in percentages. These changes in output (trade flows) are ranging from 2% increase mostly for the road transport in ports to 5% decrease for the short-sea shipping mode. Figure 13 demonstrates changes in overall consumer prices in percentages. Here we can see that the absolute changes presented above are quite low in terms of percentage changes. Therefore, the average changes in overall consumer prices per all ports and all modes is 1% increase, with maximum of 7% increase for rail transport in the port of Amsterdam.

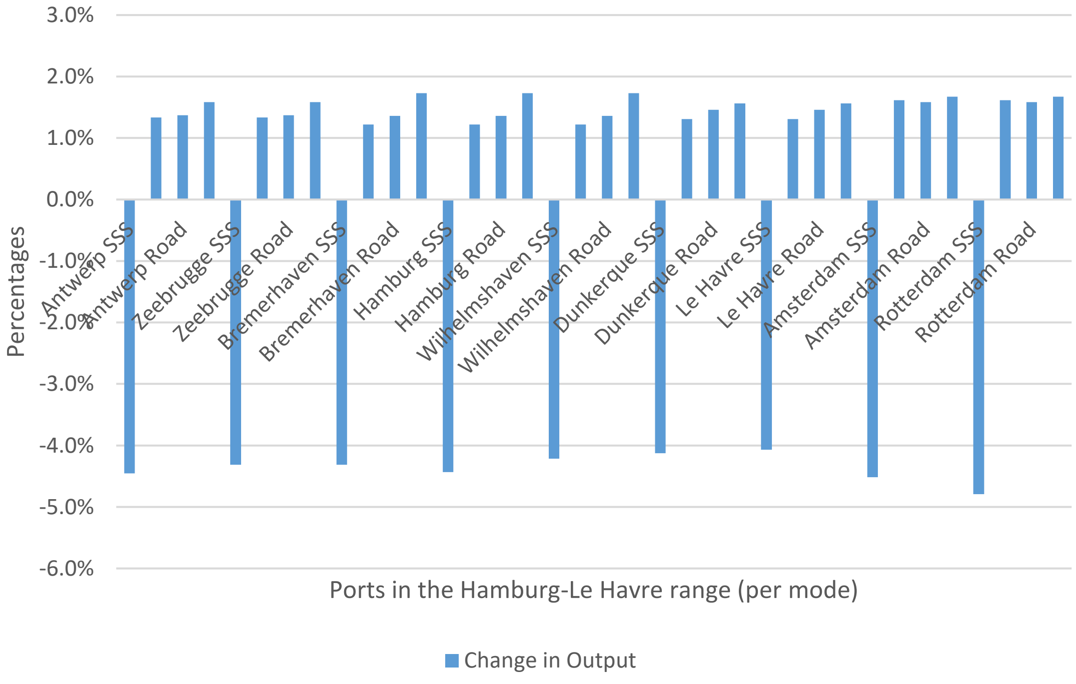

Figure 12. Trade flow changes in percentages per port per mode (low scenario for traditional shipping)

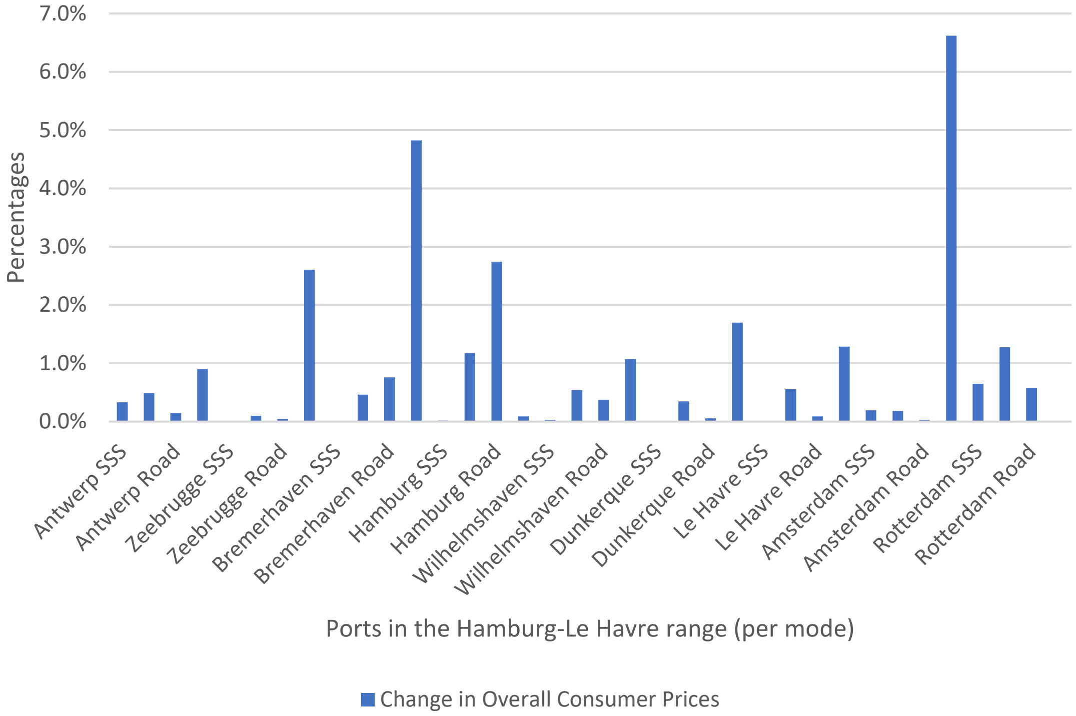

Figure 13. Price changes in percentages per port per mode (low scenario for traditional shipping)

5.2. High fuel price scenario for traditional shipping

High fuel price scenario for the traditional short-sea shipping is characterised by the freight tariff increase of 20% due to the sulphur regulations. This 20% increase is incremented into the final trade barriers of the model.

Changes in consumer (cargo owners) and producer (shipping companies) surplus and net economic welfare are presented in Figure 14.[5] So, the shipping lines get the positive producer surplus only in the port of Le Havre amounting to €1.4 billion which is a twofold increase in comparison with the first scenario. And the total producer surplus for the ports in the Hamburg-Le Havre range is negative amounting to €9 billion. The consumer surplus is also negative and equals €164 billion, with the port of Rotterdam having the biggest negative figure of €90 billion. And the total net welfare effect equals to €195 billion loss.

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[5] Individual changes for these categories can be seen in the Excel spreadsheet called GSIM – High Scenario – Traditional Shipping which is available upon request.

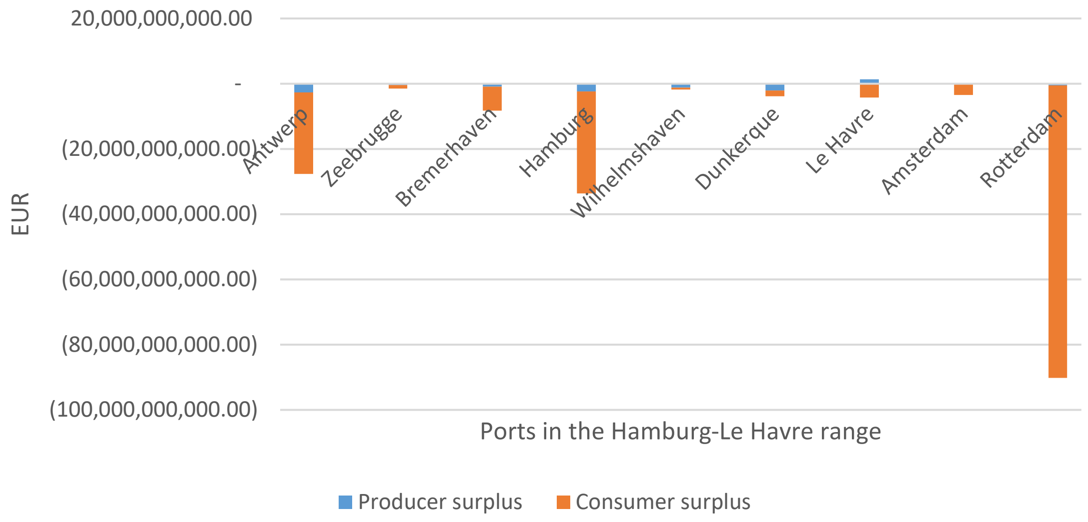

Figure 14. Changes in producer and consumer surplus and net economic welfare per port (high scenario for traditional shipping)

Figure 15 illustrates the absolute changes in the trade flow values per port. Similarly to the first scenario, the ports of Antwerp, Hamburg and Bremerhaven lose on the annual basis €6.9 billion, €3 billion and €2.3 billion respectively. The port of Wilhelmshaven is the only one that benefits from the new phase of sulphur regulations, gaining €921 million per year.

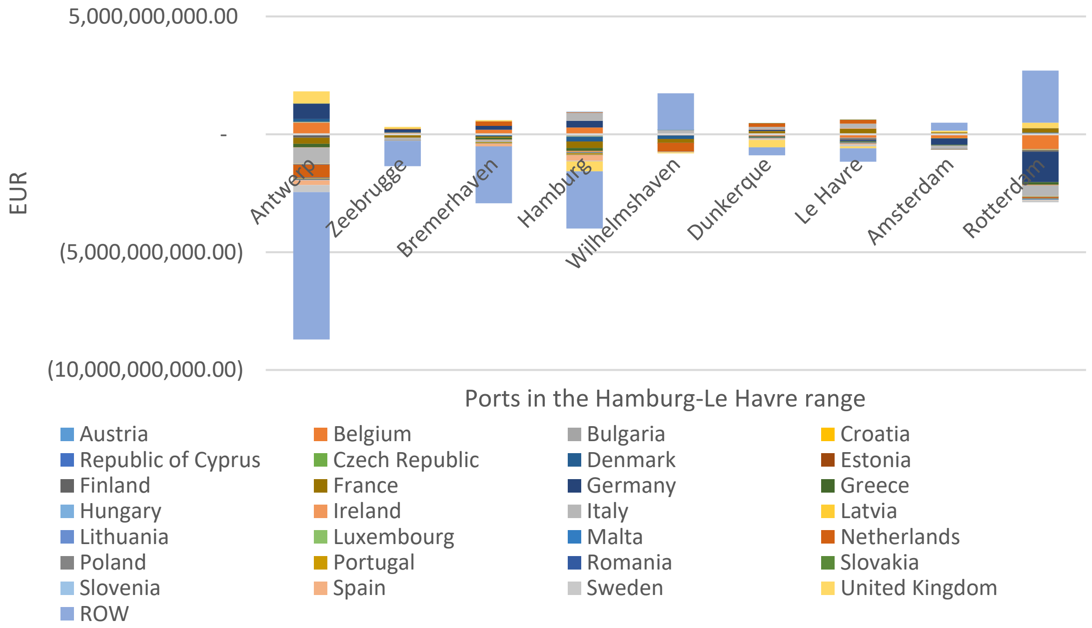

Figure 15. Trade flow value changes per port (high scenario for traditional shipping)

Figure 16 presents the absolute changes in trade flow values per port per mode. It shows decrease for the short-sea shipping mode and increase for the hinterland modes in money value for all nine ports. For instance, the port of Rotterdam is losing €13 billion by the short-sea shipping, which is the highest loss in the Hamburg-Le Havre range.

At the same time, the port of Rotterdam also has the highest trade flow increase in absolute value via road transport which equals €6 billion. Besides the port of Rotterdam, the ports of Zeebrugge, Wilhelmshaven, Dunkerque and Le Havre show similar situation where we also observe the increase of the trade flows transported by road. As a result, the major modal backshift can be observed for the ports of Antwerp, Wilhelmshaven, Dunkerque, Le Havre and Rotterdam.

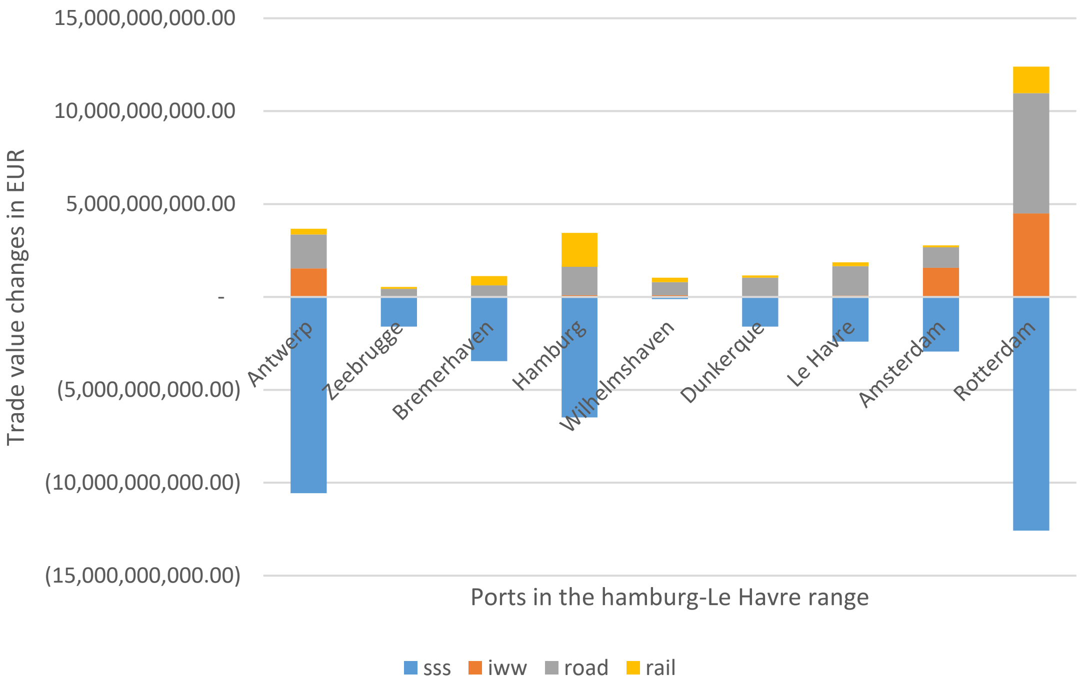

Figure 16. Trade flow value changes per port per mode (high scenario for traditional shipping)

Examining the changes in the trade flows in terms of percentages gives us a better view on the new situation. Figure 17 demonstrates changes in output (trade flows) in percentages. These changes in output (trade flows) are ranging from 3% increase mostly for the road transport in ports to 9% decrease for the short-sea shipping mode.

Figure 18 demonstrates the changes in overall consumer prices and changes in output (trade flows) in percentages. Here we can see that the absolute changes presented above are still low in terms of percentage changes. Therefore, the average changes in overall consumer prices per all ports and all modes is 2% increase, with maximum of 12% increase for rail transport in the port of Amsterdam.

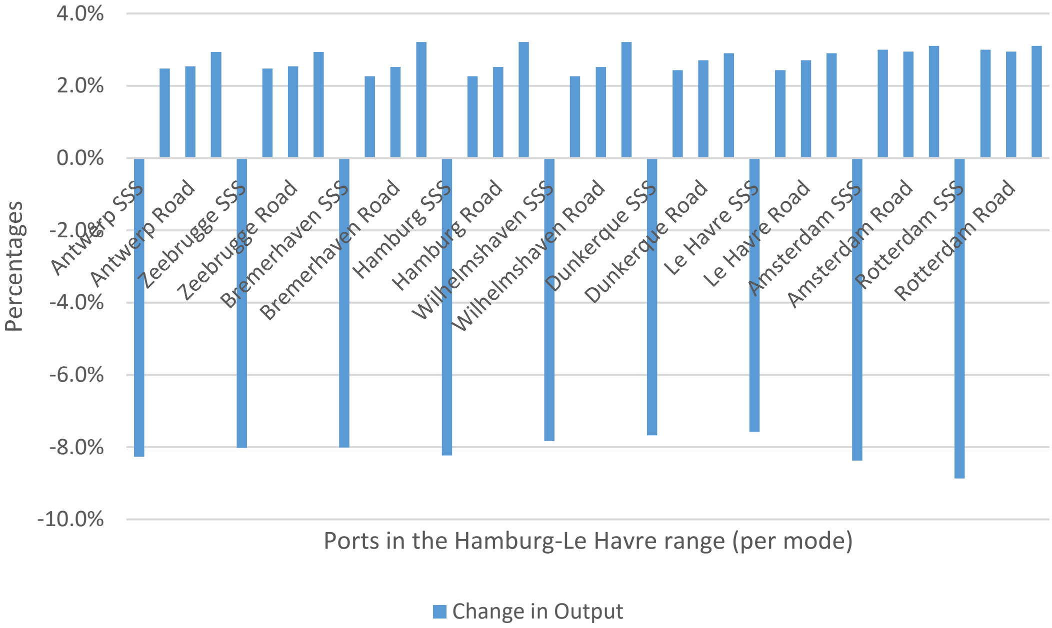

Figure 17. Trade flow changes in percentages per port per mode (high scenario for traditional shipping)

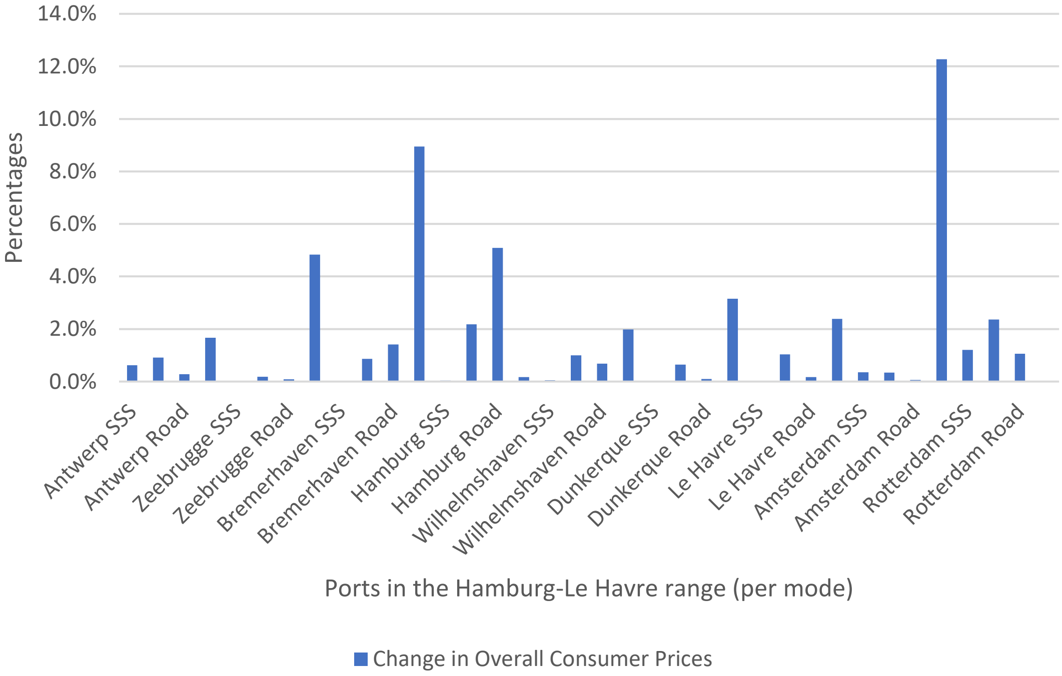

Figure 18. Price changes in percentages per port per mode (high scenario for traditional shipping)

5.3. Low and fast fuel price scenarios for fast shipping

Low scenario for the fast short-sea shipping is characterised by the freight tariff increase of 25% and the high scenario – for 40% due to the sulphur regulations. These 25% and 40% increases are incremented into the final trade barriers of the model.

Changes in consumer (cargo owners) and producer (shipping companies) surplus and net economic welfare are presented in Figure 19 and Figure 20.[6] Based on these figures, the shipping lines get the producer surplus only in the port of Le Havre amounting to €1.7 billion in the low scenario and €2.7 billion in the high scenario. The total producer surplus for the ports in the Hamburg-Le Havre range is negative amounting to €11 billion in the low scenario and €15.8 billion in the high scenario.

The consumer surplus of the cargo owners is also negative and equals €205 billion for the low scenario, with the port of Rotterdam having the biggest negative figure of €112 billion; and it equals €325.8 billion for the high scenario (€179 billion loss for the Port of Rotterdam). And the total net welfare effect equals to €246 billion loss (low scenario) and €405 billion loss (high scenario, with the port of Rotterdam having €185 billion loss).

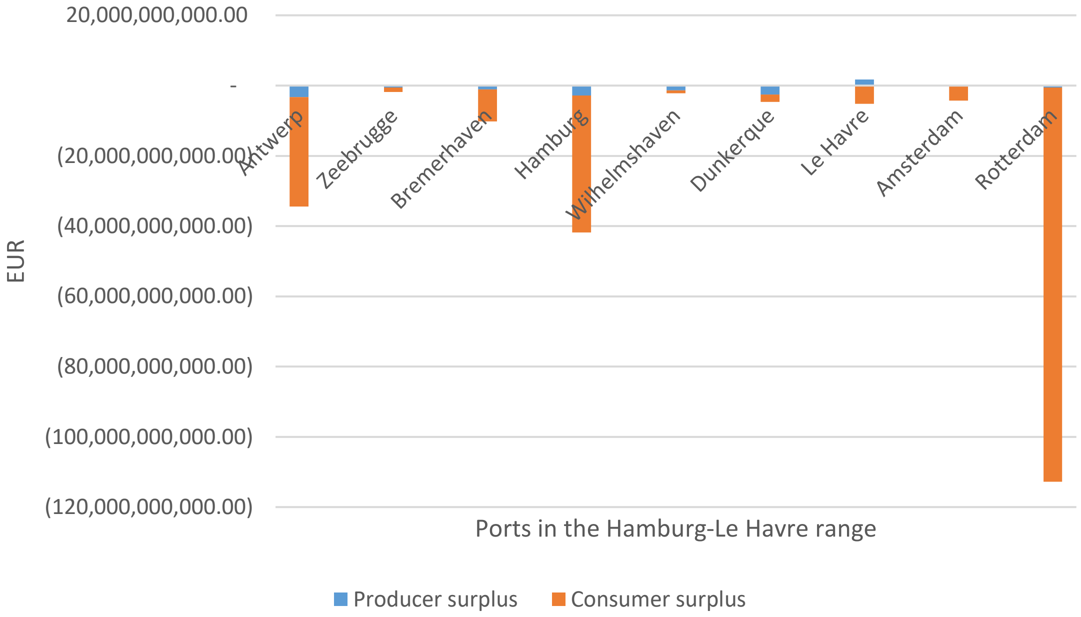

Figure 19. Changes in producer and consumer surplus and net economic welfare per port (low scenario for the fast short-sea shipping)

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[6] Individual changes for the aforementioned categories can be seen in the Excel spreadsheets called GSIM – Low Scenario – Fast Shipping and GSIM – High Scenario – Fast Shipping available upon request.

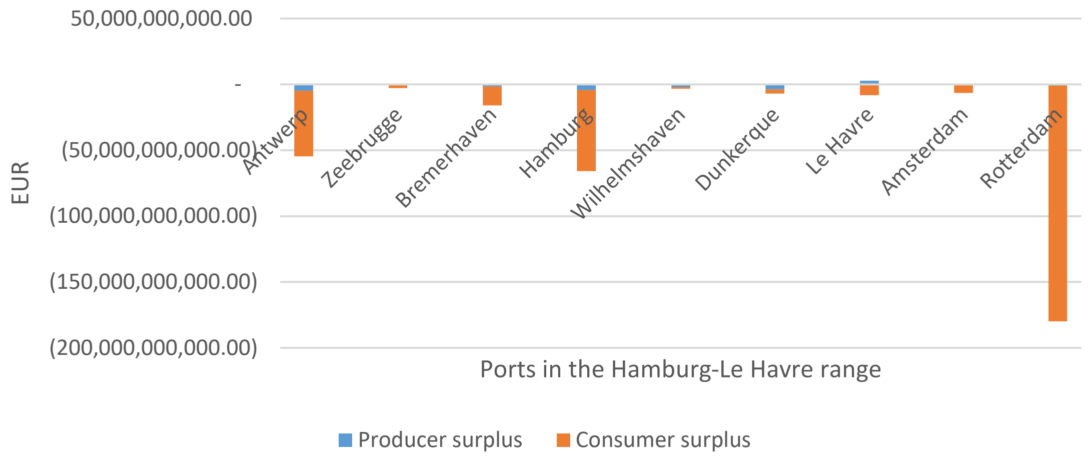

Figure 20. Changes in producer and consumer surplus and net economic welfare per port (high scenario for the fast short-sea shipping)

Figure 21 and Figure 22 illustrate the absolute changes in the trade flow values per port. Identical to the first two scenarios, the ports of Antwerp, Hamburg and Bremerhaven lose quite big amounts in the absolute numbers (€8.4billion, €3.7billion, €2.8 billion respectively for the low scenario; €12 billion, €5 billion, €4 billion respectively for the high scenario). The port of Wilhelmshaven is the only benefiting port in the low scenario (€1.1 billion), while in the high scenario the port of Rotterdam also remains in benefit (€777 million) and the port of Wilhelmshaven gets €1.8 billion.

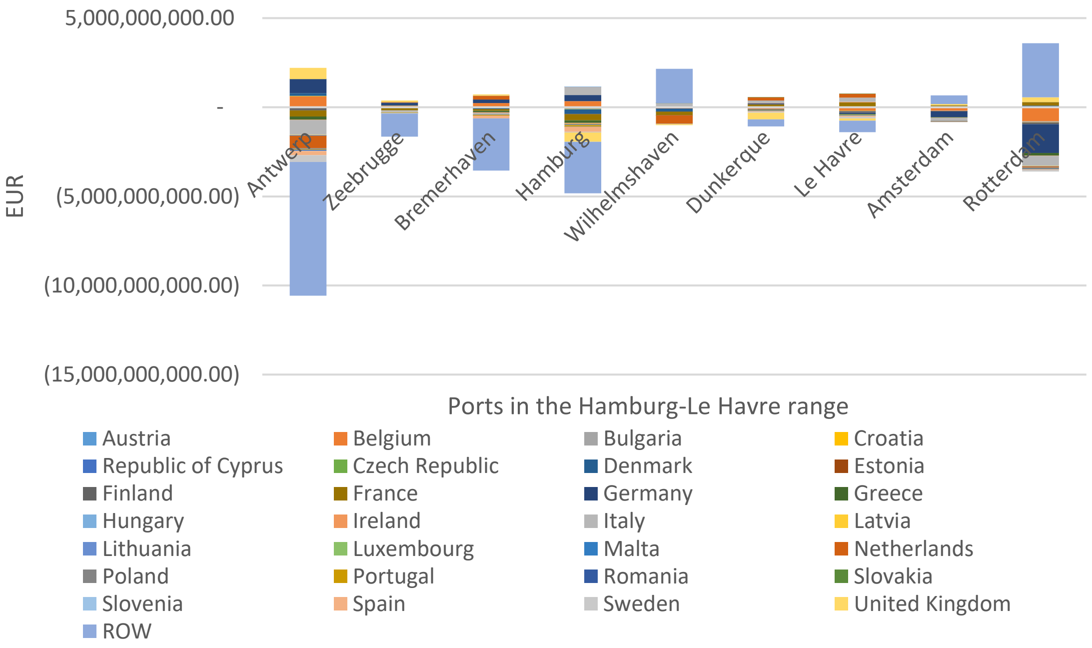

Figure 21. Trade flow value changes per port (low scenario for the fast short-sea shipping)

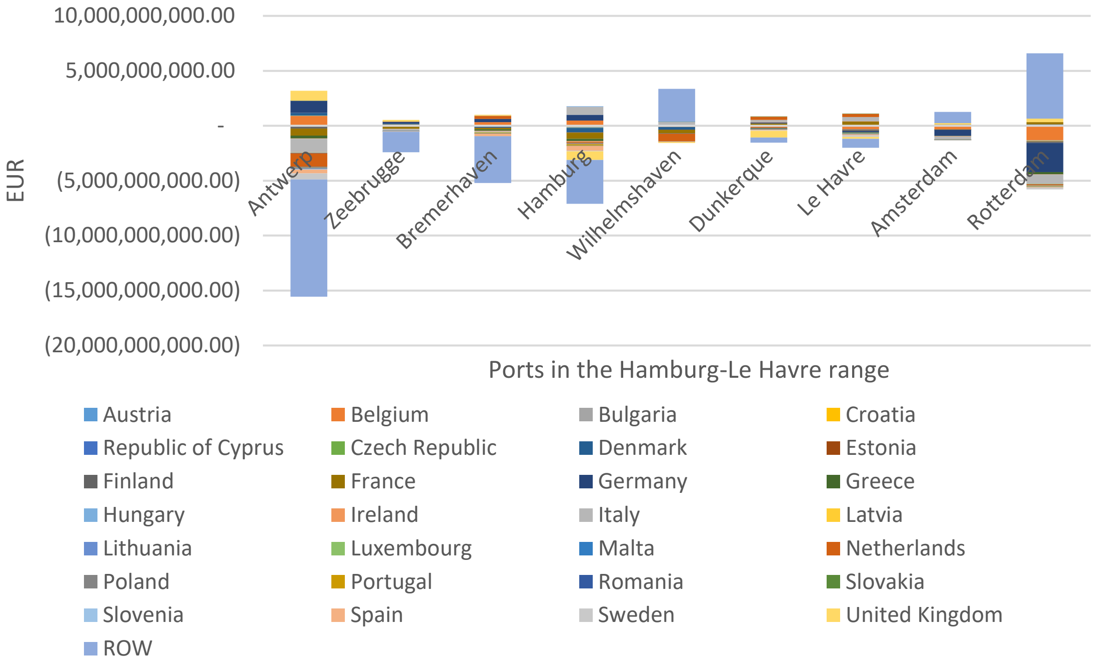

Figure 22. Trade flow value changes per port (high scenario for the fast short-sea shipping)

Figure 23 and Figure 24 show the absolute changes in the trade flow values per port per mode for both scenarios. The short-sea shipping mode suffers even more in these two scenarios in comparison with the two previous ones pointing at the modal backshift, as the cargo transported by road increases much.

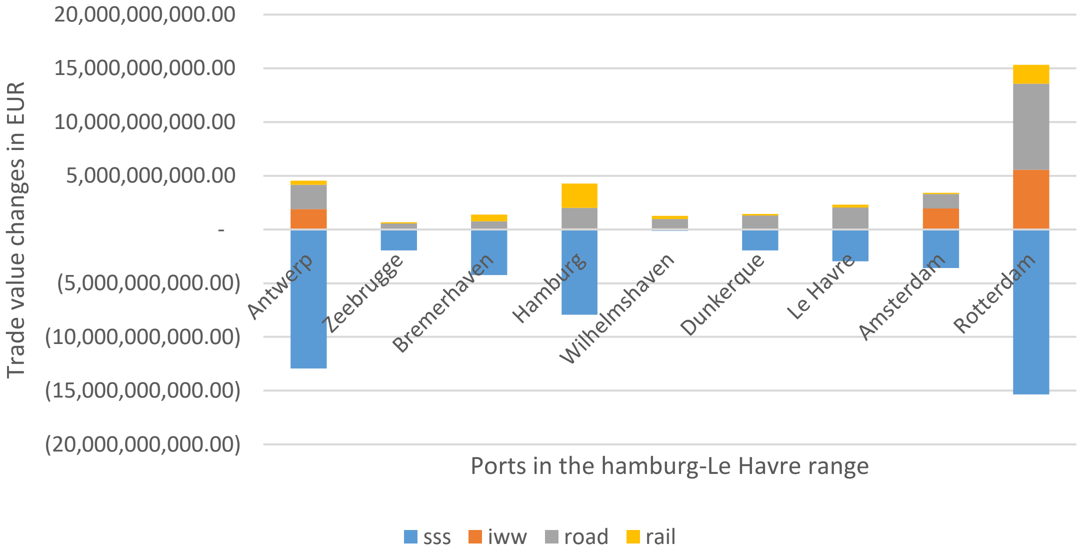

Figure 23. Trade flow value changes per port per mode (low scenario for fast shipping)

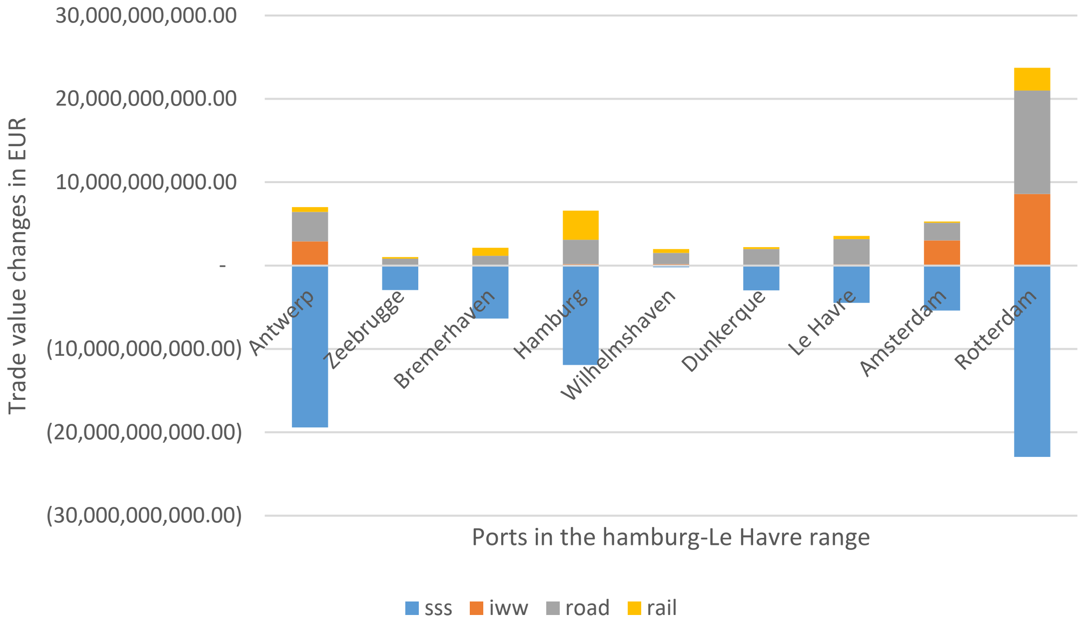

Figure 24. Trade flow value changes per port per mode (high scenario for fast shipping)

Figure 25 and Figure 26 demonstrate changes in output (trade flows) in percentages. These changes in output (trade flows) are ranging between 4% increase mostly for the road transport in ports and 11% decrease for the short-sea shipping mode (low scenario), and between 6% increase mostly for the road transport in ports and 17% decrease for the short-sea shipping mode (high scenario).

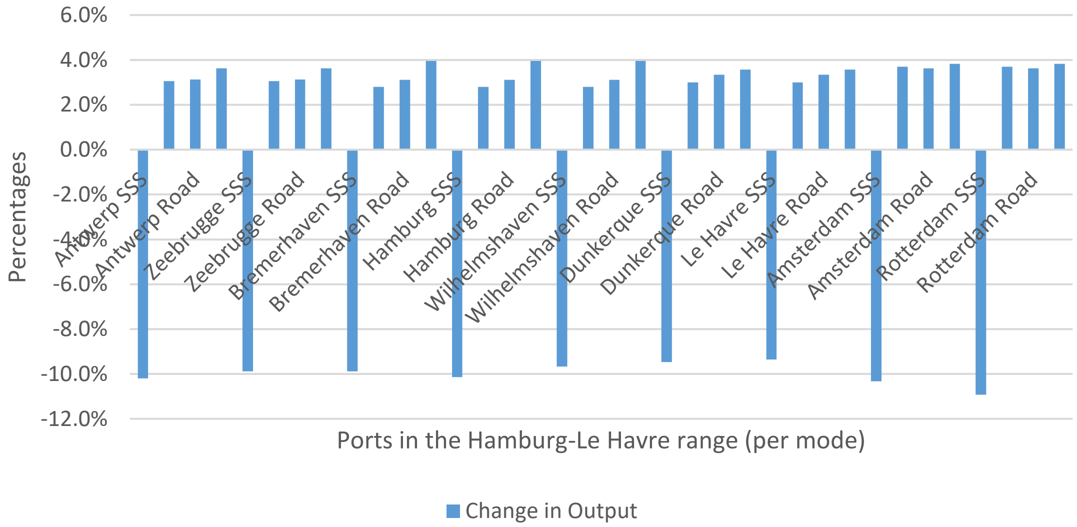

Figure 25. Trade flow changes in percentages per port per mode (low scenario for fast shipping)

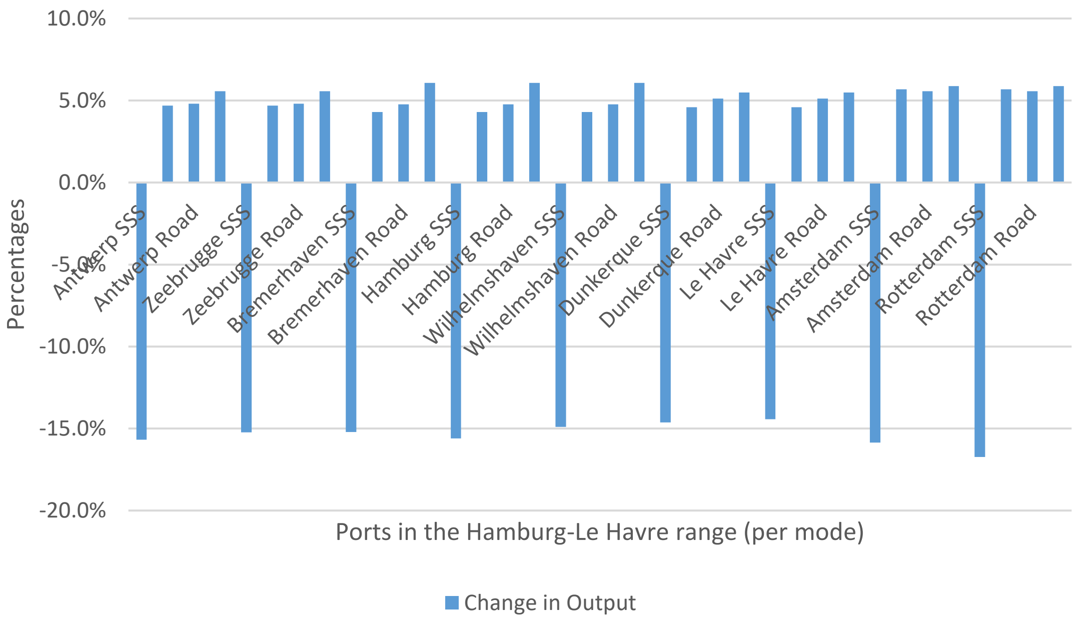

Figure 26. Trade flow changes in percentages per port per mode (high scenario for fast shipping)

Figure 27 and Figure 28 illustrate changes in overall consumer prices. The average changes in overall consumer prices per all ports and all modes are 2% and 3% increase for the low and high scenarios respectively, with maximum of 23% increase for rail transport in the port of Amsterdam 17% increase for rail transport in the port of Bremerhaven (both in the high scenario).

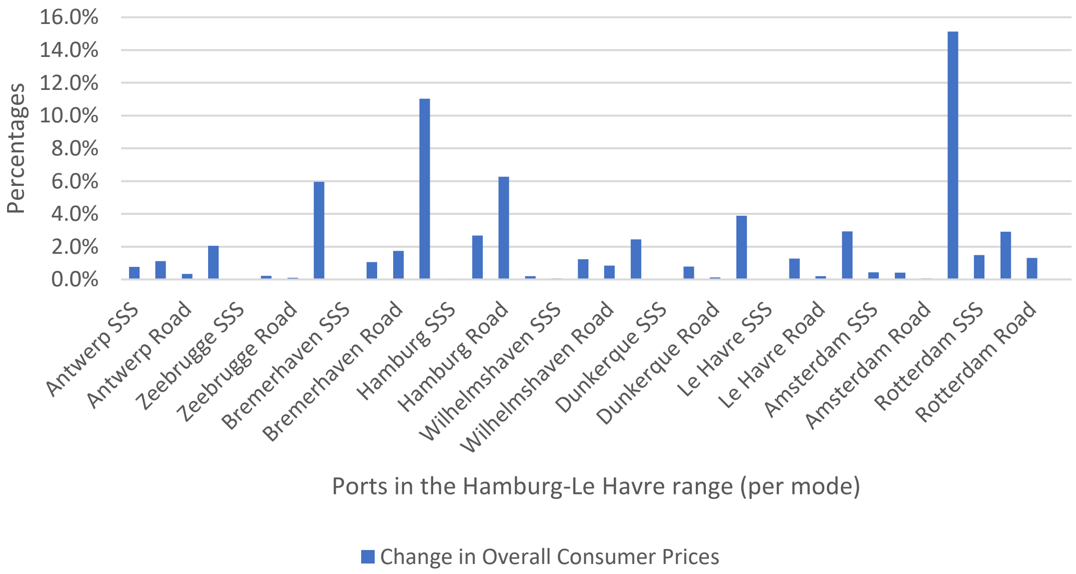

Figure 27. Price changes in percentages per port per mode (low scenario for fast shipping)

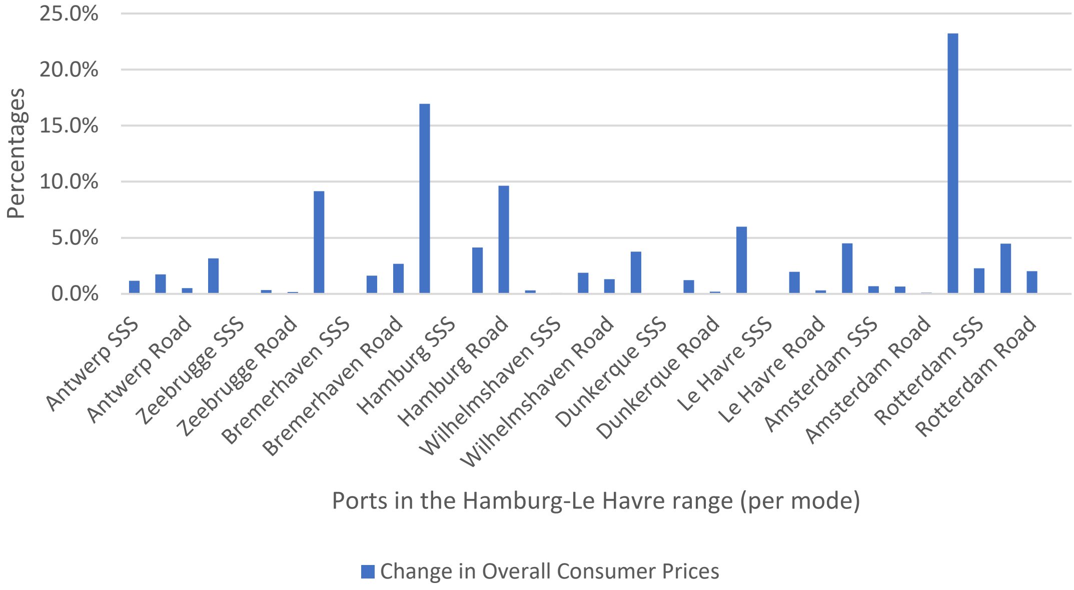

Figure 28. Price changes in percentages per port per mode (high scenario for fast shipping)

5.4. Comparison of the four scenarios

This section presents a comparative analysis of the four scenarios. And as we focused on the individual outcomes of the GSIM model in the previous sections, here we decided to illustrate the major economic and trade impact which are net welfare effect, output changes and trade flow value changes, per port per mode. We must also mention that the changes due to the sulphur regulations are not very significant for the three first scenarios, and are relatively more essential for the high fuel price scenario for fast shipping. Because all the scenarios have an equal chance to occur, we will compare the changes between the average values of the first three scenarios and the values of the fourth scenario.

Table 25 below presents net welfare effects for nine ports per mode per scenario in absolute terms. As it was stated earlier, the total net welfare effects for all ports in all four scenarios is negative. Coming to the net welfare effects per port per mode, it differs depending on the degree of substitutability of the mode for each port. In the short-sea shipping mode, the port of Wilhelmshaven has the only positive (and thus the lowest negative) effect (€8.9 million and €18.6 million for the first three scenarios and the fourth scenario respectively), while the port of Rotterdam has the highest effect (- €66.9 billion and - €146 billion). In the inland waterways mode, the port of Hamburg has the lowest effect (€680.4 million and €1.4 billion), while the port of Rotterdam has the highest effect (- €5.2 billion and - €6.3 billion). In the road transport, the port of Zeebrugge has the lowest effect (€95.6 million and €199 million), while the port of Rotterdam has the highest effect (- €11.6 billion and - €24 billion). In the rail mode, the port of Antwerp has the lowest effect (€82.5 million and €172 million), while the port of Hamburg has the highest one (- €6 billion and - €12.6 billion). As a result, the port of Rotterdam has the highest negative net welfare effect as a result of sulphur regulations in all four scenarios for all modes of transport in absolute terms.

Table 26 shows output changes for nine ports per mode per scenario in percentages. In the short-sea shipping mode, the port of Rotterdam has the highest output change (-8.2% and -16.7% for the first three scenarios and the fourth scenario respectively), while the port of Le Havre has the lowest one (-7% and -14.4%). In the inland waterways mode, Dutch ports have the highest output changes (2.8% and 5.7%), while German ports have the lowest ones (2.1% and 4.3%).

In the road transport, Dutch ports have the highest output changes (2.7% and 5.6%), while German ports have the lowest ones (2.3% and 4.8%). In the rail mode, German ports have the highest output changes (3% and 6.1%), while French ports have the lowest output changes (2.7% and 5.5%). Hence, Dutch ports have the highest output changes, and French and German ports the lowest ones as a result of sulphur regulations in relative terms.

Finally, Table 27 shows trade flow value changes for nine ports per mode per scenario in absolute terms. In the short-sea shipping mode, the port of Rotterdam has the highest trade flow value changes (- €9.8 billion and - €22.9 billion for the first three scenarios and the fourth scenario respectively), while the port of Wilhelmshaven has the lowest net welfare effect (- €108.4 million and - €216.9 million). In the inland waterways mode, the port of Bremerhaven has the lowest net welfare effect (€17.5 million and €36.2 million), while the port of Rotterdam has the highest changes (€4.1 billion and €86 billion).

In the road transport, the port of Zeebrugge has the lowest changes (€370 million and €765.1 million), while the port of Rotterdam has the highest changes (€6 billion and €12.4 billion). In the rail mode, the port of Zeebrugge has the lowest changes (€93.7 million and €194 million), while the port of Hamburg has the highest one (€1.7 billion and €3.5 billion). Thus, as a result of sulphur regulations, the port of Rotterdam has the highest trade flow value changes in all four scenarios for all modes and the port of Zeebrugge – the lowest ones.

It should be noted that the port of Rotterdam has the highest economic and trade impact in all four scenarios for all modes, in comparison with other eight ports. Additionally, the effects of the sulphur regulations on the short-sea shipping mode are quite interesting. The net welfare effects are the highest for the port of Rotterdam and the lowest for the port of Wilhelmshaven. The output changes are the highest for the port of Rotterdam, while the port of Le Havre has the lowest output changes. The trade flow value changes are the highest for the port of Rotterdam, and the lowest for the port of Wilhelmshaven.

Table 25. Net welfare effects comparison between four scenarios

Port	Mode	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Antwerp	sss	(14,709,156,534.12)	(27,878,230,039.09)	(34,744,222,659.16)	(55,028,317,237.17)
	iww	106,739,424.56	200,603,017.22	248,972,293.25	389,848,782.99
	road	(35,002,093.91)	(62,747,362.50)	(76,012,639.99)	(110,942,049.97)
	rail	47,736,105.81	89,313,381.73	110,602,675.10	172,120,197.42
Zeebrugge	sss	(897,668,103.82)	(1,658,548,591.30)	(2,040,899,337.27)	(3,119,348,683.27)
	iww	9,094,955.36	16,957,494.70	20,963,165.84	32,464,643.99
	road	55,313,029.96	103,448,190.50	128,081,093.58	199,208,431.56
	rail	18,856,590.00	35,233,794.82	43,603,613.23	67,731,228.37
Bremerhaven	sss	(4,213,869,710.29)	(7,880,706,245.86)	(9,757,070,152.65)	(15,174,437,419.53)
	iww	4,051,519.47	7,549,869.51	9,330,707.09	14,438,789.44
	road	(85,246,525.00)	(157,634,915.54)	(194,061,909.85)	(297,012,492.86)
	rail	(126,512,776.85)	(234,860,763.67)	(289,706,367.62)	(445,899,576.67)
Hamburg	sss	(13,378,902,018.51)	(25,322,551,967.70)	(31,538,194,061.39)	(49,860,581,095.10)
	iww	394,795,538.23	736,217,093.81	910,201,311.32	1,409,917,176.20
	road	(1,337,964,472.68)	(2,496,203,036.46)	(3,086,828,080.74)	(4,784,671,916.33)
	rail	(3,480,775,922.43)	(6,527,494,653.15)	(8,092,661,265.23)	(12,633,705,537.74)
Wilhelmshaven	sss	5,157,027.17	9,647,657.50	11,946,713.61	18,588,961.82
	iww	84,139,762.45	156,923,944.97	194,020,647.25	300,594,054.37
	road	(273,227,807.03)	(507,883,784.42)	(626,896,649.11)	(966,673,126.66)
	rail	(808,451,628.02)	(1,475,118,399.47)	(1,803,502,684.70)	(2,705,108,515.61)
Dunkerque	sss	(656,662,783.32)	(1,225,493,535.44)	(1,515,693,795.16)	(2,350,423,307.21)
	iww	133,811,407.94	249,522,886.50	308,484,775.30	477,822,781.73
	road	(140,718,177.42)	(260,250,121.92)	(320,413,949.92)	(490,498,327.27)
	rail	(1,417,436,465.18)	(2,579,133,822.04)	(3,148,848,726.89)	(4,703,952,388.42)
Le Havre	sss	(1,562,597,651.79)	(2,926,675,432.96)	(3,626,230,768.78)	(5,651,731,164.81)
	iww	340,921,777.13	635,729,103.24	785,951,044.21	1,217,387,279.55
	road	(258,601,530.12)	(477,632,588.46)	(587,653,062.09)	(897,859,027.62)
	rail	(37,654,600.39)	(69,064,815.94)	(84,667,148.57)	(127,994,540.47)
Amsterdam	sss	(1,405,094,639.36)	(2,623,344,750.96)	(3,245,227,972.50)	(5,035,309,552.75)
	iww	(18,006,898.46)	(32,083,396.39)	(38,738,915.33)	(55,974,451.37)
	road	(81,881,678.01)	(151,328,624.07)	(186,245,621.25)	(284,818,322.82)
	rail	(348,465,758.39)	(636,426,882.17)	(778,454,008.87)	(1,168,947,755.93)
Rotterdam	sss	(37,711,298,415.08)	(72,301,293,450.69)	(90,611,133,183.00)	(145,678,327,670.12)
	iww	(1,777,056,786.20)	(3,305,430,331.93)	(4,081,351,675.21)	(6,299,344,443.42)
	road	(6,700,724,130.94)	(12,509,253,740.77)	(15,473,952,897.90)	(24,006,373,754.21)
	rail	(1,138,921,712.68)	(2,101,309,797.16)	(2,583,790,702.70)	(3,940,199,057.78)

Table 26. Output changes comparison between four scenarios

Port	Mode	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Antwerp	sss	-4.46%	-8.27%	-10.19%	-15.67%
	iww	1.34%	2.48%	3.05%	4.69%
	road	1.37%	2.54%	3.13%	4.81%
	rail	1.58%	2.94%	3.62%	5.57%
Zeebrugge	sss	-4.32%	-8.01%	-9.89%	-15.23%
	iww	1.34%	2.48%	3.05%	4.69%
	road	1.37%	2.54%	3.13%	4.81%
	rail	1.58%	2.94%	3.62%	5.57%
Bremerhaven	sss	-4.31%	-8.01%	-9.88%	-15.21%
	iww	1.22%	2.27%	2.79%	4.29%
	road	1.36%	2.52%	3.11%	4.77%
	rail	1.73%	3.21%	3.96%	6.08%
Hamburg	sss	-4.43%	-8.23%	-10.14%	-15.60%
	iww	1.22%	2.27%	2.79%	4.29%
	road	1.36%	2.52%	3.11%	4.77%
	rail	1.73%	3.21%	3.96%	6.08%
Wilhelmshaven	sss	-4.21%	-7.83%	-9.67%	-14.90%
	iww	1.22%	2.27%	2.79%	4.29%
	road	1.36%	2.52%	3.11%	4.77%
	rail	1.73%	3.21%	3.96%	6.08%
Dunkerque	sss	-4.13%	-7.67%	-9.47%	-14.62%
	iww	1.31%	2.43%	2.99%	4.60%
	road	1.46%	2.70%	3.33%	5.12%
	rail	1.56%	2.90%	3.57%	5.49%
Le Havre	sss	-4.07%	-7.57%	-9.35%	-14.44%
	iww	1.31%	2.43%	2.99%	4.60%
	road	1.46%	2.70%	3.33%	5.12%
	rail	1.56%	2.90%	3.57%	5.49%
Amsterdam	sss	-4.51%	-8.37%	-10.32%	-15.86%
	iww	1.62%	3.00%	3.70%	5.68%
	road	1.59%	2.94%	3.63%	5.57%
	rail	1.67%	3.10%	3.82%	5.87%
Rotterdam	sss	-4.79%	-8.87%	-10.92%	-16.73%
	iww	1.62%	3.00%	3.70%	5.68%
	road	1.59%	2.94%	3.63%	5.57%
	rail	1.67%	3.10%	3.82%	5.87%

Table 27. Trade flow value changes comparison between four scenarios

Port	Mode	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Antwerp	sss	(5,785,076,707.37)	(10,565,588,044.32)	(12,924,455,096.93)	(19,418,167,552.95)
	iww	822,202,257.29	1,531,171,414.96	1,891,735,199.72	2,924,736,011.84
	road	987,205,764.13	1,838,813,294.57	2,272,043,819.22	3,513,684,397.47
	rail	166,194,137.79	309,802,640.72	382,943,242.21	592,869,936.31
Zeebrugge	sss	(871,656,687.63)	(1,594,443,949.91)	(1,951,934,446.50)	(2,938,994,368.87)
	iww	22,969,657.58	42,775,950.55	52,848,930.28	81,707,614.04
	road	214,960,681.94	400,395,311.82	494,729,778.25	765,092,771.59
	rail	54,388,536.06	101,385,718.65	125,321,642.59	194,022,053.59
Bremerhaven	sss	(1,888,409,076.53)	(3,454,397,927.87)	(4,228,972,950.70)	(6,367,778,724.71)
	iww	10,177,931.29	18,945,851.03	23,402,110.96	36,158,639.88
	road	324,273,602.06	603,929,376.66	746,169,399.23	1,153,732,826.77
	rail	270,213,979.36	503,885,946.51	622,958,653.39	964,945,149.30
Hamburg	sss	(3,548,147,532.13)	(6,481,716,318.76)	(7,929,764,183.89)	(11,917,915,729.52)
	iww	45,900,478.66	85,442,081.11	105,538,941.43	163,068,390.88
	road	826,220,619.38	1,538,758,938.36	1,901,174,006.37	2,939,609,776.04
	rail	979,055,935.85	1,825,710,602.00	2,257,142,168.75	3,496,248,707.96
Wilhelmshaven	sss	(64,117,668.95)	(117,414,207.70)	(143,818,709.78)	(216,877,765.33)
	iww	51,020,260.51	94,972,369.88	117,310,852.59	181,257,190.05
	road	375,724,397.39	699,751,690.15	864,560,192.67	1,336,789,576.25
	rail	130,639,798.75	243,612,705.76	301,180,543.30	466,520,053.52
Dunkerque	sss	(870,183,549.78)	(1,595,105,331.40)	(1,954,794,328.84)	(2,951,927,788.25)
	iww	22,388,837.51	41,692,678.44	51,509,560.24	79,632,480.49
	road	536,467,255.58	999,626,913.54	1,235,377,393.21	1,911,517,530.25
	rail	66,837,788.81	124,587,666.14	153,998,364.23	238,406,432.22
Le Havre	sss	(1,313,780,955.08)	(2,409,768,441.25)	(2,954,088,281.65)	(4,464,869,641.53)
	iww	35,790,251.25	66,648,901.99	82,341,930.54	127,298,547.04
	road	857,583,510.52	1,597,979,277.97	1,974,844,262.46	3,055,705,445.13
	rail	106,845,264.02	199,162,813.73	246,178,040.57	381,110,725.67
Amsterdam	sss	(1,605,533,163.24)	(2,930,342,295.31)	(3,583,400,341.57)	(5,378,964,370.43)
	iww	842,954,383.23	1,571,559,230.40	1,942,713,515.57	3,008,254,386.98
	road	592,783,210.12	1,105,038,533.60	1,365,943,702.17	2,114,827,575.23
	rail	49,882,824.07	93,016,394.37	114,994,877.01	178,114,594.39
Rotterdam	sss	(6,909,282,919.58)	(12,571,874,625.40)	(15,350,318,734.10)	(22,945,367,947.49)
	iww	2,408,626,713.16	4,490,515,286.42	5,551,037,829.22	8,595,674,950.64
	road	3,479,375,957.69	6,486,088,742.86	8,017,486,993.14	12,413,104,983.89
	rail	760,067,486.29	1,417,296,201.02	1,752,183,617.00	2,713,942,415.14

5.5. Modal split changes

The new regulations for sulphur emissions in SECA also cause changes in the modal split of the ports. These changes differ from port to port and depend on different factors, including the initial modal split, distances to the examined destinations, and port and mode specific elasticities. Table A6 in the Appendix shows the old modal split, Tables A7 to A10 in the Appendix demonstrate the calculations undertaken to get the new modal splits per ports. And Table A11 in the Appendix reports the old and new modal splits and the differences between the old and new ones, per port. Figure 29 reflects the modal split comparison between all four scenarios.

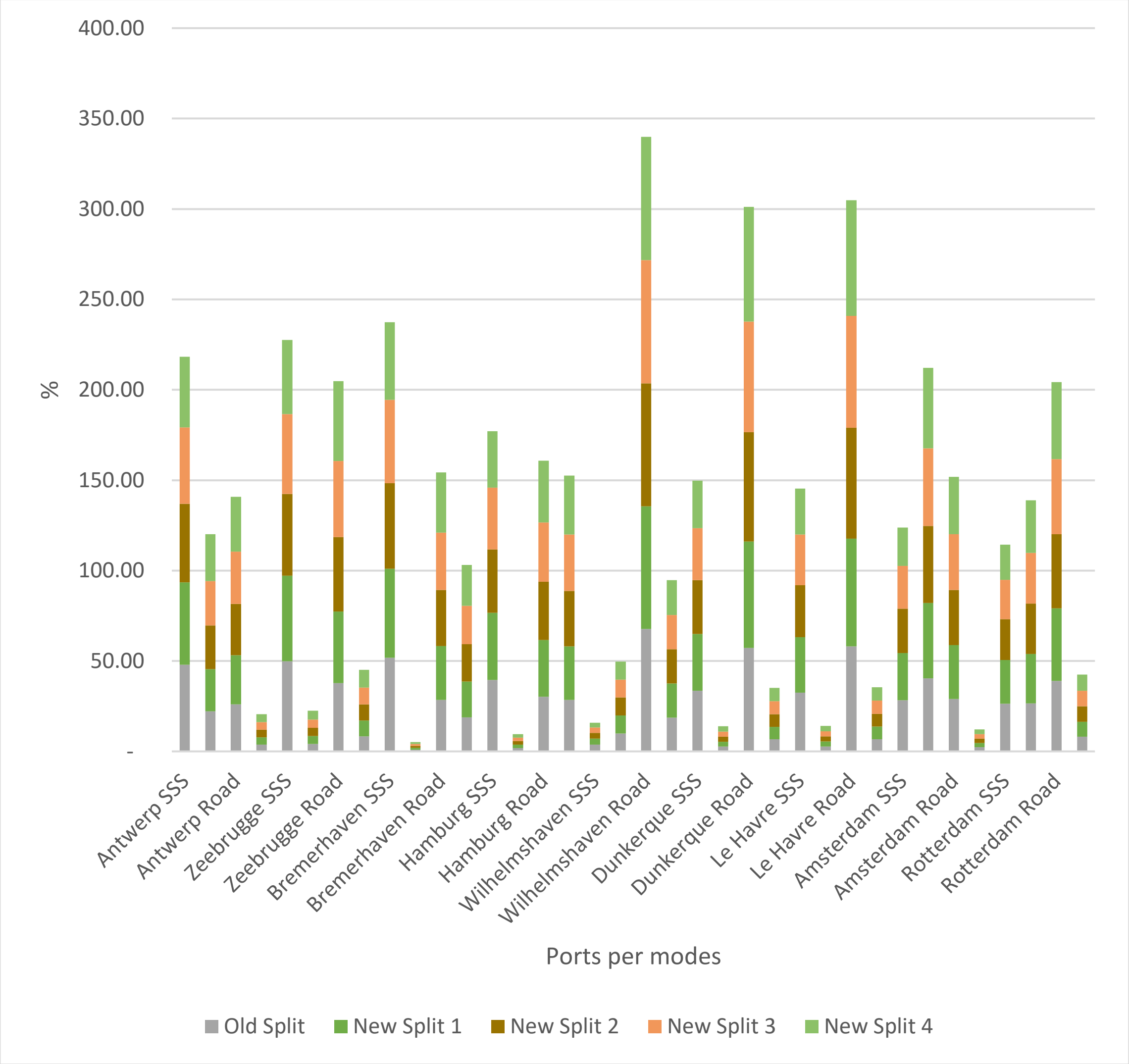

Figure 29. Modal split comparison between four scenarios

Short-sea shipping decreases for all ports in the Hamburg-Le Havre range, throughout all four scenarios, with the highest increase in the high scenario for the fast short-sea shipping. All ports except the port of Wilhelmshaven experience short-sea shipping decrease of 2-2.5% in the low scenario for the traditional shipping, while the ports of Dunkerque, Le Havre, Amsterdam and Rotterdam have around 7% decrease, and the ports of Antwerp, Zeebrugge, Bremerhaven and Hamburg – around 9% decrease. The port of Wilhelmshaven experiences the lowest modal shift ranging from 0.32% decrease in the low scenario for the traditional shipping, and 1.05% decrease in the high scenario for the fast shipping.

At the same time, we can see the increase in the road transport percentages in the low scenario for the traditional shipping ranging from 1% to 2%; and in the high scenario for the fast shipping ranging from 4% to 7%. The port of Wilhelmshaven gets the lowest increases also in terms of the road transport (0.16% in the low scenario for the traditional shipping, and 0.52% in the high scenario for the fast shipping). The port of Amsterdam has the biggest modal shift towards the inland waterways mode of 3.96% in the high scenario for the fast shipping, in comparison with 2.78% increase in the road transport in the same scenario. Rail transport experiences the lowest overall change.

Ultimately, we can observe the modal backshift from the short-sea shipping mode towards the road transport for all the ports in the Hamburg-Le Havre range, which increases with the appropriate increase in the freight tariff barriers caused by the bunker fuel price increase as a result of sulphur regulations. It is important to mention that the modal backshift is the modal shift from sea to land. The reason is that the main goal of the EU is to shift long distance land transport to more environmentally friendly transport, while the modal shift described above works in the opposite direction (European Commission, 2011).

What is important here is that this modal backshift assumes a decrease of the SOx emissions coming from the short-sea shipping mode, and an increase of the CO2 emissions coming from the land-based modes. The following statistics can prove this statement.

While shipping is favourable in terms of CO2 emissions being around 2-3% of total global emissions, the air emissions from shipping are considerable (Merk, 2014). The output of SOx by shipping is in the range of 5-10% of total global emissions, which exceeds the emissions of land transport by a factor of 1.6 to 2.7 (Friedrich, et al., 2007). According to Eyring et al. (2005), international shipping produces approximately 80 times more SOx emissions than aviation due to the high sulphur content in ship fuel (Eyring, et al., 2005).

At the same time, transportation in general is responsible for almost 27% of the total CO2 emissions, and a large proportion of it is attributed to the road transport. International shipping contributes only 2.7% of the total, and aviation contributes 1.9% (Schinas & Hartmann, 2010).

6. Conclusions, Recommendations and Limitations

6.1. *Key findings and implications*

The new phase of the low sulphur fuel regulations means a sulphur limit in the marine fuel of 0.1%, which leads to the shift from HFO to MGO and therefore assumes an increase in fuel prices and freight rates. This thesis compares possible economic and trade impacts of these regulations on the nine ports in the Hamburg-Le Havre range, namely the ports of Antwerp, Zeebrugge, Bremerhaven, Hamburg, Wilhelmshaven, Dunkerque, Le Havre, Amsterdam and Rotterdam (two remaining ports in the range, the ports of Ghent and Zeeland Seaports are not in the scope of this research due to lack of data availability). It is relevant to examine what role the ports play when it comes to sulphur regulations, how these regulations affect the trade flows transported through the ports, overall consumer prices, consumer (cargo owners) and producer (shipping companies) surplus, as well as the net economic welfare.

Therefore, the four scenarios developed are based on the expected changes in freight rates caused by the shift from HFO to MGO. We consider each of them to analyse the research question:

What is the expected economic and trade impact of the low sulphur fuel requirements on the ports in the Hamburg-Le Havre range?

The literature review shows that abatement of the sulphur emissions is crucial for the health of people. That is why compliance with the regulations adopted by the IMO and the EU is very important. However, compliance may cause a modal backshift from shipping to the hinterland modes, especially to the road transport. The deep-sea shipping is expected to be highly influenced in absolute values rather than short-sea shipping. However, in relative terms the opposite picture emerges due to the fact that it is difficult to substitute the deep-sea shipping by any other mode of transport.

An interesting point here is to find out if the compliance with the sulphur regulations in the ports in the Hamburg-Le Havre range changes the trade flows transported through these ports to the 28 EU member states and the rest of the world, causing the modal backshift. The outcome of the assessment should prove a significant or non-significant shift of the trade flows between the short-sea shipping, rail, road and inland waterways modes, as well as an overview of the change in the freight transport patterns across the ports in the Hamburg-Le Havre range. It should be noted that the deep-sea shipping and air modes are not addressed in this thesis.

The (partial equilibrium) GSIM model is used in this thesis to help answer the research question in a quantitative way. This model is broadly used for the impact assessment of changes in trade policy but it can also be used to look at non-tariff measures like new regulations of sulphur guidelines. The original model has the dimensions of 25x25, hence we expand the model to higher dimensions (36 x 29). By doing so we can make data calculations for the nine ports in the Hamburg-Le Havre range, the 28 EU member states and the rest of the world, grouping the data based on the four modes of transport: short-sea shipping, inland waterways, road and rail.

We define four different scenarios:

a. Low fuel price scenario for the traditional short-sea shipping with 10.5% freight tariff increase (the vessels are sailing at 18.5 knots on average),
b. High fuel price scenario for the traditional short-sea shipping with 20% freight tariff increase,
c. Low fuel price scenario for the fast short-sea shipping with 25% freight tariff increase (the vessels are sailing at 25 knots on average),
d. High fuel price scenario for the fast short-sea shipping with 40% freight tariff increase.

The reasons for developing these four scenarios are that the two different types of shipping (traditional and fast) are used depending on the sailing speed of the vessels; and that new low sulphur fuel requirements lead to a shift from HFO to MGO, inducing further freight rate increases. In addition, the price difference between HFO and MGO is not constant and depends on particular circumstances which change with time, but MGO is usually more expensive than HFO.

The analysis of the four different scenarios shows that depending on the level of increase in the freight rate, the economic and trade impact of the sulphur regulations differs from port to port. The absolute changes in the trade flow values per port are negative for all ports except the port of Wilhelmshaven. The ports of Antwerp, Hamburg and Bremerhaven are particularly set to lose quite big chunks of trade in absolute terms (€12 billion, €5 billion, €4 billion respectively in the high fuel price scenario for the fast short-se shipping).

The absolute changes in the trade flow values per port per mode for both scenarios illustrate that the short-sea shipping mode suffers in all four scenarios in comparison with the hinterland modes of transport pointing at the modal backshift, as the cargo transported by road increases substantially. The GSIM model shows some interesting patterns in the modal split change. For some ports the share of the rail and inland waterways modes increases as a result of the new regulations (e.g. for the ports of Amsterdam, Antwerp and Rotterdam). For these ports, the share of the inland waterways transport increases by 4.0%, 3.7% and 2.5% respectively, in the high scenario for the fast short-sea shipping. The ports of Hamburg and Bremerhaven experience an increase in the share of rail transport by 4.2% and 3.7% respectively, in the high scenario for the fast short-sea shipping. Intermodal shifts in the low and high scenarios for the traditional short-sea shipping, however, show only marginal changes, in the range of 1%-2% on average.

The average changes in overall consumer prices for all ports and all modes show an increase of between 1% and 3%, with a maximum of 23% increase for the rail mode in the port of Amsterdam and 17% increase for rail transport in the port of Bremerhaven (both in the high fuel price scenario for the fast short-sea shipping). This is because of the additional freight tariffs caused by the fuel shift. At the same time, the changes in output (trade flows) range between a 2% increase (mostly for road transport) and a 5% decrease for short-sea shipping in the low fuel price scenario for the traditional short-sea shipping. This change is between a 6% increase mostly for road transport and a 17% decrease for short-sea shipping in the high fuel price scenario for the fast short-sea shipping. Especially the latter result is very significant. This has a major impact on the ports of Rotterdam, Hamburg and Antwerp. The size of the effect can be explained by high trade flow shares for these three ports. Hence, the port of Wilhelmshaven benefits relatively most from the sulphur regulations (€1.8 billion in total for all four modes in the high fuel price scenario for fast shipping), and the port of Antwerp benefits relatively least from the sulphur regulations (negative €12.4 billion in total for all four modes in the high fuel price scenario for fast shipping). The main reason is that the cargo transported through the port of Antwerp to the destination countries by short-sea shipping is the highest among the nine ports in combination with the average distances to cover. And for the port of Wilhelmshaven, short-sea shipping is relatively a much less important mode of transport.

Finally, the shipping lines get producer surplus in the port of Le Havre only (amounting to €2.7 billion in the high scenario for fast short-sea shipping). Total producer surplus for the ports in the Hamburg-Le Havre range is a negative amount of €5 billion in the low scenario for the traditional shipping and €15.8 billion in the high scenario for the fast shipping. Consumer surplus is also negative and equals €86 billion for the low scenario in the traditional shipping, and €325.8 billion in the high scenario for the fast shipping (with the price effects of trade through the port of Rotterdam have a €179 billion loss which is biggest among the ports in question). The highest total loss for the nine ports is €63 billion (high scenario with the fast shipping). And the total net welfare effect equals to €100 billion loss (low scenario for the traditional shipping) and €405 billion loss (high scenario for the fast shipping where actors in the port of Rotterdam and consumers that demand cargo going through the Port of Rotterdam face a Euro 185 billion welfare loss). The port of Wilhelmshaven is the only port which benefits from a positive net welfare effect in all four scenarios.

In answering the research question, we conclude that the economic and trade impact of the new legislation on sulphur fuel regulations is relatively low in the low and high fuel price scenarios for the traditional short-sea shipping and in the low fuel price scenario for the fast short-sea shipping. However, the regulation becomes quite important in the high fuel price scenario for the fast short-sea shipping. Thus, the port of Rotterdam experiences the highest economic and trade impact in all four scenarios for all modes, in comparison with the other eight ports. Additionally, the effects of the sulphur regulations on the short-sea shipping mode are quite interesting. The net welfare effects are the highest for the port of Rotterdam (- €66.9 billion and - €146 billion for the first three scenarios and the fourth scenario respectively), and the lowest for the port of Wilhelmshaven (€8.9 million and €18.6 million). The output changes are the highest for the port of Rotterdam (-8.12% and -16.7%), while the port of Le Havre has the lowest output changes (-7% and -14.4%). The trade flow value changes are the highest for the port of Rotterdam (- €9.8 billion and - €22.9 billion), and the lowest for the port of Wilhelmshaven (- €108.4 million and - €216.9 million).

Moreover, the modal backshift is observed in all four scenarios. It is marginal in the low and high fuel scenarios for the traditional short-sea shipping and the in the low fuel price scenario for the fast short-sea shipping. It is, however, substantial in the high fuel price scenario for the fast short-sea shipping. In terms of the intermodal split shares, short-sea shipping would be reduced by 7.1% on average, with the highest decreases for the ports of Bremerhaven (8.8%) and Antwerp (8.8%). At the same time, the road transport would benefit 4.3% on average (Zeebrugge having 6.5% and Dunkerque 6.2% as the highest increase), while the inland waterways and rail transport would benefit only marginally (1.3% and 1.5% respectively).

Although the results of the GSIM model indicate significant percentage changes for specific scenarios, the absolute values of changes of the trade flows and modal shift are relatively small. However, in the high scenario for the fast short-sea shipping these results are significant. This can be explained by quite high additional freight tariffs due to the price difference caused by the fuel shift. And in all four scenarios the absolute values of trade flow and modal split changes are related to the degree of substitutability of the modes that are also different for each port.

All in all, our findings imply that the sulphur regulations, aiming to abate air emissions and by doing so improving the health of people, may in some circumstances lead to the opposite effect because of the modal backshift effect. The reason is that the main goal of the EU is to shift long distance land transport to more environmentally friendly modes of transport, while the modal shift described above works in the opposite direction. As a result, this modal backshift may indeed lead to the intended decrease of SOx emissions coming from the short-sea shipping mode, while not having a strong increase in SOx emissions for the other modes. However, the modal backshift to – for example – road transport, will surely lead to an increase of CO2 emissions coming from the land-based modes that is higher than the decrease in CO2 emissions from short-sea shipping. That is, the sulphur regulations are expected to lead to a shift to the more CO2 emitting modes of transport.

The main transport barrier in this case is the shipping freight rate, and in order to overcome these contradictory consequences, special road environmental taxes can be erected or subsidies provided for the inland waterways and rail modes that have shifted to low sulphur fuel. It is also recommended to pay more attention to the inland waterways mode and to improve its infrastructure and increase promotion, as the analysis of the freight costs show that for the two categories of distances (between 500 and 1000 km, and more than 1000 km) the inland waterways is more competitive than the road transport. On the other hand, ports should strengthen their position in terms of the incentives provided to the shipping companies and cargo owners. A strong and smart port policy in terms of port prices, incentives and specialised port facilities may decrease the effect of the sulphur regulations and compensate the volume losses for the most vulnerable market actors.

6.2. Limitations and further research suggestions

We make many assumptions while working with the data for the GSIM model matrices. These assumptions are primarily based on the outcomes of the literature review including different studies and research papers. We believe that if more specific research could be done into trade flows transported through the ports, freight cost components incorporated into the initial and final trade barriers, and composite demand elasticity calculations, it would lead to further evidence and detailed analysis of the issue at hand. The author admits that this research – as is always the case – rests on assumptions made during the whole procedure. Further research could therefore be carried out to corroborate or refute our research conclusions. Nevertheless, there is enough confidence that the available data is used cautiously and the conclusions drawn in an indicative representation of the economic and trade impact of the low sulphur fuel requirements on the ports in the Hamburg-Le Havre range.

A limitation of our research is that our analysis does not take into account some other factors that are also important as cost elements, besides the freight costs, such as specific port prices, incentives, specialised port facilities (infrastructure) and other port related indicators, relevant to the cargo owners and shipping companies. Also, we did not base ourselves on a market demand forecast for the destination points. Though we were able to ignore these parameters because of the use of the GSIM model, further research would be useful to see if evidence would corroborate the GSIM findings.

The deep-sea shipping and air transport modes are not considered in this research. This is not a significant limitation given the focus of our research. However, more precise outcomes could be gained if these two modes were also incorporated into the model inputs. For this research, that has not been attempted due to lack of data. Hence, it is an interesting area for future research. The GSIM model does not delve into the cross-split of the trade flow values which leads to the fact that the reached outcomes describe only the trade flows transported from the ports to the destination states. Thus, this can be another interesting area for further research.

As we shift to more CO2 emitting modes of transport, we talk about the modal backshift assuming a decrease of the SOx emissions coming from the short-sea shipping mode, and an increase of the CO2 emissions coming from the land-based modes. This issue was not studied separately, as it is outside the scope of our research. Nevertheless, calculating the effect of the sulphur guidelines for total and mode based SOx emissions and total and mode based CO2 emissions can also be an interesting area of further research, as this could potentially lead to interesting and important policy conclusions.

Finally, some specific trade barriers investigated on the country basis, specific sulphur emissions or port incentives could be explored in more detail. Nonetheless, this thesis focused only on the freight costs part of the trade barriers on purpose.

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Appendix

Table A1. ROW countries and related distances (in km)

Port	Mode	Norway	Russia	Turkey	Ukraine	Average distance
Antwerp	sss	1468.636	3055.8	2533.536	7533.936	3647.977
	iww	1354	2503	2670	2037	2141
	road	1354	2503	2670	2037	2141
	rail	1354	2503	2670	2037	2141
Zeebrugge	sss	1414.928	3002.092	6900.552	7641.352	4739.731
	iww	1451	2600	2787	2133	2242.75
	road	1451	2600	2787	2133	2242.75
	rail	1451	2600	2787	2133	2242.75
Bremerhaven	sss	901.924	2489.088	7415.408	8156.208	4740.657
	iww	982	2230	2514	1762	1872
	road	982	2230	2514	1762	1872
	rail	982	2230	2514	1762	1872
Hamburg	sss	963.04	2550.204	7476.524	8217.324	4801.773
	iww	813	2095	2483	1628	1754.75
	road	813	2095	2483	1628	1754.75
	rail	813	2095	2483	1628	1754.75
Wilhelmshaven	sss	857.476	2444.64	7328.364	8069.164	4674.911
	iww	1021	2268	2553	1802	1911
	road	1021	2268	2553	1802	1911
	rail	1021	2268	2553	1802	1911
Dunkerque	sss	1511.232	3098.396	6643.124	7383.924	4659.169
	iww	1516	2665	2831	2665	2419.25
	road	1516	2665	2831	2665	2419.25
	rail	1516	2665	2831	2665	2419.25
Le Havre	sss	1811.256	3398.42	6491.26	7232.06	4733.249
	iww	1800	2927	2940	2460	2531.75
	road	1800	2927	2940	2460	2531.75
	rail	1800	2927	2940	2460	2531.75
Amsterdam	sss	1129.72	2716.884	7028.34	7769.14	4661.021
	iww	1267	2435	2715	1968	2096.25
	road	1267	2435	2715	1968	2096.25
	rail	1267	2435	2715	1968	2096.25
Rotterdam	sss	1311.216	2900.232	6963.52	7704.32	4719.822
	iww	1300	2469	2728	2002	2124.75
	road	1300	2469	2728	2002	2124.75
	rail	1300	2469	2728	2002	2124.75

Source: Google Maps (2016); Ports.com (2016)

Table A2. Transport costs distribution per distance category

Transport costs for several European routes per mode up to 500 km								
Mode	Routes							Average
	1	2	3	4	5	6	7	
sss	475	475						475.00
iww	330	410	330	300	370	280	290	330.00
road	275	300	470	310	170	240	350	302.14
rail	430	560	800	580	810	440	450	581.43

Transport costs for several European routes per mode, 500-1000 km								
Mode	Routes							Average
	1	2	3	4	5	6		
sss	650	600	600	775				656.25
iww	300	460	420	480	490	470		436.67
road	560	590	880	560	890	510		665.00
rail	580	980	650	1150	710	755		804.17

Transport costs for several European routes per mode for 1000+ km								
Mode	Routes							Average
	1	2	3	4	5	6		
sss	2600	1875						2,237.50
iww	450	750	800	560	930	730		703.33
road	1450	1660	1290	1750	1600	2370		1,686.67
rail	1390	1250	1450	1220	2075	1610		1,499.17

Source: own compilation based on Meyer-Rühle, et al. (2008)

Table A3. SSS corrected for high scenario for traditional short-sea shipping

sss	Transport costs up to 500 km	Transport costs 500-1000 km	Transport costs 1000+ km
Transport costs	570.00	787.50	2,685.00
Freight tariff coefficients	1.887	1.803	3.818

Source: own compilation

Table A4. SSS corrected for low scenario for fast short-sea shipping

sss	Transport costs up to 500 km	Transport costs 500-1000 km	Transport costs 1000+ km
Transport costs	593.75	820.31	2,796.88
Freight tariff coefficients	1.965	1.879	3.977

Source: own compilation

Table A5. SSS corrected for high scenario for fast short-sea shipping

Sss	Transport costs up to 500 km	Transport costs 500-1000 km	Transport costs 1000+ km
Transport costs	665.00	918.75	3,132.50
Freight tariff coefficients	2.201	2.104	4.454

Source: own compilation

Table A6. Old modal split per port

	Total per mode (EUR)	Total	Old Split (%)
Antwerp SSS	79,311,357,737.17	165,343,396,310.52	47.97
Antwerp IWW	36,742,849,807.37		22.22
Antwerp Road	43,016,019,286.67		26.02
Antwerp Rail	6,273,169,479.31		3.79
Zeebrugge SSS	12,331,631,838.05	24,777,650,305.22	49.77
Zeebrugge IWW	1,026,475,749.87		4.14
Zeebrugge Road	9,366,591,217.56		37.80
Zeebrugge Rail	2,052,951,499.74		8.29
Bremerhaven SSS	26,743,490,035.37	51,664,743,831.02	51.76
Bremerhaven IWW	498,425,075.91		0.96
Bremerhaven Road	14,703,539,739.43		28.46
Bremerhaven Rail	9,719,288,980.30		18.81
Hamburg SSS	48,884,229,655.68	123,810,881,923.06	39.48
Hamburg IWW	2,247,799,568.02		1.82
Hamburg Road	37,463,326,133.69		30.26
Hamburg Rail	35,215,526,565.67		28.44
Wilhelmshaven SSS	928,413,450.06	25,162,372,821.22	3.69
Wilhelmshaven IWW	2,498,521,211.17		9.93
Wilhelmshaven Road	17,036,473,437.93		67.71
Wilhelmshaven Rail	4,698,964,722.07		18.67
Dunkerque SSS	12,868,916,715.84	38,390,552,734.96	33.52
Dunkerque IWW	1,020,865,440.76		2.66
Dunkerque Road	21,948,606,976.44		57.17
Dunkerque Rail	2,552,163,601.91		6.65
Le Havre SSS	19,690,639,368.69	60,488,906,147.89	32.55
Le Havre IWW	1,631,930,671.17		2.70
Le Havre Road	35,086,509,430.12		58.00
Le Havre Rail	4,079,826,677.92		6.74
Amsterdam SSS	21,729,618,500.23	76,908,118,170.67	28.25
Amsterdam IWW	31,104,120,264.23		40.44
Amsterdam Road	22,292,113,866.86		28.99
Amsterdam Rail	1,782,265,539.36		2.32
Rotterdam SSS	88,182,627,341.95	335,059,749,996.13	26.32
Rotterdam IWW	88,875,764,155.50		26.53
Rotterdam Road	130,844,875,006.71		39.05
Rotterdam Rail	27,156,483,491.96		8.10

Source: own compilation

Table A7. New modal split per port (low scenario for the traditional short-sea shipping)

	Total per mode (EUR)	Total	New Split 1 (%)
Antwerp SSS	73,526,281,029.80	161,533,921,762.35	45.52
Antwerp IWW	37,565,052,064.65		23.26
Antwerp Road	44,003,225,050.80		27.24
Antwerp Rail	6,439,363,617.09		3.99
Zeebrugge SSS	11,459,975,150.42	24,198,312,493.17	47.36
Zeebrugge IWW	1,049,445,407.45		4.34
Zeebrugge Road	9,581,551,899.50		39.60
Zeebrugge Rail	2,107,340,035.80		8.71
Bremerhaven SSS	24,855,080,958.84	50,381,000,267.20	49.33
Bremerhaven IWW	508,603,007.20		1.01
Bremerhaven Road	15,027,813,341.50		29.83
Bremerhaven Rail	9,989,502,959.66		19.83
Hamburg SSS	45,336,082,123.55	122,113,911,424.82	37.13
Hamburg IWW	2,293,700,046.68		1.88
Hamburg Road	38,289,546,753.07		31.36
Hamburg Rail	36,194,582,501.52		29.64
Wilhelmshaven SSS	864,295,781.11	25,655,639,608.92	3.37
Wilhelmshaven IWW	2,549,541,471.67		9.94
Wilhelmshaven Road	17,412,197,835.32		67.87
Wilhelmshaven Rail	4,829,604,520.82		18.82
Dunkerque SSS	11,998,733,166.07	38,146,063,067.08	31.45
Dunkerque IWW	1,043,254,278.27		2.73
Dunkerque Road	22,485,074,232.02		58.94
Dunkerque Rail	2,619,001,390.72		6.87
Le Havre SSS	18,376,858,413.61	60,175,344,218.60	30.54
Le Havre IWW	1,667,720,922.42		2.77
Le Havre Road	35,944,092,940.63		59.73
Le Havre Rail	4,186,671,941.94		6.96
Amsterdam SSS	20,124,085,336.99	76,788,205,424.85	26.21
Amsterdam IWW	31,947,074,647.46		41.60
Amsterdam Road	22,884,897,076.98		29.80
Amsterdam Rail	1,832,148,363.43		2.39
Rotterdam SSS	81,273,344,422.38	334,798,537,233.69	24.28
Rotterdam IWW	91,284,390,868.66		27.27
Rotterdam Road	134,324,250,964.40		40.12
Rotterdam Rail	27,916,550,978.25		8.34

Source: own compilation

Table A8. New modal split per port (high scenario for the traditional short-sea shipping)

	Total per mode (EUR)	Total	New Split 2 (%)
Antwerp SSS	68,745,769,692.86	158,457,595,616.46	43.38
Antwerp IWW	38,274,021,222.33		24.15
Antwerp Road	44,854,832,581.25		28.31
Antwerp Rail	6,582,972,120.02		4.15
Zeebrugge SSS	10,737,187,888.14	23,727,763,336.33	45.25
Zeebrugge IWW	1,069,251,700.42		4.51
Zeebrugge Road	9,766,986,529.38		41.16
Zeebrugge Rail	2,154,337,218.39		9.08
Bremerhaven SSS	23,289,092,107.50	49,337,107,077.35	47.20
Bremerhaven IWW	517,370,926.94		1.05
Bremerhaven Road	15,307,469,116.10		31.03
Bremerhaven Rail	10,223,174,926.81		20.72
Hamburg SSS	42,402,513,336.92	120,779,077,225.77	35.11
Hamburg IWW	2,333,241,649.13		1.93
Hamburg Road	39,002,085,072.05		32.29
Hamburg Rail	37,041,237,167.67		30.67
Wilhelmshaven SSS	810,999,242.36	26,083,295,379.31	3.11
Wilhelmshaven IWW	2,593,493,581.04		9.94
Wilhelmshaven Road	17,736,225,128.08		68.00
Wilhelmshaven Rail	4,942,577,427.83		18.95
Dunkerque SSS	11,273,811,384.44	37,961,354,661.68	29.70
Dunkerque IWW	1,062,558,119.20		2.80
Dunkerque Road	22,948,233,889.99		60.45
Dunkerque Rail	2,676,751,268.05		7.05
Le Havre SSS	17,280,870,927.44	59,942,928,700.33	28.83
Le Havre IWW	1,698,579,573.16		2.83
Le Havre Road	36,684,488,708.09		61.20
Le Havre Rail	4,278,989,491.65		7.14
Amsterdam SSS	18,799,276,204.92	76,747,390,033.72	24.50
Amsterdam IWW	32,675,679,494.63		42.58
Amsterdam Road	23,397,152,400.46		30.49
Amsterdam Rail	1,875,281,933.72		2.44
Rotterdam SSS	75,610,752,716.55	334,881,775,601.04	22.58
Rotterdam IWW	93,366,279,441.93		27.88
Rotterdam Road	137,330,963,749.57		41.01
Rotterdam Rail	28,573,779,692.98		8.53

Source: own compilation

Table A9. New modal split per port (low scenario for the fast short-sea shipping)

	Total per mode (EUR)	Total	New Split 3 (%)
Antwerp SSS	66,386,902,640.24	156,965,663,474.73	42.29
Antwerp IWW	38,634,585,007.08		24.61
Antwerp Road	45,288,063,105.89		28.85
Antwerp Rail	6,656,112,721.52		4.24
Zeebrugge SSS	10,379,697,391.56	23,498,616,209.84	44.17
Zeebrugge IWW	1,079,324,680.15		4.59
Zeebrugge Road	9,861,320,995.81		41.97
Zeebrugge Rail	2,178,273,142.33		9.27
Bremerhaven SSS	22,514,517,084.67	48,828,301,043.90	46.11
Bremerhaven IWW	521,827,186.87		1.07
Bremerhaven Road	15,449,709,138.66		31.64
Bremerhaven Rail	10,342,247,633.69		21.18
Hamburg SSS	40,954,465,471.79	120,144,972,855.72	34.09
Hamburg IWW	2,353,338,509.46		1.96
Hamburg Road	39,364,500,140.05		32.76
Hamburg Rail	37,472,668,734.42		31.19
Wilhelmshaven SSS	784,594,740.28	26,301,605,700.00	2.98
Wilhelmshaven IWW	2,615,832,063.76		9.95
Wilhelmshaven Road	17,901,033,630.60		68.06
Wilhelmshaven Rail	5,000,145,265.37		19.01
Dunkerque SSS	10,914,122,387.00	37,876,643,723.80	28.81
Dunkerque IWW	1,072,375,001.01		2.83
Dunkerque Road	23,183,984,369.65		61.21
Dunkerque Rail	2,706,161,966.14		7.14
Le Havre SSS	16,736,551,087.04	59,838,182,099.82	27.97
Le Havre IWW	1,714,272,601.71		2.86
Le Havre Road	37,061,353,692.58		61.94
Le Havre Rail	4,326,004,718.49		7.23
Amsterdam SSS	18,146,218,158.66	76,748,369,923.86	23.64
Amsterdam IWW	33,046,833,779.79		43.06
Amsterdam Road	23,658,057,569.03		30.83
Amsterdam Rail	1,897,260,416.37		2.47
Rotterdam SSS	72,832,308,607.85	335,030,139,701.38	21.74
Rotterdam IWW	94,426,801,984.72		28.18
Rotterdam Road	138,862,361,999.85		41.45
Rotterdam Rail	28,908,667,108.96		8.63

Source: own compilation

Table A10. New modal split per port (high scenario for the fast short-sea shipping)

	Total per mode (EUR)	Total	New Split 4 (%)
Antwerp SSS	59,893,190,184.23	152,956,519,103.19	39.16
Antwerp IWW	39,667,585,819.20		25.93
Antwerp Road	46,529,703,684.14		30.42
Antwerp Rail	6,866,039,415.62		4.49
Zeebrugge SSS	9,392,637,469.19	22,879,478,375.57	41.05
Zeebrugge IWW	1,108,183,363.91		4.84
Zeebrugge Road	10,131,683,989.14		44.28
Zeebrugge Rail	2,246,973,553.33		9.82
Bremerhaven SSS	20,375,711,310.66	47,451,801,722.26	42.94
Bremerhaven IWW	534,583,715.79		1.13
Bremerhaven Road	15,857,272,566.20		33.42
Bremerhaven Rail	10,684,234,129.61		22.52
Hamburg SSS	36,966,313,926.16	118,491,893,068.42	31.20
Hamburg IWW	2,410,867,958.91		2.03
Hamburg Road	40,402,935,909.73		34.10
Hamburg Rail	38,711,775,273.63		32.67
Wilhelmshaven SSS	711,535,684.73	26,930,061,875.72	2.64
Wilhelmshaven IWW	2,679,778,401.22		9.95
Wilhelmshaven Road	18,373,263,014.18		68.23
Wilhelmshaven Rail	5,165,484,775.59		19.18
Dunkerque SSS	9,916,988,927.59	37,668,181,389.67	26.33
Dunkerque IWW	1,100,497,921.25		2.92
Dunkerque Road	23,860,124,506.70		63.34
Dunkerque Rail	2,790,570,034.13		7.41
Le Havre SSS	15,225,769,727.15	59,588,151,224.20	25.55
Le Havre IWW	1,759,229,218.21		2.95
Le Havre Road	38,142,214,875.25		64.01
Le Havre Rail	4,460,937,403.59		7.49
Amsterdam SSS	16,350,654,129.79	76,830,350,356.84	21.28
Amsterdam IWW	34,112,374,651.21		44.40
Amsterdam Road	24,406,941,442.09		31.77
Amsterdam Rail	1,960,380,133.75		2.55
Rotterdam SSS	65,237,259,394.46	335,837,104,398.30	19.43
Rotterdam IWW	97,471,439,106.14		29.02
Rotterdam Road	143,257,979,990.60		42.66
Rotterdam Rail	29,870,425,907.10		8.89

Source: own compilation

Table A11. Modal split changes and differences

	Old Split	New Split 1	Dif 1	New Split 2	Dif 2	New Split 3	Dif3	New Split 4	Dif 4
Antwerp SSS	47.97	45.52	(2.45)	43.38	(4.58)	42.29	(5.67)	39.16	(8.81)
Antwerp IWW	22.22	23.26	1.03	24.15	1.93	24.61	2.39	25.93	3.71
Antwerp Road	26.02	27.24	1.22	28.31	2.29	28.85	2.84	30.42	4.40
Antwerp Rail	3.79	3.99	0.19	4.15	0.36	4.24	0.45	4.49	0.69
Zeebrugge SSS	49.77	47.36	(2.41)	45.25	(4.52)	44.17	(5.60)	41.05	(8.72)
Zeebrugge IWW	4.14	4.34	0.19	4.51	0.36	4.59	0.45	4.84	0.70
Zeebrugge Road	37.80	39.60	1.79	41.16	3.36	41.97	4.16	44.28	6.48
Zeebrugge Rail	8.29	8.71	0.42	9.08	0.79	9.27	0.98	9.82	1.54
Bremerhaven SSS	51.76	49.33	(2.43)	47.20	(4.56)	46.11	(5.65)	42.94	(8.82)
Bremerhaven IWW	0.96	1.01	0.04	1.05	0.08	1.07	0.10	1.13	0.16
Bremerhaven Road	28.46	29.83	1.37	31.03	2.57	31.64	3.18	33.42	4.96
Bremerhaven Rail	18.81	19.83	1.02	20.72	1.91	21.18	2.37	22.52	3.70
Hamburg SSS	39.48	37.13	(2.36)	35.11	(4.38)	34.09	(5.40)	31.20	(8.29)
Hamburg IWW	1.82	1.88	0.06	1.93	0.12	1.96	0.14	2.03	0.22
Hamburg Road	30.26	31.36	1.10	32.29	2.03	32.76	2.51	34.10	3.84
Hamburg Rail	28.44	29.64	1.20	30.67	2.23	31.19	2.75	32.67	4.23
Wilhelmshaven SSS	3.69	3.37	(0.32)	3.11	(0.58)	2.98	(0.71)	2.64	(1.05)
Wilhelmshaven IWW	9.93	9.94	0.01	9.94	0.01	9.95	0.02	9.95	0.02
Wilhelmshaven Road	67.71	67.87	0.16	68.00	0.29	68.06	0.35	68.23	0.52
Wilhelmshaven Rail	18.67	18.82	0.15	18.95	0.27	19.01	0.34	19.18	0.51
Dunkerque SSS	33.52	31.45	(2.07)	29.70	(3.82)	28.81	(4.71)	26.33	(7.19)
Dunkerque IWW	2.66	2.73	0.08	2.80	0.14	2.83	0.17	2.92	0.26
Dunkerque Road	57.17	58.94	1.77	60.45	3.28	61.21	4.04	63.34	6.17
Dunkerque Rail	6.65	6.87	0.22	7.05	0.40	7.14	0.50	7.41	0.76
Le Havre SSS	32.55	30.54	(2.01)	28.83	(3.72)	27.97	(4.58)	25.55	(7.00)
Le Havre IWW	2.70	2.77	0.07	2.83	0.14	2.86	0.17	2.95	0.25
Le Havre Road	58.00	59.73	1.73	61.20	3.19	61.94	3.93	64.01	6.00
Le Havre Rail	6.74	6.96	0.21	7.14	0.39	7.23	0.48	7.49	0.74
Amsterdam SSS	28.25	26.21	(2.05)	24.50	(3.76)	23.64	(4.61)	21.28	(6.97)
Amsterdam IWW	40.44	41.60	1.16	42.58	2.13	43.06	2.62	44.40	3.96

Amsterdam Road	28.99	29.80	0.82	30.49	1.50	30.83	1.84	31.77	2.78
Amsterdam Rail	2.32	2.39	0.07	2.44	0.13	2.47	0.15	2.55	0.23
Rotterdam SSS	26.32	24.28	(2.04)	22.58	(3.74)	21.74	(4.58)	19.43	(6.89)
Rotterdam IWW	26.53	27.27	0.74	27.88	1.36	28.18	1.66	29.02	2.50
Rotterdam Road	39.05	40.12	1.07	41.01	1.96	41.45	2.40	42.66	3.61
Rotterdam Rail	8.10	8.34	0.23	8.53	0.43	8.63	0.52	8.89	0.79

Source: own compilation