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Economic Impact Analysis on maize based products in the North Sea Seca after the implementation of Marpol Annex VI regulation in 2015

by

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Abstract

This paper deals with the impact on freight rates for the market of maize because of the implementation of the revised regulation of MARPOL Annex VI in 2015, which sets a maximum of 0.1% of sulphur limitation, primarily in the North Sea SECA region. Prompted from the existing bibliography the three most possible to be implemented scenarios were investigated in order to compare and contrast the cost differences between these alternatives. By combining all the viable methodological approaches, the GSIM model was actually used in order to quantify the costs of alternatives for compliance with the new requirements. The inputs for the model are the world imports and exports, the additional costs of each alternative incorporated in the freight rates and the elasticities of supply, demand and substitution. The output of the model consists of tables and figures illustrating changes in exports as well as the consumer and producer surpluses for specified regions, namely the North Sea European SECA , the remainder European countries, Middle East/Africa, North America, Central/South America, Asia/Oceania and Rest of the World (ROW). The main findings of the paper include in a decrease in output in most of the investigated regions and a significant negative consumer and producer surplus for the North Sea SECA area, while they tangibly demonstrate the most costly efficient solution, in terms of instant implementation, by the ship-owners in order to cope with this issue. Nevertheless, the final decision on which solution is the most appropriate and economically advantageous in the long-run is yielding upon the discretion and the strategic plan of each operator.

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List of Abbreviations

ABS: American Bureau of Shipping

AEA: British Consulting Company

AMEC: Global Consultancy and Project Management Company

CGE: Computable General Equilibrium Model

DG-ENV: Directorate General for the Environment

DMA: Danish Maritime Authority

DNV: Det Norkse Veritas

EMEC: European Marine Equipment Council

EMSA: European Maritime Safety Agency

ENTEC: British Engine Corporation

FIBC: Flexible Intermediate Bulk Container

GL: Germanischer Lloyd

GSIM: Global Simulation Model

HFO: Heavy Fuel Oil

I/O: Input-Output Table

IBC: Intermediate Bulk Container

IMO: International Maritime Organization

IOE: Input-Output Econometric Model

ISL: German Institute of Shipping Economics and Logistics

LNG: Liquefied Natural Gas

LSF: Low Sulphur Fuel

MARPOL: Maritime Pollution Convention

MEPC: Marine Environment Protection Committee

MEPC: Marine Environment Protection Committee

MGO: Marine Gas Oil

NOx: Nitrogen Oxide

PM: Particulate Matter

Ro-Ro: Roll on/off Vessel

SCMF: Sulphur Content Marine Fuel Directive

SECA: Sulphur Emission Control Area

SGC: Svenskst Gastekniskt Center

SKEMA: French Business School

SOx: Sulphur Oxide

SWECO: Swedish Consulting Company

UN COMTRADE: United Nations Trade and Statistics Database

UNCTAD: United Nations Conference on Trade and Development

WITS: World Integrated Trade Solutions

1 INTRODUCTION

Over 90% of global trade is transported by approximately 50,000 marine vessels, meaning that the shipping industry makes a significant contribution to the climate change problem. In particular, ships are responsible for more than 3% of the world's carbon dioxide emissions (Keith and Noble, 2008). In order to tackle this problem, the International Maritime Organization (IMO)'s Marine Environment Protection Committee (MEPC) revised MARPOL Annex VI regulations on the 10th of October 2008. The primary revisions of Annex VI were the reduction of SOx (sulphur oxide), NOx (nitrogen oxide) and PM (particulate matter) emissions throughout the world and particularly in the Sulphur Emission Control Areas (SECAs) (University of Turku, 2009). The SECAs consist of the North Sea, the Baltic Sea, the English Channel, both the east and west coasts of the United States, and the Caribbean Sea, where from the 1st of July of 2010 the sulphur level allowed is 1% and from 1st January 2015, the sulphur limit will be reduced to 0.1% (IMO, 2014). Furthermore, since 1st January 2012, the global sulphur limit of ship fuel was reduced from 4.5% to 3.5% and is planned to become even lower and reach 0.5% on 1st January 2020 (IMO, 2014).

By setting a 0.1% sulphur limit effective from 2015, the MARPOL Annex VI Regulation is going to have considerable impacts on the shipping sector, mainly on the routes passing through the SECAs. Several relevant literature sources have identified alternative options for shipping companies to comply with the new requirements of the amendments to the MARPOL Annex VI regulation (AMEC, 2013). According to the University of Turku (2009), the increase in fuel costs because of the new regulation will be completely integrated in freight rates, causing them to increase substantially. In essence, the sector has to cope with a trade-off between reducing the environmentally harmful particulates emitted by vessels and the consequent imposed large costs that ship-owners have to be burdened with, at least at a primary stage, in order to comply with the specific regulations. The decisions as to how they will address this issue are left to each private company by means of strategic management. Unfortunately, there are not enough studies justifying or conducting meticulous analysis on economic consequences after implementing the specific regulation.

Either way the costs that will be imposed to the shipping companies should not exceed the corresponding benefits. The objective of this thesis is to provide a quantitative analysis of the effects on costs for ship owners, arising from the alternative choices of compliance, as well as the impact on international trade assuming the costs are passed on to the market. Three cost scenarios for each alternative were evaluated: switching from Heavy Fuel Oil (HFO) to Marine Gas Oil (MGO), use of scrubber technology and use of Liquefied Natural Gas (LNG). Besides the aforementioned alternatives, the option of methanol as an alternative fuel will also be described, but because of its premature testing phase it cannot be considered as a viable solution, and thus it remains outside of the scope of this study. For the cost analyses, the Global SIMulation (GSIM) model was used for estimating the costs in the container sector and in particular for maize products. The global maize market was selected for this analysis specifically due to its intertwined linkage to the container shipping sector, as its transportation on a global scale is being carried out through the specific vessel category.

Therefore, the main topic of attentiveness and consequently the main research question is;

What is the impact on the maize market due to the increased costs associated with the vessels operating in the North Sea SECA region and having to comply with the MARPOL Annex VI sulphur limitation regulation in 2015?

Three complementary sub-questions are also encompassing the preceding one. Pointedly;

1. Which are the alternatives for the ship companies in order to comply with the specific amendment?

2. How do costs of these alternatives affect the container sector for the market of maize and to what extent this extra costs are transferred to both sides (ship-owners-consumers)?

3. What is the general trade picture of the specific commodity globally after the implementation of the specific regulation?

The main research questions and the three sub-research questions will be answered quantitatively, with a qualitative illation regarding the results of the analysis that will be given at the last part of the thesis.

Through investigating these topics, specific issues are approached, such as the viable choices that ship owners have at their disposal in order to comply with the regulation, how the costs of different alternatives affect the container sector for the market of maize products in terms of net welfare performance, consumer and producer surpluses and what the general picture of global trade of the specific commodity is after the implementation of the regulation in 2015.

The structure of this thesis consists firstly of an extensive literature review, which provides a spherical picture of cost estimates for the three compliance alternatives conducted by various authors, while extensive discussions have been made regarding the viability of each of them. The extracted results of this chapter will be used as our principal levers that, in their turn, will be later used in chapter four, for the three consecutive tests that will be conducted and fulfill our model. Then, on the third chapter through an assiduous overview on the possible and potential methodological approaches, the GSIM model has eventually been chosen in order to let us confront with our research problem. Besides, its total theoretical structure and framework are being presented in order to provide the reader with the principal functions of the model, viz the steps that have to be fulfilled on the chapter that follows it. Subsequently, on chapter four, the methodology followed in order to implement the GSIM model is explained thoroughly. Thus, the model will test the extra cost implied for each of the three scenarios as well as the economic consequences of the revised MARPOL Annex VI unto the maize market. Sequentially, on chapter five by adjusting the theoretical knowledge into practice of the thesis, useful analysis of the extracted results will be considered that, in its turn, will guide us to draw our final conclusions that will be presented in chapter six, which makes up the last chapter of the thesis.

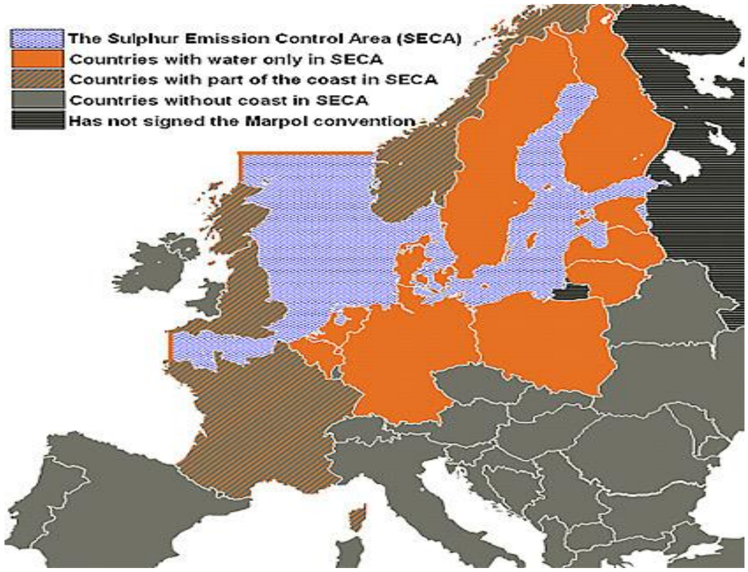
2 LITERATURE REVIEW

In principal, Annex VI's amended Directives are setting the foundations for ship operators who act in the North Sea SECA. Sequentially, and prompted from the existing bibliography the latters have three major alternatives in order to align with the set norms. On sub-paragraph 2.1 the essential scopes and objectives of the latest MARPOL Annex VI are being presented. These guidelines are actually challenging the ship-owners in order to practically align with them. Hence, we need to evaluate and meticulously analyze the three major alternatives that ship-owners have to consider in order to comply with IMO's amended regulation. From paragraph 2.2 to paragraph 2.2.3 current trends of the three major alternatives are being assessed. Subsequently, these direct consequences are being burdened to the containership sector that facilitates maize transportation. On sub-paragraph 2.3 extended analyses is been given on the manners of transporting this type of commodity, by emphasizing mostly at the liner shipping industry. On the aftermath, the data that will be discussed in this chapter will later be used as principal levers for the extra costs of each alternative that will be a matter of discussion on chapter four. Overall, this chapter provides the reader with a holistic picture of 2015 sulphur limitation regulation, as well as with an overview of the current considerable patterns of aligning.

2.1 Objective of MARPOL Annex VI

International trade, and in particular seaborne trade, has been increased rapidly over the last years and this has resulted in more and more ships operating worldwide. Given the fact that fuel used in ships has a particularly high concentration of sulphur, higher than any other means of transport, ships have the largest sulphur emissions per ton-mile of freight transported (Wang and Corbett, 2007; Jiang, et al, 2014; Cullinane and Bergqvist, 2014). The International Maritime Organization (IMO), member of the United Nations and the most statutorily competent authority for the nautical safety and security and for the prevention of pollution caused by ships, via MARPOL 73/78 Protocol of 1997 that is incorporated in Annex VI of the Convention, aimed to delineate and set standard limits on the SOx emissions from ship exhausts (AMEC, 2013). The specific regulation entered into force in May 2005. Moreover the regulation specifies a 4.5% cap by mass on the sulphur content of the fossil fuel on a global scale and in parallel sets provisions for specific designated areas (SECAs'), where the fuel oil used from vessels should not exceed 1.5% m/m, or gives the alternative of implementing a solution that can fulfill the specific requirements. The Baltic Sea was the first area assigned as a SECA within the Protocol and in July 2005 the North Sea was also incorporated, by getting into full effect on 22nd November 2007.

Figure 2-1: Map of the total European SECA



Source: Jernkontoret, 2013

In July 2005 the European Parliament amended a previous Directive, namely "Directive 1999/32/EC" to a new Directive, called "Directive 2005/33/EC" with respect to the sulphur content of marine fuels (ISL, 2010). The latter, which is also termed as "Sulphur Content of Marine Fuel Directive or (SCMF) Directive" is inextricably intertwined with MARPOL Annex VI and together they set a maximum allowable sulphur content on marine fuels within the SECAs'. The main elements of the specific Directive can be concentrated as follows: Firstly, a 1.5% sulphur limit had been set for all ships that operate within the European SECA. In details, as regards to the Baltic Sea the specific measure counts from 11th August 2006 and for the North Sea and English Channel from 11th August 2007. Secondly, a 1.5% sulphur cap has been approved for all the passenger ships that regularly service EU ports from 11th August 2006 and lastly a 0.1% sulphur limitation has been endorsed for all inland waterway ships and by seagoing vessels berthed in EU ports from 1st January 2010.

In July 2008, Annex VI had been revised by a special IMO's committee, called Marine Environment Protection Committee (MEPC), which inter alia required the following deeds: A global 3.5% sulphur limitation in marine fuels from 1st January 2012, a further reduction up to 0.1% on fuels' sulphur content within the SECAs' active from 1st January 2015, overlapping by that manner the existing norm of 1% that has been in effect since 1st July 2010, and lastly a practical adoption of an abatement technique. Besides, the alternative of using a compliant fuel that will allow them to operate within a sulphur limited designated area has also been proposed (EMSA, 2010). With regards to complying with the new regulation, ship owners will have to incur additional costs, either in terms of an investment or increased operational costs, or both, depending on which of three options the ship owner chooses (switch to MGO, use of scrubbers, use of

LNG). Consequently, the selection of the compliance alternative is vital for the ship owner and after evaluating the given options, the least expensive one should be chosen (Cullinane and Bergqvist, 2014).

2.2 Compliance Alternatives

In order for the ship owners to comply with the new MARPOL Annex VI regulations, there are four options that they can follow, bur the three of them can be considered as the most probable to be implemented in the future (Brink&Froberg, 2013). The first option is to switch from the HFO that they have been using until this point to Marine Gas Oil (MGO), which is also known as Low Sulphur Fuel (LSF). The second option is to continue the usage of the HFO and adopt an abatement technology by installing scrubbers. A third option is to use an alternative fuel, in particular Liquefied Natural Gas (LNG), which by default has low sulphur levels. Finally, the last and most unlikely to be applied option is the usage of a bio-fuel and specifically methanol (AMEC, 2013).

The low sulphur fuel solution has limited up-front investment costs and is also technically feasible. Of course proper provision must be undertaken on tank clearance issues as the pots must be assiduously prepared in order to not contaminate the two fuel grades. Most of the existed diesel engines are able to combust both fuels even with nil or just a few modifications from the manufacturer and thus any technical investment on that solution can be considered median to low. Nevertheless, and prompted from the market price differential between HFO and MGO, vessel operators tend to incur relatively high operational costs as MGO prices are already in a rather high level in comparison with HFO prices, approximately 40-60% and future trends show that they will continue to follow an ascending swing, especially due to the limited European refinery capacity (DMA, 2012). Consequently, as the amount of the imported to Europe fuel persists to be in relatively high levels in order to meet the expected demand, extra cost will undergo, by occurring certain implications to the shipping industry and its direct and indirect stakeholders.

The second solution that emerges installation of a sulphur abatement technique, i.e. scrubbing systems, is also a technically feasible solution, but also a speculative one. By adopting this technique, the vessels can operate with the regular type of fuel-HFO- with the condition that after installing it, each operator has to be aligned with the prescribed IMO's specifications on sulphur emissions. On the other hand, scrubbing systems are not totally proven as reliable, as until the 1st January 2015 just a few scientific tests will have been done in order to extract precise and accurate results. Although current studies have shown that the technology works in high trustworthiness levels. Thus, many ship operators tend to be cautious on adapting this method (AMEC, 2013). Moreover, sludge wastes that are occurred after the utilization of that system, hamper its usage, as till now there is now specific provision on the deposition of these wastes in a reception facility in ports. This is an issue that IMO has already considered and try to resolve. Finally, installing scrubbers may occur a space delineation on board and hence a partial loss of cargo capacity.

Liquefied natural gas (LNG) is natural gas that is stored as liquid at -163ºC. Its utility as an alternative to meet IMO's sulphur regulation of 2015 can certainly be considered as contingent and plausibly overwhelmed. LNG meets 0.1% sulphur limit concentration by default and this fact makes it a promising long term solution for ship operators, but there are some reservations regarding its short term usage. Within shipping industry it is widespread that it constitutes a presumable green solution and according to SWECO, 23 LNG ships are currently operating in the North Sea and Baltic Sea SECA (SWECO, 2012). One of its dominant advantages is that its price in the market is currently much lower than the respective prices of HFO and MGO and that entails a comparative advantage towards them. In addition, its energy content is highly upgraded and thus outweighs the corresponding content of both high and low sulphur fuel. According to SGC new build LNG vessels imply a 5-50% cost increase and that makes them considerably more expensive in contrast with regular vessels that operate on regular fuels. Besides, retrofitting an old vessel by modifying and upscaling its systems according to LNG specifications occurs acutely high expenses with the additional cost lying around USD 7.5 million (SGC, 2011). As a result the time for amortizing this kind of investment on old ships is relatively narrow and that implies a high concern on ship operators. Last but not least space on board for LNG tanks and port infrastructure for the fuel are also excess issues on this direction. According to ISL, LNG tanks are four to five times larger that the respective HFO tanks and hence cargo space may also be limited. Regarding ports' side and how suppliers will react with the upcoming demand constitutes an evasive issue, as on the one hand LNG providers are not willing to invest on port infrastructure without being assured from shipping operators that the demand will be relatively high and on the other hand the latters do not seem to be eager on investing in LNG vessels without have the appropriate port infrastructure been met in advance (ISL, 2010).

The last alternative that will not be a matter of further research on this thesis is the usage of methanol as an alternative bio-fuel. Most of the scholars agree that this solution in comparison with the three aforementioned has the least possibilities to be implemented as a compliance scenario, at least within the following years. (NyTeknik, 2013; AEA, 2009; Business Region Goteborg, 2012; IMO, 2009). The specific bio-fuel became a matter of interest as one of the largest Swedish shipping companies, Stena Line, took initiative and firstly switched to methanol as a fuel for their vessels. After assiduous collaboration and research with engine manufacturing companies, such as Wartsila, Stena tested methanol with positive and encouraged results and decided to modify 24 ships of its fleet to operate with the specific bio-fuel. One of the basic advantages of methanol is that there is no extra necessity for further infrastructure and fuel stations, as the already existed ones' can be safely used without any particular concerns, due to the fact that it can be liquefied at room temperature. Besides, it is stated that methanol includes lower emissions of particulate matters and NOx, as well as there is a highly increased tension as a road fuel, a fact that, in its turn, may lead to an opportunity for the shipping sector (AMEC, 2013). Nevertheless, and due to the short time period that it is tested we cannot extract certain results and currently amplify it as a solution to the upcoming IMO's regulation. Another matter of concern is that methanol is not characterized by high energy content and thus larger volumes are needed in the tanks in order to operate a vessel. Lastly, its prices fluctuate in parallel manner as HFO's, but remain in relatively lower levels than MGO's. Also, and in comparison with LNG, it can be considered as a rather expensive solution (Brink, 2013).

2.2.1 Switching from HFO to MGO (Low Sulphur)

Regarding the first option of using the MGO, we are dealing, in essence, with a switch from residual fuel oil to distillate fuel oil. Consequently, this matter will incur certain impacts on the shipping industry, especially on shipping operators who act within the SECA frequently and of course on other stakeholders, such as refineries. With regards to the formers, proper measures and precautions should be taken, as there is a high necessity for circumstantial and detailed inspection and cleaning of the tanks that for many years have been used for bunkering HFO and now have to facilitate another distillate that in no occasion should be mixed with the above-mentioned fuel. Any kinds of mixture between these two dissimilar fuels will definitely damage the engine and cause a general machinery failure. In addition, contingent consequences will probably undergo in the respect that downstream markets are going to be affected and conceivably carry an indirect burden that will be transferred to them from operators' side. Sequentially, there are overwhelmed possibilities for these markets to be negatively affected and phenomena such as port unemployment, losses for sea-mariners and for shipping industry in general might appear. With respect to the latters, the most predominant issue that they have to deal with is the reverse demand tension for HFO and MGO respectively. In other words, while the demand for MGO will begin to rise, the respective demand for HFO will descend. Following that path, European refineries that currently do not have the adequate production capacity for distillate fuels are obliged to import the respective gas types from other parts of the globe, such as middle east that, in turns, imply a kind of surcharges to the final recipient. In order to adjust and cope with this challenge, EU refineries either have to invest on facilities that convert residual oil to distillate oil, or accelerate the production of residual oil and export it in exchange to distillate products (AMEC, 2013). Overall, definite incremental costs will be occurred, as while the initial investment required by the ship owners for modifying the existing system of their fleet is relatively low, the operational costs are considerably high. Since July 1st 2010, ships operating in the SECAs use HFO fuel with 1% level of sulphur, with a price ranging from \$693.5 to \$717 per ton. However, the MGO fuel (low sulphur) containing 0.1% sulphur weight is priced at \$1,005 per ton (AMEC, 2013). Therefore, the ship owners will incur an increase of 40 - 45% in their fuel costs, which can be even higher because, as the demand for the MGO rises, so will its price (AMEC, 2013).

The University of Turku (2009) estimated between the years 2006 to 2008 that the average price difference between the HFO with a sulphur weight of 1.5% and the MGO with a sulphur weight of 0.1% is 73-85%. Specifically, the report estimates that the price per ton of HFO (1.5% sulphur) is €271 and the respective price for MGO is €470-500. Regarding the 1% sulphur weight fuel, the authors estimate its price to be between €290-330, which is 7-22% higher than the HFO of 1.5% sulphur (University of Turku, 2009).

The ISL (2010) report illustrates the prices in the range of Antwerp, Hamburg, Copenhagen and Gothenburg in 2008 and shows that reducing the sulphur level from 1% that is currently enforced in the SECAs to 0.1% which will be implemented in 2015 incurs a $520 surcharge per ton and has a price of $1,155. It is also stated that in 2015 the HFO of 1.5% sulphur content will be priced at $271 and the MGO of 0.1% sulphur content will have a price of $485, thus the two fuel types will have a difference of $214 (ISL, 2010).

In two other scientific studies conducted at the same year, Panagiotopoulos (2011) and Purvin (2011) have projected that the price differential between the heavy fuel of 1% sulphur concentration and the low sulphur concentration fuel of 0.1% is lying at USD 320 per tonne and USD 275 per tonne respectively in 2015. While Sweco (2012) concluded that the price premium between the two combustibles will range in an interval of USD 290 and USD 440 or more till 2015. Prompted from the above researches there are no doubts that there is an assiduous and unremitting ascending trend for the MGO prices, with an approximate deviation of 60%.

According to the European Maritime Safety Agency (EMSA) report the price premium between the 0.1% sulphur weight MGO and HFO is approximately 50-80%, mainly due to the fact that is a distillate fuel and because of the extra cost incurred after the desulphurization process. Besides, it is stated that the price difference between the heavy fuel oil and the low sulphur fuel with a concentration of 0.1% has fluctuated between 20-245% over a time period of 10 years and has a long term average of 95% (EMSA, 2010). Moreover the European Agency concentrated the results of eight scientific researches, conducted form both academic institutes and governmental organizations and quotes the undermentioned table as an overall summary regarding the price trends and projections for MGO fuel for 2015.

Table 2-1: MGO price estimates in 2015

Study	Expected price for MGO (0,1 % S) per ton in USD in 2015	Conversion to EUR	Expected differential per ton between 1.5% S and 0.1% S, if indicated
ECSA	Low: 500 USD Medium: 750 USD High: 1000 USD	379 568 758	80%
Sweden	Low: 662 USD Medium: 1158 USD High: 1650 USD	502 877 1250	
Finland	470-500 EURO (historic price) (633-673 USD)	470-500	73-85% (historic price difference 1,5% to 0,1 % S) The historic price difference between 1,0 % and 0,1% S has been 51-62%
UK	Scenario 1: 545 USD Scenario 2: 727 USD	413 551	Scenario 1: 92 and 42% Scenario 2: 119 and 59%
SKEMA	656 EURO (883 USD)	656	

COMPASS	656 EURO (883 USD)	656	65%
AEA	No comparable values provided		No comparable values provided.
Germany	Low: 850 USD High: 1300 USD	644 985	70-86% (price difference 1,5% to 0,1% S) 57-75% (price difference 1,0% to 0,1% S)

Source: EMSA, 2010

Four out of the eight researches have been performed either by or on behalf of some of the European SECA countries. The study of the University of Turku in Finland is called "Finland" and inspects the consequences of Annex VI in the Finnish shipping industry, while the study that had been conducted by the Swedish maritime administration in 2009, is called "Sweden". By using the abbreviation "UK" we refer to a study that had been made by ENTEC in 2009 and with "Germany" we refer to a 2010 study, conducted by the German Institute of Shipping and Logistics. The last three studies are being concerned with the matter of how the incremental fuel costs will affect the shipping industry in relation with other modes of transport.

The European Community Ship-owner Association (ECSA), which is a shipping organization in conjunction with the Institute of Transport and Maritime Management in Antwerp, had performed their own study, focusing on modal shifting after the implementation of Annex VI, in 2010. The remainder three studies had been commissioned by the European Commission. The "SKEMA" study was performed by SKEMA and assessed the impact on European SECA short sea shipping, the "AEA" study was performed by AEA and used a cost benefit analysis in order to estimate the consequences of a European amended Directive and lastly, the "COMPASS" study conducted in 2010, by the Transport and Mobility Leuven and examined the competiveness of European short sea shipping in comparison with rail and road transport. In general most of these studies examined the economic effects after implementing the 0.1% sulphur regulation in 2015 and the consequences of this regulation on transport patterns.

Overall, and based on the aforementioned information, we estimate that the increase between the fuel with 1% sulphur content and the one with 0.1% is approximately 60% or an average of USD 310 per tonne or approximately €230. These elements can be considered reliable and consistent with our literature and they will be adopted later in our study.

2.2.2 Scrubber Technology

The second option of abatement technology, according to AMEC (2013), are scrubbers capable for removing 90-95% of sulphur contained in the cheap HFO fuel. The specific technology was firstly introduced on-shore in industrial areas exactly for the same reason, viz SOx reduction. In essence, the basic characteristic of a scrubbing system is the usage of a fluid with capacity to absorb SOx and defuse the concentrated waste in contact with the exhaust gas. Consequently, a chemical reaction is being made and on the aftermath the sulphur contained product leaves the scrubber with an effluent and the emitted gas that goes through the funnel intend to be highly de-sulphurized (EMSA, 2010). The specific effluent is also known as sludge in the maritime sector. Afterwards, the sludge is being laid in a temporary storage place on the vessel and when the ship berths is transferred in an appropriate facility within the port.

Sea water is one of the most common materials that is being used for that particular reason, due to its highly concentration in alkalis, which is a chemical compound that neutralizes with acids. This kind of technology has been extensively used over the last twenty years in order to clean the exhaust gas either from main or auxiliary vessels' engines. According to DG ENV (2006) and after multiple trials and tests that have been made within this time frame, an excess sulphur cleaning efficiency of more than 90% has been achieved. Therefore, some classification societies such as GL and DNV have certified certain scrubbing equipment that is backed up with multifold successful scientific and technical trials (DNV, 2013).

Nowadays, there are four widespread scrubbing technologies that are utilized for commercial purposes. The seawater or open scrubbers, the freshwater or closed-loop scrubbers, a combination of both aforementioned (hybrid tech), and lastly the CSNOx system that except from sulphur is also aiming to vanish NOx and CO_2 particles.

The seawater scrubbers (SWS) are based on the natural alkaline characteristic of seawater and are suitable for new constructed vessels and also for retrofit installation. This type can be installed in engines that their power varies from 500kW to 78MW. A study that had been conducted in 2010 by the European Marine Equipment Council (EMEC) and used a seawater scrubbing system on a cruise ferry of about 40MW engine and on a regular cargo ship of about 20MW engine, demonstrated that 99% of SOx had been removed as well a 70% of particular matter. On that point, it has to be noticed that both vessels used a high sulphur fuel oil (HFO) of 3.5% sulphur content (EMEC, 2010). In addition the specific report indicates that the cost of installing a seawater scrubber in a new builds lies from €2,1 million to €3 million and for a retrofit installation from €2,4 million to €2,5 million. Besides, estimates that the usage of that system by combusting in parallel an HFO raises the fuel consumption almost 1-3%. The British scrubbing manufacturing company Hamworthy (2009) in its report estimates that until 2015, five hundred vessels will operate by using that system. AEA (2009) in its study that had been conducted on behalf of the European Commission, concludes that the cost to install an open scrubber system on a new vessel is approximately €1,2 million with fifteen years lifespan and annual operating and maintenance costs estimated to be around €28,000. Besides, the expected fuel costs are approximately €41,000 per vessel and the total annual cost for applying this technology is €167,000. The same study and with regards to retrofitting purposes the cost of a seawater scrubbing system is approximately €2.3 million, with a lifespan of 12.5 years, the operational and maintenance costs are estimated around €28,000 per ship, while the fuel costs per vessel are once more €41,000. Finally, the total annual costs are expected to be €301,000. ENTEC (2009) supports that the efficiency of seawater scrubbers is 96% and Jiang L. et al, (2014), state that these scrubbers can achieve reduction of sulphur equal to 98% but the initial investment required for the installment is high. Jiang makes a distinction between the cost of installing SWSs in a new ship, which is €118 per kW installed with a lifespan of 15 years and the cost of retrofitting and setting up the scrubber in an already existing ship, which is €168 per kW installed with a lifespan of 12.5 years. In both cases, the operational and maintenance costs are €0.3 per MWh. It must be mentioned that the author made his calculations for repair and maintenance costs based on the specifications of a ship that has main engine capacity above 15,000 kW. A more general approach of scrubber costs is taken by ENTEC (2009), which supports that the introduction of SWS will incur an increase in operating costs due to higher consumption of HFO equal to 1.7%, while the maintenance costs are equal to 2% of the total capital costs of new ships. The study also notes the importance of the cost that occurs from dumping the sludge created by the use of the scrubber but the exact numerical value of this cost was unconfirmed. Another related study (SKEMA, 2010) states that even though the SWS technology is still in an initial level and despite the doubts of the roll-on/roll-off (RoRo) sector shareholders, there is a theoretical belief that the installation of SWS in RoRo vessels can potentially balance the consequences of the new regulation.

The next scrubbing technology that it is also available in the market is the freshwater scrubbing technology. Its major advantage is that it can be used in sea areas where the natural alkalinity of water is not sufficient to accomplish the SOx removing process. Thus, it uses caustic soda in order to offset this matter. The sludge that will be created after the chemical reaction has to follow exactly the same procedure as the sludge generated from a seawater scrubbing system. The specific technology can be applied in all types of diesel engines and it can also be used for both new vessels as well as for retrofitting purposes. EMSA (2010), quotes the results of a study that had been made on behalf of an Italian ship-owner, named Ignazio Messina, and states that approximately 97.15% of the sulphur had been removed, after installing freshwater technology on 10 vessels of his fleet that they were operating on HFO. EMSA's study stipulates that the cost to install a freshwater scrubbing system on a new vessel is about €1,9 million to €2,4 million and for retrofit purposes from €2,4 million to €3,4 million. AEA (2009) in its study stipulates that the cost to install such technology in a new build vessel is €2.3 million with a lifespan of 15 years, operating and maintenance costs are €198,000, fuel cost remain constant at €41,000 and the total expected annual costs are €441,000. AEA's study continue with retrofitting installation costs that are being expected to be €4.5 million with a lifespan of 12.5 years, operational and maintenance costs per vessel are €198,000,fuel cost per ship are €41,000 and the total estimated annual cost are approximately €708,000.

The third proposed scrubbing technology is the hybrid tech that combines both seawater and freshwater technologies. One of the manufacturing companies of the specific system, Aalborg (2009) in its report specifies that after applying the specific mechanism that these days is on pilot stage, on a Ro-Ro vessel of 21MW engine, named “Tor Ficaria”, 98-100% of the sulphur had been removed, as well as 80% of particular matter. It is estimated that the cost to install this system on a new build vessel lies between €2,6 million to €3,8 million and for a retrofit process from €3million to €4,3 million. Nevertheless, multiple tests have been conducted till nowadays in order to enhance the reliability of the specific technology and grant its commercial usefulness.

Finally the last available but also under early stage technology that is being tested till these days by giving promising results is the usage of the CSNOx system. The Singaporean company Ecospec, which is one of the first companies that has been testing this system for several years, claims that the specific technology is dedicated to diminish CO_2, SOx and NOx emissions. Briefly, the system works based on enriched seawater that removes the SO_2 and with the usage of ultra-low frequency it is conditioned to boost the water in order to absorb more efficiently these kinds of detrimental particles. By that process the water tends to become basic, by increasing its ph values and finally removes both NOx and CO_2. The American Bureau of Shipping (ABS) has tested this technique on an Aframax tanker and stipulates that the percentages of the toxic particles that had been removed were 99%, 77% and 66% for SOx, CO_2 and NOx respectively (ABS, 2010). The Royal Caribbean Cruise Lines is also one of the companies that has already put this system into action on its fleet and at the end of 2014 will present the primal results.

Overall, and according to ENTEC (2009) the uptake of seawater scrubbers tends to be a more cost effective solution in comparison with the option of switching to MGO because it demands a large initial investment but has very low operational costs.

2.2.3 LNG Fuel

The LNG fuel is one of the most widespread green alternatives on nowadays global energy issue. It is mostly produced in Russia, Qatar and Iran. Its global resource situation is better than oil in terms of reserves-to-production ratio. New reserves are being discovered every day and researchers tend to agree that it will definitely substitute the usage of crude oil in a significant percentage. In general, LNG prices fluctuate less than HFO and MGO prices and on average it has a constant trend to range below the prices of these fuels. This can be partially explained from the fact that demand and supply for LNG are following adverse routes, especially due to the high production of shale gas and the relatively low demand for gas. With regards to its implication on the shipping industry it is a trustworthy environmental solution to air pollution as by default meets the 0.1% sulphur emission limit that is been set by the IMO. Its sulphur and particulate matter emissions tend to be nil. Besides there is no necessity on the shore side to facilitate any kind of sludge as it does not generate any. Using LNG on operational issues does not include any disadvantages regarding the operational quality of the vessel, such as its cruising speed, but on the other hand it involves some extra running and technical complexities and consequently the necessity of a special trained crew is mandatory (EMSA, 2010). Moreover, the option of complying with the new MARPOL regulations via the use of LNG is stated to be an unlikely scenario for the already existing ships but is more likely to be used in new ships (AMEC, 2013; ISL 2010). The reason for this is that the market for LNG is not mature enough yet and that suitable supply chain networks or land infrastructure is not built yet to support LNG use (AMEC, 2013). ISL (2010) also states that there is a requirement to place dual-fuel engines or LNG engines in existing ships, which would lead to instant depreciation on ship engines regardless of their age. In addition, this situation will lead to unstable prices for LNG, creating an uncertain environment for its market (AMEC, 2013; ISL 2010).

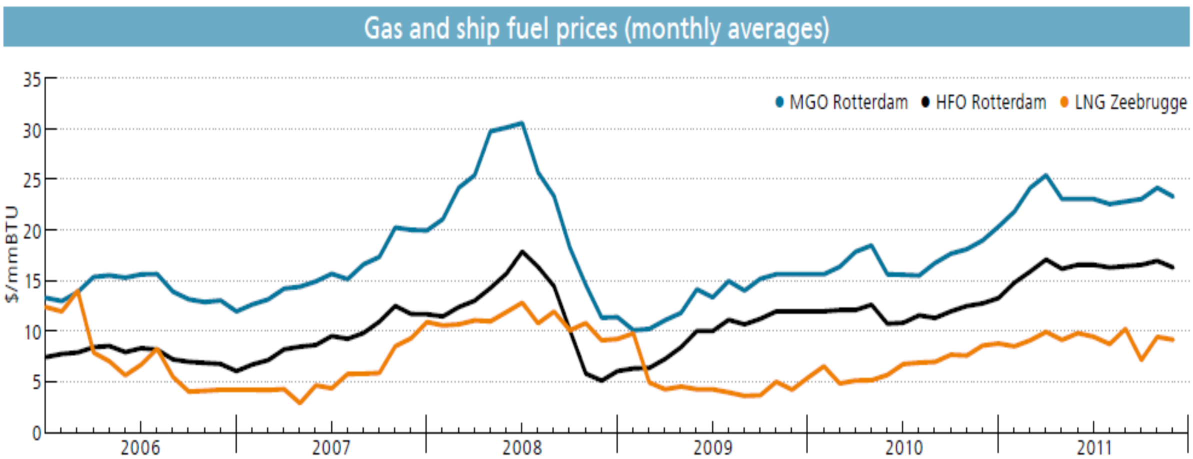
Currently there are thirty LNG ships that operate in the European SECA and most of them are based in Norway. Most of the industry's stakeholders are Ro-Ro operators, port service vessels, and ship operators who are dedicated to short-sea shipping, by servicing coastally nearby areas. Prompted from a study that had been conducted in 2006 by DG-ENV around 200 Ro-Ro vessels are operating in the European SECA, with most of them exceeding their 20th operating year. Thus, it is mandatory for their operators to orientate to a way out of this situation and adopting LNG could easily be a realistic and possible resolution towards that issue.

Utilization of LNG arises implications for both off-shore and on-shore sides. With regards to the former the cryogenic cylinder format tanks that are required in order to facilitate the liquefied gas on vessel are excessively larger than the regular HFO/MGO tanks at approximately 3-5 times. It is estimated that containerships immolate 3-4% of their cargo capacity in order to be compatible with this technology. Nevertheless, LNG engines do not abstain from the respective diesel engines, in terms of size captured, while some of the latters can also be enhanced with "LNG kits" in case of a retrofit. A tangible retrofit occasion is the chemical tanker "Bit Viking" of the M/V shipping company that it will be equipped with a dual fuel engine in order to operate on both HFO and LNG. Besides the small container vessel "Drury" that belongs to Maersk will be retrofitted in order to use LNG on its two auxiliary engines. EMSA (2010) estimates that the additional investment cost in new vessels lies between €1 million to €8 million, depending on the complexity and the arduousness of installation. As the market of LNG manufacturers increases the above amounts will tend to decrease and be stabilized. Moreover, ship operators do not seem to be extremely positive on investing in LNG, until LNG suppliers create the adequate facilities in order to service that demand (Brink, 2013). . ENTEC (2009) also predicts that a very small percentage of ships will adopt pioneering resolutions, such as dual engine system by 2020, enabling them to operate on LNG.

On the shore side now, the basic problem has to be confronted from the industry is the shortage of LNG facilities in ports. Nowadays, just a few LNG facilities are available across Europe and bunkering constitutes a principal issue for potential LNG operators. Of course, this problem can be coped with multiple manners, such as fixed installations, tank trucks or a ship-to-ship transfer with small bunker barges. Nonetheless and with the absence of commercial interest this kind of infrastructure is in relatively premature stage and is still under incubation. As a result this tends to be a chicken-and-egg problem since none of the two sides is willing to take initiative for the development of this alternative (DMV, 2012). ENTEC (2009) declares that LNG is not a feasible solution at least until 2020 because it requires a significant investment and creates problems regarding the necessary infrastructure, bunkering, storage and engine specifications. LNG is presented as an unrealistic but efficient way to comply with the new regulations, as it has sulphur abatement efficiency of 99% (meaning that it achieves a 99% emission reduction). If LNG was to be used, it would most likely be implemented in vessels operating on a port-to- port basis without requiring extensive infrastructure, as well as tankers (ENTEC, 2009).

In terms of prices, the Danish Maritime Authority (2012) indicates that in 2011 the price of LNG was about $400 per ton, while the price of HFO was about $600 per ton. Figure 2-2 is representative of price fluctuation among the three fuels from 2006 to 2011.

Figure 2-2 Price fluctuation of HFO, MGO and LNG



Source: GL&MAN study, 2011

As it is depicted bunker fuel prices are too volatile either in the short-run or in the long-run. Especially, for HFO and for MGO prices tend to have a relatively ascending trend before the boom in the mid 2008 but also after that in the beginning of 2009. On the other hand LNG prices are comparably stable in relation with those of MGO and HFO, with the only discordance arising in 2008, but recurring within the first months of 2009. This graph consists a proof of the significant lower price that LNG had on average within the specific time period, as well an indicator of correlation among these combustibles. According to GL&MAN (2011), the degree of correlation between LNG-HFO and LNG-MGO is 0.68 and 0.88 respectively. Since there is a medium to high correlation between these fuel prices it is pivotal for the ship-owner to make the appropriate decisions with regards to the adopted compliance strategies. With regards to future fluctuation scenarios, MGO prices are expected to be risen, as well the prices for LNG but in a more gradual and mild manner. This can be explained from the expected heightened demand for low sulphur fuel oils in order to meet SECAs' regulations and from the parallel diminished demand for high sulphur fuel oils. Of course these trends will also be affected from the proportion of ship-operators who will decide to switch to an alternative fuel, as well from the future levels of production of these alternative fuels (DMA, 2012). Estimates give a price interval of $300-$800 per tonne in 2015. Finally, the same study results that the upcoming cost for a ship-owner in order to install an LNG combustion system on both main and auxiliary engines is €570,000 and €1.1million for a retrofit and for a new vessel respectively. Sames (2011) GL's vice president estimates the prices for LNG in 2015 will lie between $400 -$700 per tonne.

2.3 Maize Transportation

Maize can be considered as an extremely perishable and vulnerable commodity and quality will be quickly relegated if moisture content is not properly managed or the containers that it is transferred are not insect-proof. Besides, due to the reason that maize has a low value-to-weight ratio, transportation costs are significantly important and can be considered as one of the most pivotal key-determinants of enterprise viability (UNCTAD, 2009). Thus, the safest and in parallel the most cost-effective transport mean must be chosen in order to serve growers and assist the connection of maize suppliers with international markets. The main transport manner that is used and facilitates maize products' transportation is liner shipping, which is generally the cheapest and in essence the only way that can enables global trade among the continents. From that point and after and with the usage of lorries, trains and barges the product can be distributed within neighboring countries and in general to any other places of demand.

There are two possible manners that can enable maize transportation through liner shipping. The first is via bulk containers, which are also known as "intermediate bulk containers" (IBC) and the other is through standard containers under the form of bulk bagged cargo that can also be met with the industrial terminology of "flexible intermediate bulk container" (FIBC). Regarding the former, advantages can be extracted from its cubic form that has by default and consequently it can transport larger commodity amounts in comparison with other cylindrical shaped containers, or even in comparison with standardized packaged consumer quantities. Moreover and due to its ergonomic and holistic operating loading and unloading system, IBC can be easily adjusted to other discharging systems and sequentially can agglutinate the excess advantage of packaging the commodity in the destination country, according to each domestic rules and regulations, avoiding by that way any unforeseen sanctions and of course any implied extra costs for packaging the commodity at the origin country in advance. Terry Gardner, head of North American product marketing of the " Pioneer Hi-Bred's" corn company, states that he expecting a steady increase for bulk shipping of maize seeds, as farm sizes get larger and planters get bigger. Besides, he claims that there is a clear direction that the majority of his company's sails will be transported via the IBC method on the upcoming future (Gardner, 2011). Finally, purchasing or leasing that kind of container can be considered an absolutely reliable process, as each container has its own barcode and tracking system that are offered from the manufacturing company. With respect to the latter type of container and as prompted from its appellation, FIBC is made of flexible fabric, which is designed to be transferred or stored and contains flowable products. Subsequently, these bags are loaded and transported on pallets in standard containers. The advantage of that sort is that provides stowing flexibility to its operators, as it can be met in six different forms, namely core construction, round construction, baffle construction, four-side panel construction, circular or tubular construction and U-panel construction. Nevertheless, trends indicate that this method of transportation tends to descend, as in many cases it is added as an extra cost to the total transport expenses for both supplier and consumer (Yam, 2009). On that point, it should be mentioned that both of these manners require cool and dry transportation environment, in conjunction with a proper ventilation system, which will ensure the safe and sheltered transportation of the commodity. Thus, complying with IMO's "Code for Safe Carriage of Grain in Bulk" regulation, which includes maize transportation, can be considered as totally imperative.

Use of lorries and trains for maize transport also takes place but they can only carry a limited number of containers. Price differences prompted from aligning with each of the three alternatives will actually specify the degree of competition between "short-sea/truck" and "truck-only" alternative. In order to offset possible implied unfair competition and take precautions for a possible forthcoming decreased competiveness of shipping and in particular of the short-sea shipping sector, the European Union via its program, named "Marco Polo" is actually attempting to promote a modal shift from land to short-sea transport shipping, by targeting in reducing road congestion and in parallel restraining gas emissions (EU, 2003). By that manner, the European Union attempts to cooperate with the states and support investment decisions on that direction. With regards to rail modal shifting that just acquires a minimal of 8% in total cargo transportation within Europe it could be stated that is one of the most upcoming trends on cargo transit. Inter-modality in ports is one of the most principal and widespread concepts nowadays and large investments have been made towards this direction. Notwithstanding, technical inefficiencies, interoperability problems and lack of capacity constitute major impediments unto that mean of transportation. Overall, the exact degree of modal shift towards to the "truck-only" or to the rail mode solution cannot be determined accurately (Notteboom, 2011).

2.4 Conclusion

In total, these new trends show that the increased costs incurred due to the MARPOL Annex VI revision, in conjunction with the extra costs that will be passed on to the customer through the increased freight rates. Three alternatives can be considered as the most viable and realistic in order to be implemented. Switching to MGO, scrubbing technology installation and operating with LNG. Scholars' opinions towards which technique is the most appropriate for a ship operator that serves the North Sea SECA lane are being divided, by leaving the initiative of undertaking one of the options up to the ship-owners. Price fluctuations among the different fuel types are certainly a trustworthy indicator, but on the other side the energy sector is significantly vulnerable and very nebulous in order to be projected accurately. Nevertheless, these extra induced costs will have an effect on the containership sector, as it is the principal manner that facilitates the global trade of maize. It is stated that a modal shift from sea transport to land transport is mostly expected to be occurred, when it comes to trade between regions that are connected by land (Danish Maritime Authority, 2012). Thus, selecting an alternative is paramount in order to face unfair competition. Of course our essential field of interest lies on the economic impacts on the North Sea SECA after implementing IMO's amended regulation. On the following chapter we will discuss possible methodological approaches that can cope with our problems and we will result on the most proper and accurate method that is able to give direct answers on our research questions.

3 LITERATURE OVERVIEW

On the specific chapter our principal matter of concern is the methodological approach that aligns more properly with our scientific targets and provides the most accurate and useful results by giving direct answers towards our research scope. Prompted from the existing bibliography three methods tend to draw useful results, by corresponding on our matter of discussion. After evaluating these scientific manners, on sub-chapter 3.1 we finally conclude on the most suitable one that aligns with our study and we give its theoretical framework on sub-chapter 3.2.

3.1 Methodological Evaluation

Principally, an economic impact analysis is required in order to determine the direct, indirect and induced consequences in the North Sea SECA maize market. Thus, we have to mention and argue on the correct and proper methodological approach that should be considered in our case. At first it would be useful to define the examined topic. There is no doubt that the notion of an economic impact analysis is to measure and estimate how spending associated with a particular event flows through a designated economy (Campbell, 2011). This fact holistically aligns with our tendency to calibrate any transferable costs, due to the incumbent MARPOL regulation, from a ship-owner whose vessels are operating in the N.S. SECA to the respective supplier and consequently to the final consumer.

After an attentive bibliographic research on the proposed methodological approaches that can be used by the scholars, in order to provide them with the required quantitative results after conducting an economic impact analysis, three scientific techniques seem to excel and gain comparative precedency. The models that had been used most frequently, by the majority of the researchers, can be namely classified as: Input-Output tables (I/O), Input-Output Econometric models (IOE) and Computable General Equilibrium models (CGE). According to the Queensland Government Statistician's Office (QGSO) these three most frequently used techniques can grant secure and concrete results for an economic impact analysis (QGSO, 2012). This approach is amplified by Glen and Burton Weisbrod who had presented in 1997 an assiduous study explaining what are the trade-offs and the principals for each scholar that aims to conduct an economic impact analysis. The authors thoroughly explain the differences between the three available techniques and finally suggest the most compatible one, depending on the expected outcome of the study. (Burton&Glen, Weisbrod,1997). Deller, (2007), and on behalf of the University of Wisconsin has conducted an economic impact analysis on possible increases of taxes to cooperatives. In order to confront with the respective analysis that needed to be undertaken, he rigorously explains the possible patterns than can be used and he states that I/O, IOE and CGE are the three most distinctive potential practices for quantifying an economic impact analysis. Finally, he closes up his study by conducting one of them. Kinnaman (2010), in order to conduct an economic impact analysis after the shale gas revolution in the U.S. of America, through a painstaking overview is also suggesting these three available and plausible manners of conducting an economic impact analysis. Even if the terminology used by the scholar is slightly different than the regular used by the majority of the researchers, the principals and fundamentals on the notion of the methodological approaches remain essentially the same. Finally, Jia (2000) investigate the future economic impacts after implementing a specific technological innovation within a part of the Japanese grid, which implies extra costs to the Japanese electricity providers and she eventually applies an integrate and holistic model approach that in essence combines two of the three available approaches and concludes to the usage of a CGE model as the most compatible and accurate manner that aligns with her study.

The first technique concerns a simple input-output analysis (I-O). This type of analysis relies on inter-industry data and determines how effects in one industry will have an impact on other sectors. Relatively with the other two manners this approach is characterized for its clarity and simplicity. In addition, I-O analysis involves the use of multipliers to calculate the overall economic impact after the implementation of a specific policy. The first type of multipliers, namely Type I, measures the industrial response to the change, while the second one, Type II, complementary calibrates also the consumption-induced response. On the one hand this method can be assessed as transparent and easy to be used, as in most of the cases it is based on limiting and unrealistic assumptions. This is a fact that sequentially makes it a relatively inaccurate and imprecise method. Besides, and due to the usage of fixed coefficients, which indicates that an industrial structure remains unaffected by the economic event, this method can be assed as inflexible and relatively fallacious. Moreover, another considerable limitation is the lack of supply side restraints alongside with a significant overstatement of the impacts on employment and gross state product. The aforementioned statement can be justified from the fact that fluctuations in prices and consequently changes in consumption patterns for both supplier and consumer do not seem to occur under this method (Burton&Glen,Weisbrod,1997). All embracing, the specific methodological approach even if it analyzes the magnitude of the primary after the shock effects, it does not encompass price effects and the timing of adjustment. Tangible examples of I-O models are IMPLAN, RIMS-II and EMSI (Shackleton, 1993).

The second most frequently used technique is the input-output econometric modelling (IOE). In essence, this method is a hybrid extension of the simple I-O method, by also integrating econometric relationships, estimated from time series into an I-O framework. Via that manner IOE addresses the shortcoming of average relationships in simple I-O analysis and provides the adjustment path of the economy to an economic impact (Bureau of Economic Analysis, 2011). In comparison with I-O this technique incorporates the supply side constraints. These kinds of constraints are embodied via econometric relationships that provide an estimate of the price responsiveness of goods as a result of changes in demand and supply. Hence, both consumer and producer behavior is affected from by these price fluctuations resulting in respective changes in production and consumption patterns. In addition, this kind of modelling estimates both intermediate and final demands, consumption and stock, technical change and international trade separately at its primal stage of calculations and then aggregates the aforementioned results. In essence, the model imitates the economy by constructing the overall industrial and consumer activity and then connects and associates the changes prompted from a specific industrial sector with changes of supplementary or substituting industries. On the aftermath, these results are used as input data on a simple input-output table in order to provide the researcher with the corresponding outflows, by using a “row scalar” technique. Nevertheless, the specific model, which is also known as a “tailpipe” model, neither pledge consistent and trustworthy forecasts between the detailed results and the driving aggregates, nor involves systematic price changes and their consequent response (Shackleton, 1993).

The last methodological approach that can derive results from an economic impact analysis is the computable general equilibrium modelling (CGE). The specific technique is actually using a typical I-O table by disaggregating it into two components, price and quantity. Both of them are allowed to adjust under any fluctuation of different factors. CGE are frequently used in order to calculate profit maximization, dictating in parallel cost minimization for the investor. Based on one of the economic principals, consumers, here, are assumed to maximize utility in their consumption decisions, responding to price differences. Besides, prices adjust in goods and factor markets to equate demand and supply. This category is divided to other two sub-categories, comparative static and recursive dynamic. As the former does not include time dimension, the latter can be linked to a macro-econometric model to produce a “business-as-usual” forecast and sequentially determine the economic adjustment as a difference between two chronical periods. Additionally, the specific model structure is competent for providing results prompted from potential supply’s and demand’s elasticity shifts, changes in taxes and costly investment decisions (Bellu, 2009). The specific model formulation is able to reckon up to thirty-five different industrial sectors aggregately and dispense detailed and comparatively with the aforementioned methods more reliable and precise results, by also considering the degree of substitution between primary and alternative consumer choices, within the resolution process.

In any case the strongest point of CGE is its correspondence and reaction to an exogenous shock, in our case different compliance costs and simultaneously how these induced costs will be allocated throughout the specific market field of the specific commodity (maize), within the specific examined area (N.S. SECA). Therefore the technique that aligns with the scope of our subject is the CGE modelling, without considering any time variables. A typical example of a comparative static CGE modelling is the Global Simulation Model (GSIM) that was developed by Francois and Hall in 2003 and it has been commissioned by the European Union. The specific model will be used in order to provide us with the specific answers that correspond to our research questions.

3.2 GSIM-Theoretical Framework

In essence, the GSIM is a multiregional, imperfect substitute model of world trade. It is formulated in order to require relatively small amount of data, while it is able to provide insights about the impact of trade policy changes on trade flows, welfare aspects of trade, and tariff revenue effects, after an economic shock. This includes reciprocal interaction among the various trading partners within a designated market, such as importers (consumer surplus) and exporters (producer surplus).

With regards to its mathematical structure, the GSIM applies a linearized (percentage change) representation of import demand in combination with the respective export-supply equation. According to that manner a potential large system of bilateral flows can be met in a reduced-form of global demand and supply. This kind of form comprises as many equations as the number of exporters and then it is solved for the set of the world prices. Moreover the model is based on the assumption of national product differentiation. This means that imports constitute imperfect substitutes for each other and as a result all the required elasticities, viz elasticity of demand, elasticity of supply and elasticity of substitution remain in aggregate constant across all the formed pairs of importers and exporters.

With respect to the demand side, the relationship that describes the import demand (M) of a country is given by the formula:

$$\boldsymbol{M_{m,p,x} = f(P_{m.p,x}; P_{m.p.\neq x}; Y_{m,p})} \quad (1)$$

Where, m stands for the country, p stands for the product and x stands for the exporter country that exports product p. As a result, $P_{m.p,x}$ is the domestic price of product p in country m that is exported by country x, $P_{m.p.\neq x}$ is the domestic price of product p in country m (including tariffs) that is exported by the rest of the countries and $Y_{m,p}$ stands for the total import expenditures of country m for product p.

Thus, it could be inferred that:

$$P_{m,p,x} = (1 + t_{m,p,x})P^*_{p,x}$$

Where, $t_{m,p,x}$ represents the imposed tariff by country m on its imports for product p that is exported by country x and $P^*_{p,x}$ stands for the global price of product p that is exported by country x.

On the aftermath, after differentiating (1), by taking into account Slutsky's decomposition of partial demand and Hicksian's zero homogeneity property of demand, the following equations can be derived:

$$\boldsymbol{\varepsilon_{m,p,x} = \theta_{m,p,x}(\varepsilon_{m,p} + \sigma_{m,p})} \text{ and } \boldsymbol{\varepsilon_{m,p,\neq x} = \theta_{m,p,\neq x}\varepsilon_{m,p} - (1 - \theta_{m,p,\neq x})\sigma_{m,p}} \quad (2)$$

Where, $\theta_{m,p,x}$ stands for the expenditure share of p that is exported by x in accumulated imports of p by country m. It is extracted that $\varepsilon_{m,p}$<0 is the composite import demand function for country m and that $\sigma_{m,p}$>0 is the elasticity of substitution for p in country m exported from different countries. Consequently, $\varepsilon_{m,p,x}$is the import demand for p that is exported by country x to country m and $\varepsilon_{m,p,\neq x}$ is the cross price elasticity of the import demand function for p in country m exported by x, when the price for p changes by importing it from other countries.

By following the same pattern and with respect to the supply side we can express export supply (X) functions as a function of the world prices, viz:

$$\boldsymbol{X_{p,x} = g(P^*_{p,x})} \quad (3)$$

Then, after differentiating the above formula, by formatting it on percentage terms we derive the final export supply elasticity condition which is:

$$\boldsymbol{e_{p,x}} = \frac{\widehat{\boldsymbol{X}}_{\boldsymbol{p,x}}}{\widehat{\boldsymbol{P}}^{*}_{\boldsymbol{p,x}}} > \boldsymbol{0} \quad (4)$$

Hereafter and in order to define the new market equilibrium after the economic shock, which is interpreted in terms of world price increases after a trade reform in one or more countries or in a designated region, we simply resolve the new re-equilibrates supply and demand for a specific commodity. Due to the imperfect substitution that it was mentioned above, fluctuations in tariffs on products that are exported from other countries imply changes on the import demand, as that was suggested by the cross price elasticity in condition (2).

After explaining the principal conditions that set the foundation of the model, we will continue with the required and tangible elements of the model, which are the matrices of imports, tariffs and elasticities. Via that manner any changes in world prices that follow a trade policy reform can be easily extracted. Firstly, we will denote $E_{m,p}$ that represents the aforementioned diagonal x by x matrix of import elasticities in country m for product p. Prompted from the conditions (2) and (4), the elements in the diagonal are equal to$\varepsilon_{m,p,x}/e_{p,x}$. Besides, the elements off the diagonal are equal to$\varepsilon_{m,p,x}/e_{p,x}$. Then, and in order to solve for the changes in world prices we have to denote the following; Let P_p^* be a vector of percentage changes in world price for product p. In addition, let $T_{m,p}$ be a vector of tariff changes that are imposed by country m, for imports of product p from differing countries. Additionally, after denoting $\boldsymbol{E_p} = \sum_{\boldsymbol{m}} \boldsymbol{E_{m,p}}$ and $\boldsymbol{B_p} = \sum_{\boldsymbol{m}} \boldsymbol{E_{m,p}} \boldsymbol{T_{m,p}}$ and by also imposing the market clearing conditions, we extract the following relationship with respect to changes in world prices.

$$\boldsymbol{P_p^*} = (\boldsymbol{I} - \boldsymbol{E_p})^{-\boldsymbol{1}} \boldsymbol{B_p} \quad (5)$$

Thereby, is a casual graphical representation of the above-mentioned matrices.

Figure 3-1: Matrix of imports

trade at world prices:

		destination			
		USA	JAPAN	INDIA	CONGO
origin	USA	14596604.37	125478.24	1541275.24	5263.19
	JAPAN	11256897.50	458963.07	125698.24	25632.82
	INDIA	125478.85	614945.26	125899.23	2543.30
	CONGO	1256.98	458.85	99471.25	128963.14

Figure 3-2: Matrix of Initial Tariff Barriers

initial bilateral import tariffs	destination			
origin	USA	JAPAN	INDIA	CONGO
USA	1.0014324	1.0026423	1.0010353	1.0010549
JAPAN	1.0014700	1.0034076	1.0015680	1.0015503
INDIA	1.0000133	1.0015133	1.0015513	1.0015557
CONGO	1.0000237	1.0000965	1.0015213	1.0034029

Figure 3-3: Matrix of Final Tariff Barriers

final bilateral import tariffs	destination			
origin	USA	JAPAN	INDIA	CONGO
USA	1.0028100	1.0045091	1.0014871	1.0015153
JAPAN	1.0012957	1.0014076	1.0015680	1.0015503
INDIA	1.0015992	1.0005133	1.0015513	1.0015557
CONGO	1.0013469	1.0000965	1.0013264	1.0034129

Figure 3-4: Matrix of Elasticities

Elasticities:				
	USA	JAPAN	INDIA	CONGO
Composite Demand	-0.2	-0.2	-0.2	-0.2
Industry Supply	0.2	0.2	0.2	0.2
Substitution	5	5	5	5

Thus, after obtaining the percentage changes in world prices, by using formula (5), there is no difficulty on obtaining changes in tariff revenues, producers' and consumers' surpluses, net welfare and import and export revenues.

In particular, after considering (4) and (5), exporter's (producer's) surplus is given by the equation:

$$\boldsymbol{\Delta PS_{p,x} = P^*_{p,x} X_{p,x} \widehat{P}^*_{p,x} (1 + \frac{e_{p,x}\widehat{P}^*_{p,x}}{2})}$$

Where, $P^*_{p,x}$ reflects the percentage change in the world price of product p that is exported from country x.

Regarding the percetage change in imports, it can be calculated after using condition (2) in conjunction with the definition of import demand elasticity, which is $\Delta Q / \Delta P$, where ΔQ stands for percentage quantity changes and ΔP stands for percentage price changes.

Tariff revenues are given by the linear equation:

$$\boldsymbol{\Delta TR_{m,p,x} = t_{m,p,x} M_{m,p,x} P^{*}_{m,p,x}[(\hat{t}_{m,p,x}) + \hat{P}^{*}_{m,p,x}(1 + \varepsilon_{m,p,x})]}$$

Where, $\hat{t}_{m,p,x}$ stands for the percentage change in tariff that is imposed from country m, for product, that, in its turn, it is exported from country x.

Accordingly, and with respect to the consumer (importer) surplus, is given by the usage of the formula:

$$\boldsymbol{\Delta CS_{m,p} = \sum_{x} M_{m,p,x} P^{*}_{m,p,x} T_{m,p,x}[\frac{1}{2} \varepsilon_{m,p} (\hat{P}_{m,p})^{2} sign(\hat{P}_{m,p}) - \hat{P}_{m,p}]}$$

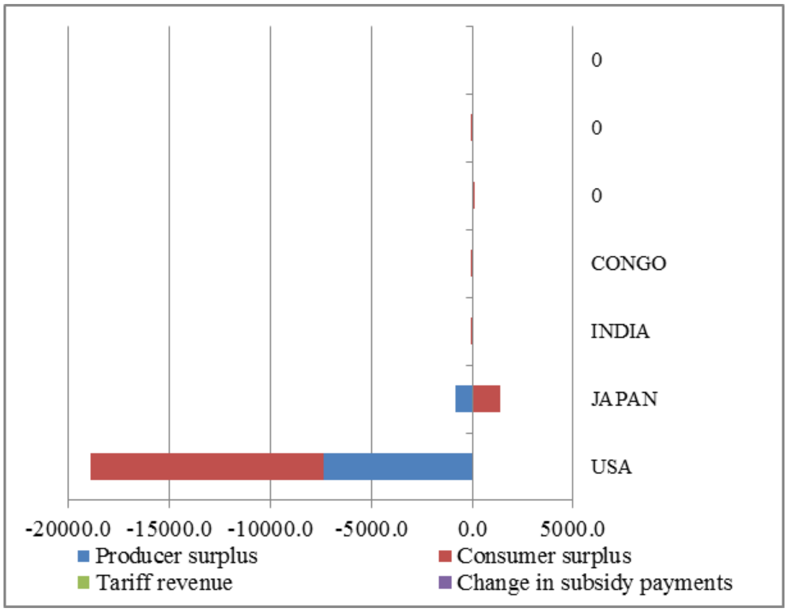
Where, $\hat{P}_{m,p} = \sum_{x} \theta_{m,p,x} \hat{P}^{*}_{p,x} + \hat{T}^{*}_{p,x}$

Finally, the net welfare is reckoned as the sum by country of producer surplus, consumer surplus and tariff revenue.

Hereby, is a casual numerical graphical representation of the relationship among the above elements.

Figure 3-5: Matrices of Welfare

	Producer surplus	Consumer surplus	Tariff revenue	Change in	Net welfare effect
USA	-7374.3	-11549.5	0.0	0.0	-18923.8
JAPAN	-810.5	1372.5	0.0	0.0	561.9
INDIA	-1.8	-17.2	0.0	0.0	-19.0
CONGO	-0.4	-27.8	0.0	0.0	-28.1



Eventually, and with the usage of the excel solver, which is provided by the Microsoft Excel, all the above calculation can be done accurately and calibrate all requested data.

3.3 Conclusion

In this chapter we argued on the three offered methodological approaches, given by the existing bibliography, namely the I/O tables, the IOE models and the CGM models. The usage of the GSIM model that is a type of CGM model was finally selected, in order to let us confront with our research questions as it is the most updated software that can provide us with direct answers. As it would be appropriate, a breakdown of its components have been made on theoretical base, giving the reader the opportunity to understand its structure and the manner of extracting the desired results. Both mathematical and graphical approaches have been presented in order to embrace and amplify its theoretical framework that will be used as a pattern in our case. On the following chapter, we will continue with implementing the GSIM in our research, according to the scope of the specific thesis, aiming to attain the respective results. Besides, the components of the specific scientific approach will be practically fulfilled.

4 METHODOLOGY

This chapter is intended to clarify the method that has been chosen in order to provide us with the mandatory quantitative results, by responding on both main and sub-research questions. Its structure consists of the steps that have to be followed in order to formulate and support the validity of the proposed methodological approach. In parallel, specific assumptions have to be made on individual sub-paragraphs, such as initial import tariffs and elasticities undertaken, aiming by that manner to offset imposed assumptions that need to be considered in favor of providing a final resolution on our issue. Overall, the reader after examining this chapter has to be able to draw his own remarks regarding the formational consistency of the suggested model, in practical terms. Hence, and as the proposed model is able to provide us with all mandatory answers towards our research questions, it will be used three consecutive times for each of the proposed alternatives. The final analysis of the model's outcomes and their respective concluding comments will be a matter of discussion in chapter five.

4.1 Model

The Global Simulation (GSIM) model, a partial equilibrium model, was applied to evaluate the impact of adopting various alternatives to comply with the MARPOL Annex VI Sulphur regulations. The model is able to support a bilateral production and trade structure of up to 25 pairs of origin-destination regions. On the following paragraphs its components-steps will be justified and will be tested in conjunction with the three distinct methods by which a ship owner might comply with the amended regulation. Each of these alternatives occur its own different costs. Thus, the model was applied under these three different scenarios to evaluate whether there would be different outcomes.

4.2 Data

The data required for the GSIM model includes 1) initial bilateral trade values, 2) initial and final bilateral import tariffs, and 3) elasticities of demand, supply and substitution, given that initial and final bilateral subsidies among each origin-destination pair remain unknown. On that point is has to be stated that both initial bilateral trade values and initial and final bilateral import tariffs are counted in "ad valorem" form. This means that all of the loaded data are measured according to their nominal value, i.e. in USD by also including inflation and not as amounts of quantities traded, e.g. tonnes. In the following sub-sections, the assumptions and methodologies for deriving the necessary data elements will be defined.

4.2.1 Input Data

The data for this analysis was queried from the World Bank (WITS) database (WITS, 2014). The query type was set as UN COMTRADE. Import trade flows from 2012 of the WTO_H4_Aggri products of the HS2012 nomenclature were selected. HS (4-digit level) chapter in this category includes code 1005, which in its turn, represents codes 110220, 110313, 110423, 110812 and 230210 that encompass all maize related products and derivatives, such as corn flour, corn hull, livestock feed and starch. For this analysis, it was necessary to investigate the European countries which are included in the North Sea SECA region separately from the rest of the European countries. According to "WITS" database several pre-defined market (reporting countries) and partner (partner countries) regions have been offered. Nevertheless, they were organized by "developed", "transition", or "developing" economies of different regions. It was considered that this did not have an influence on the trade flow in/out of the North Sea SECA region and considering that the North Sea Region was not one of the pre-defined regions all countries have been selected individually for both the markets (reporting countries) and partners (partner countries or regions). Consequently, for the North Sea SECA eight countries have been designated, namely the United Kingdom, Germany, Belgium, the Netherlands, France, Denmark, Sweden and Norway. A summary of market and partner countries was made and the countries were sorted in decreasing order according to their total import value. For this purpose the first 100 importing countries have been chosen in order to reflect the global trade of maize. From them, the top 52 importing countries were assigned to one of the following regions: Europe – North Sea SECA, Europe – Other, North America, Central & South America, Middle East & Africa, Asia & Oceania. The remaining countries were classified in the Rest of the World category (ROW). Appendix 1, is a detailed summary of the countries included in each category.

The import values were then summarized into a 7 x 7 matrix, with partners, in this case the exporting regions, listed vertically and markets, the importing regions, listed horizontally. Appendix 2, summarizes the input data used for step 2 of the model.

4.2.2 Data Analysis

On the aftermath, and in order to obtain the required initial tariff barriers, a non-tariff measure manner of offsetting this mismatch has been chosen. Four mandatory steps were selected as an attempt to answer successfully the research question of how will the maize market will be impacted due to the increased costs associated with the vessels operating in the North Sea SECA region and having to comply with the MARPOL Annex VI sulphur limitation regulation in 2015. The four steps are the follow:

1. Estimate the number of ships that operate in each origin-destination lane,
2. Assist a specific vessel category in each lane,
3. Reckon the annual freight rate for each ship type.
4. Quantify each origin-destination freight cost as a fraction of the annual freight rate of each lane over the respective annual import value.

Consequently, after implementing steps 1-4 we will obtain the required 7 x 7 initial tariff table. Thus, after evaluating the individual costs of each of our three alternatives and applying them into our initial costs, we will come up with the second 7 x 7 matrix that concerns the final tariff barriers, for each of the three applicable scenarios to comply with the amended regulation. On that point it has to be stressed that implications will be considered only in the affected lanes, viz imports and exports from the North Sea SECA and not to the remainder unaffected lanes world-widely.

4.2.3 Assumptions

It would not be possible to materialize our model if specific assumptions would not have been considered. The number of ships that operate per origin-destination lane is an approximate representation of the reality, based on the respective amounts of imports for each of the origin-destination pairs. Moreover, three ship sizes have been considered, namely a Feedermax, a Panamax and a post-Panamax vessel. The specific classification is backed by the respective vessels' capacities, in terms of low, medium and upper scale cargo transferability potential. Realistically, there are many more container vessel categories that facilitate the global maize transportation, but they could not be introduced due to the limited amount of information.

In addition, the respective vessel engine powers that have been considered represent the average cargo capacity for each of these three ship types, vis-à-vis 3,000, 5,000 and 10,000 TEU correspondingly. The exact volume capacity fluctuates for each vessel type, but for the sake of convenience TEU capacities have been rounded according to the findings of the bibliography.

The final assumption concerns the reckoned elasticities. Prompted from the principals of the model all elasticity types have to be the same across all the origin-destinations pairs. Thus, elasticity of demand has been assumed to be equal to -0.8 for all combinations and elasticity of supply is equal to 0.8. A relatively inelastic demand means that the percentage change in the quantity demanded is less than the percentage change in price. A fact that could be plausible, as genetically modified maize seeds have not been authorized and approved world-widely yet, and thus, consumers' willingness to buy remains towards the natural maize products in any price that the latters' will be offered. Similarly, the relatively inelastic supply assumption is based upon the same sceptic that asserts suppliers remain relatively irresponsive to price changes.

4.3 Conclusion

On the specific chapter a detailed description on the manner of applying the GSIM in our occasion has been presented. Firstly, the mandatory data required for the first matrix of imports have been extracted from the WITS database and then they were incorporated in our model. The 52 greater import countries have been chosen and were divided to the respective geographical regions that they belong to. Afterwards, and with regards to the initial tariff baseline, a non-tariff measure has been chosen in order to offset the missing data. This kind of approach required an initial estimation of the approximate number of vessels that operate on each of the proposed lanes of interest. Then, assumptions have been made about the size of the vessel that operates on each lane, by proposing three types of vessel. The comparatively lowest vessel has a total capacity of 3,000 TEU, the medium size container vessel with a total capacity of 5,000 TEU and the ultra-large vessel that carries 10,000 TEU. By that manner all the examined lanes could be served proportionally to the total distance covered. Later, a breakdown of the cost components of the three vessel types has to be made. In essence this reflects the annual freight spend for each of them. By dividing this number with the respective import quantities of each lane we obtain the initial import tariff amounts of each lane of an origin-destination pair. In order to obtain the final tariffs, we will focus on the three proposed alternatives, as well as to their respective costs that we will consider in each occasion. Sequentially, we will apply the aforementioned process under the new implied costs, by assuming both demand and supply elasticities relatively inelastic. The GSIM will be used three times for each of the alternatives. The analysis and the results of this process are being discussed in the following chapter, along with a detailed description of each of the steps that have been followed in order to provide us with the required results.

5 Analysis and Results

This chapter will continue with a further meticulous analysis on the statements of chapter four. It will also be related with the theoretical statements made on the literature review chapter and were related with the three possible alternatives of a ship-owner in order to comply with IMO's MARPOL Annex VI amended regulation. As it was discussed previously any given alternative that would be chosen, would imply different costs and consequently different changes on the output, regarding both producers' and consumers' surpluses, net welfare and trade values. Besides, all three scenarios will be tested for their validity in comparison with the realistic conditions that represent the manner that the container sector is operating nowadays. Furthermore, the base of a concrete conclusion will be built, according to our argumentation and final answers will be given explicitly with regards to our main and complementary research questions.

5.1.1 Initial Bilateral "Tariff" Barrier – Baseline

As it was stated above, the analysis in this research does not involve changes to import tariff rates, thus in lieu of import tariff rates, non-tariff measures, namely the annual cost to transport goods from the given origin region to the given destination region as a percentage of the value of goods traded in the same origin-destination lane were considered.

In order to determine the annual transport cost, 1) the number of ships operating in the origin-destination lane, 2) the freight charter rates per ship size, and 3) an assumption of which ship size was operating in the origin-destination lane was necessary. The following paragraphs provide estimations towards that assessment.

5.1.1.1 Number of Ships per Origin-Destination Pair

According to (Keith and Noble, 2008), there are 50,000 vessels in operation. Of this, containerships are estimated to make up 10% (Lloyd's List Intelligence, 2014). This means approximately 5,005 container vessels are in operation and all are assumed to move maize products. For this analysis, we assumed that the number of container vessels operating in a given origin-destination lane was proportional to the origin-destination lane's percentage of world maize imports and divided by the world's container fleet among the defined origin-destination regions. Due to rounding and the relatively low trade volume, there were cases the number of ships assumed for a given origin-destination region were zero. In these cases, we assumed there to be a minimum of one vessel operating. Appendix 3, summarizes the assignment of the world's containership fleet defined for the specific analysis.

5.1.1.2 Ship Size per Origin-Destination Lane

The initial approach started by extracting information from UNCTAD (2013), Danish Ship Finance (2012) and Drewry (2011) regarding the vessel type used in each of the routes. However, there was not data for all the investigated routes and therefore, some assumptions had to be made. We evaluated each origin-destination lane and made an assumption regarding the vessel size that would likely operate in that lane. Three ship types have been used in this occasion, representing the actual ships operating in the specific lanes. A Feedermax container vessel with a total capacity of 3,000 TEU, has been chosen to facilitate relatively short or nearby routes. A Panamax containership, with a total capacity of 5,000 TEU, has been used in order to serve comparatively longer routes, as it is the biggest vessel that is able to sail through the Panama Canal and mainly serves the Asia- U.S. East Coast and the transatlantic route. A Post-Panamax container vessel, with up to 10,000 TEU total capacity was assumed for any long distance water route, especially coming from Asia or Middle-East. Thus, the above classification was based on small, medium and large TEU capacities. If the route necessary to navigate involved passing through the Suez Canal, then all ship types have been assigned, depending on the length of the covered distance and consequently, all of the three ship categories have been used on the respective classification table. With respect to the Panama Canal, the vessel assigned to the origin-destination lane was either a Feedermax or a Panamax containership, depending also on the length of the covered distance. Appendix 4, summarizes the ship sizes assigned to each origin-destination lane.

5.1.1.3 Annual Freight Spend for Container Service

UNCTAD's Review of Maritime Transport (2013) identified daily charter rates of the three different containership types. Besides, the World Shipping Council (2008) recognizes bunker costs as the major component of the total annual costs of a ship, while in parallel provides a thorough breakdown on operating costs per vessel. Furthermore, and based on numerous of articles and studies, viz (Blom&Borisson, 2008), (Pocuca, 2006), (Polo, 2011), (AECOM, 2012), (Notteboom, 2009), (Drewry, 2004) and (Stopford, 2009) costs breakdown have been assigned, prompted from the annual total costs of the examined vessels. We assumed a 350 day per year operating schedule to establish the annual charter freight cost of a given ship size. Appendix 5, assorts and demonstrates the calculation of the annual charter freight costs per ship per ship size, broken down by cost components.

Considering the size of the vessel and the number of ships assumed to operate in the given origin-destination lane that are given in paragraph 4.2.2.2, the annual charter freight spend per origin-destination lane was calculated as the number of vessels multiplied by the annual charter freight cost per ship.

5.1.1.4 Freight Cost as Percentage of Value Traded

The non-tariff barrier, freight cost, was quantified as a percentage of total import value traded by dividing the annual charter freight spend by the total import value of the respective origin-destination lane.

5.1.2 Compliance Scenarios

The implementation of the MARPOL Annex VI sulphur limitations in 2015 will affect the freight cost of ships carrying import freight into and export freight out of the North Sea region. Freight costs for trade among the remaining origin-destination regions are assumed to be unaffected. Appendix 6, is a summary the lanes for which revised freight rates apply. Lanes with “TRUE” indication are those, which are affected from the regulation, while “FALSE” indication assigns for the unaffected routes.

To analyze the impact of implementing one of the evaluated solutions, it was necessary to first identify and quantify the components of the charter freight rates which would change. At the below paragraphs the general process by which the revised freight rates were reckoned, are being provided. Furthermore, we elaborate on the specific assumptions for each compliance scenario explored and comment on the respective non-tariff measure changes versus the baseline scenario.

In our research, we identified that the possible components which might be affected in order to comply with the revised MARPOL VI regulation would be additional capital investment, including financing charges, and the cost of fuel. Revised annual freight costs per ship size were calculated by adjusting the respective cost component from the baseline annual freight cost per ship up or down by the fixed amount or percentage identified in our research.

Considering the size vessel and the number of vessels determined to operate in the given origin-destination lane, annual freight spend for container services were calculated by multiplying the number of vessels (Appendix 3) by either the revised annual freight cost per ship if the lane would be affected (indicated as TRUE in Appendix 6) or by the baseline annual freight cost per ship if the lane would not be affected (indicated as FALSE in Appendix 6) by the implementation of the new regulation.

The annual freight spend per origin-destination lane was then divided by the import value of goods on the same origin-destination lane to reflect annual freight spend as a percentage of value traded. This revised amount was used as the final bilateral import tariff values for Step 4 of the GSIM model.

5.1.2.1 Scenario 1: Switching from HFO to MGO (Low Sulphur)

The first compliance scenario evaluated was using low sulphur fuel or marine gas oil (MGO) in place of heavy fuel oil (HFO). Making this switch implies changes to the capital cost, and fuel components of the freight rate. For the simplicity of this evaluation, we assumed that the ship owner would upgrade their equipment to operate on low sulphur fuel and that low sulphur fuel would be used for the entire voyage.

Required capital upgrades involve two components; tanks and engines. Additional capital costs were depreciated over 12.5 years (Jiang L., et al, 2014). Financing for the additional capital investment was assumed at 4% per year, consistent with the procurement cost financing assumptions in UNCTAD's 2013 Review of Maritime Transport. An upgrade of the tanks on a single vessel to run on alternative fuel is a cost of $50,000 (IMO, 2009). Costs for retrofitting engines are estimated between $4.56 - $10.45 per kW (ENTEC, 2009). For this analysis, we assumed $10.45 per kW. We then considered the three different ship sizes and their respective engine powers. Approximate estimations on engine powers have been made after combining information from Wartzila (2012) and Man Diesel&Turbo (2013). These are summarized in Appendix 7. With respect to fuel, we considered a premium of 60% for low sulphur fuel versus heavy motor oil (EMSA, 2010).

These changes in total resulted in an increase of the annual freight cost per ship operating in or out of the North Sea SECA region of 55%, consistent across all three ship sizes.

5.1.2.2 Scenario 2: Scrubber Technology

The next compliance scenario evaluated was to add scrubbing equipment to the existing ships. In this scenario, making this switch involves only changes to the capital cost, including financing, of the freight rate. Ship owners would continue to burn heavy fuel oil, thus no changes are assumed for the fuel cost component.

Required capital upgrades involve retrofitting an existing ship with sea-water cleaning equipment. Similar to Scenario 1, additional capital costs were also depreciated over 12.5 years (Jiang L., et al, 2014) and financing for the additional capital investment was assumed at 4% per year, consistent with the procurement cost financing assumptions in UNCTAD's 2013 Review of Maritime Transport.

Sea-water scrubbing equipment on a single vessel is estimated at €148 per kW (Jiang L., et al, 2014). For this analysis, we assumed an August 2014 currency conversion rate of EUR 1 = USD 1.34. Eventually, the same three ship sizes from Scenario 1 have been assigned and their respective engine powers have been taken into consideration in order to extract the new total costs for implementing the specific alternative. Results are summarized in Appendix 8.

5.1.2.3 Scenario 3: Switching to LNG Fuel

The third compliance scenario evaluated was using LNG fuel in place of heavy fuel oil. Making this switch involves changes to the capital cost, including financing, and fuel components of the freight rate.

Required capital upgrades involve retrofitting an existing ship with tanks and engines capable of processing LNG fuel. In this scenario, additional capital costs were depreciated over 10 years (AMEC, 2013). Financing for the additional capital investment was assumed at 4% per year, consistent with the procurement cost financing assumptions in UNCTAD's 2013 Review of Maritime Transport. We found that retrofitting existing ships, one main engine and auxiliary engines, is estimated between €12-16 million (AMEC, 2013). For this analysis, we assumed an August 2014 currency conversion rate of EUR 1 = USD 1.34.

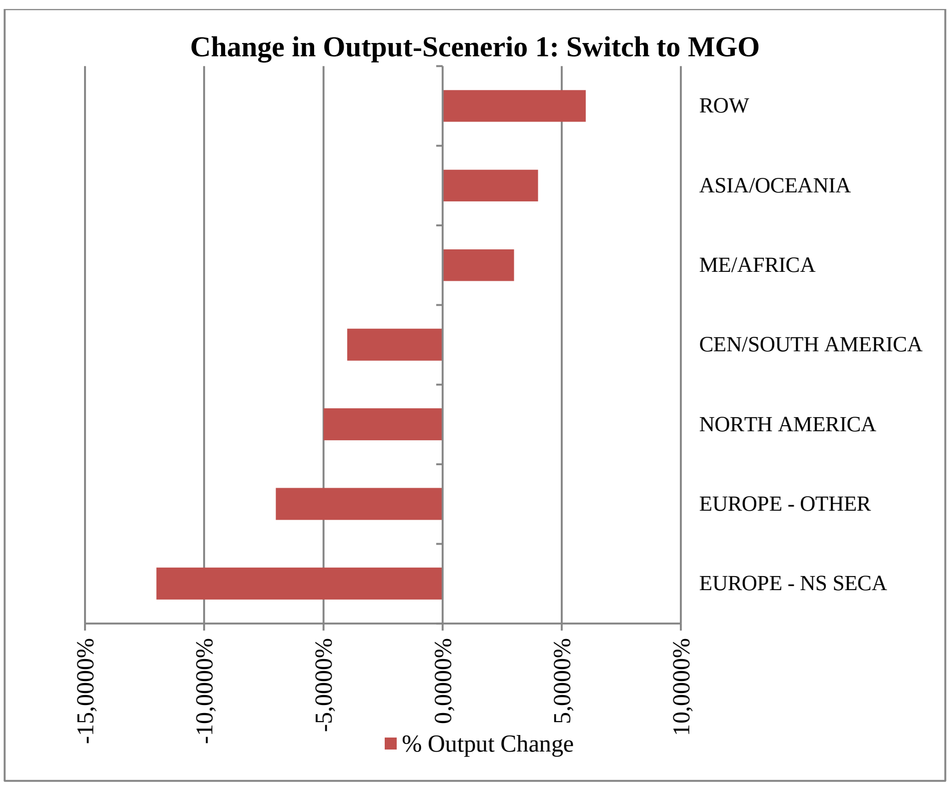
With respect to fuel, we found that LNG fuel was actually 33% less expensive versus heavy fuel oil. The Danish Maritime Authority (2012) estimates the price of LNG at $400 per ton and HFO at $600 per ton based on 2011 rates.

Considering both the increased capital costs and decreased fuel costs, this scenario resulted in an overall increase of the annual freight cost per ship operating in or out of the North Sea SECA region of 72% for Feedermax ship size, of 66% for Panamax ship size, and of 61% for Post-Panamax ship size vessels.

5.2 Changes in Output Analysis

Figure 5-1 illustrates the changes in output after implementing the first proposed solution, viz switching to low sulphur fuel.

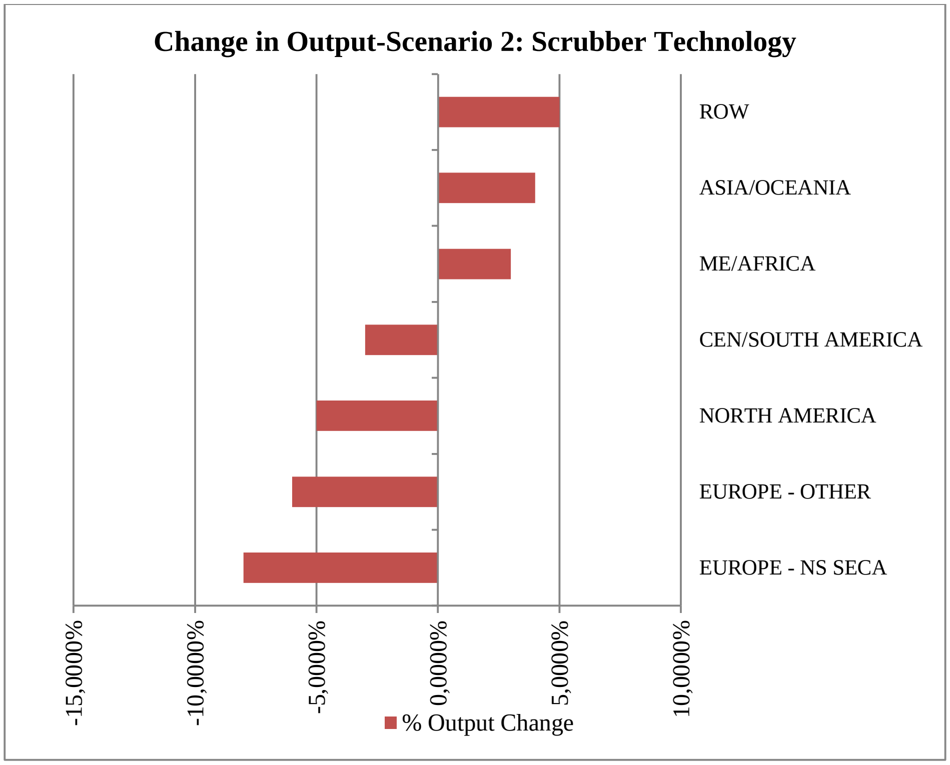
Figure 5-1: Change in Output after implementing the MGO solution



As it is depicted the most affected area through the specific regional classification is the North Sea SECA area, by the significant percentage of -12% in export quantities. This is a plausible fact, as the specific region is directly involved and consequently directly affected by the new regulation. Thus, every vessel that begins its roundtrip from this zone has in advance to meet the new IMO's Directives. This unavoidable consequence is also affecting the turnover time that the vessel needs in order to load and unload the cargo, as this time is also includable. Besides, the remainder European countries seem to be the second most affected areas, with a -0.07% in exports, as they have a hinterland connection with the examined North Sea SECA regions. Towards that path, and as it was discussed in the literature review, a possible change to other modes of transport, such as the "truck only" solution or the selection of railways in order to facilitate cargo transportation are also possible scenarios that may be implemented in order to confront with this issues. Likewise, and because of their significant contribution on the global maize production the American countries, are following a descending path by being affected negatively 0.05% and 0.04% respectively for the North and for the Central and South regions. The U.S. is the primal maize exporter in Europe and thus it is justifiable that the U.S. operators will probably keep a distance on the designated areas, by facilitating cargo transportation from other ports. Moreover, both of the U.S. coasts tend to be included under IMO's sulphur regulation and this probably consists another explanation towards their descended percentages. On the other hand, it is remarkable that the remainder of the examined regions seem to have positive signs on their exporting balance. The specific fact could either indicate an invigoration among their potential trade flows or a change towards the selection of a hub-and-spoke manner of facilitating cargo transportation. China is the second larger maize producer in the world (UNCTAD, 2013) and thus Chinese operators will perhaps begin to facilitate shorter distances and markets or retrieve for smaller ports that will consolidate cargo and alleviate themselves from any induced costs. Appendix 9 provides the detailed percentages and amounts of the new trade values and outputs after implementing the MGO alternative.

The next alternative choice that has been examined is the installation of an abatement technology and specifically the usage of scrubbers. On our study the considered costs are implied from installing a sea-water scrubbing system that its cost considered as €148/kW (Jiang L., et al, 2014). This amount was our lever on configuring the new costs implied, by aligning with the specific alternative. The results that we have gained depict similar trends, as those that have been discussed at the MGO scenario. Both of these solutions use much the same manner of implied cost structure, as the MGO consists of increase in both fuel and capital costs, while the scrubbing technology implies only increase in capital costs. Hence, as it would be logical for both of these solutions to maintain analogous directions. Of course, the difference in this occasion is that the considered costs are less, and thus, the output percentages are lesser in comparison with the low sulphur solution. This fact consists a benchmark for North Sea operators who thrive for an actual and instant solution, as in terms of a short-run period towards 2015's regulation, installation of a scrubbing technology seems to be the most cost efficient one. Figure 5-2 depicts the output after implementing the scrubbing technology.

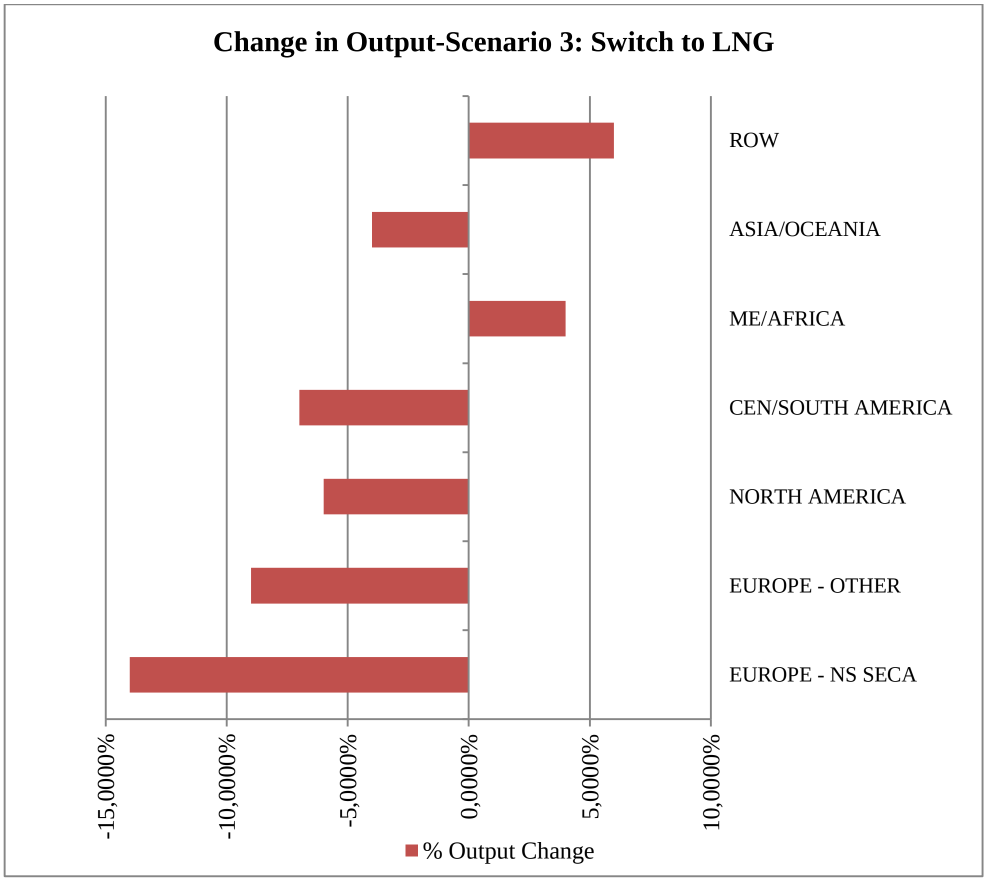
Figure 5-2: Change in Output after implementing the Scrubber Technology Solution



As it was mentioned above, scrubbing implementation choice follows exactly the same routes as those of the MGO solution. Thus, explanations of signs follow the same sceptic process, as the one made before. Besides, we should recall that any vessel that operates with scrubbing technology will continue to use the same type of bunker fuel (EMSA, 2010). Hence, the percentages of the output are normally less than those of the low-sulphur solution, as only retrofitting capital costs have been considered. Appendix 10 summarizes the respective results.

Lastly, the final scenario that consisted a matter of examination was the usage of LNG as an alternative fuel of operating. LNG meets IMO's standards by default and as a result it is probably the most viable long-run choice. Nevertheless, its volatility in the market, in terms of demand and supply, as well as its price fluctuations throughout the years cannot provide us with a clear and solid picture of how its future will look like. In terms of implementing LNG solution instantly, North Sea SECA operators seem to be burdened with the highest costs in comparison with the aforementioned solutions. An outstanding 14% reduction on the exports from the North Sea is being derived, principally due to the excess capital costs that were considered as the highest percentage of the annual freight expenses of a possible LNG container vessel. This amount excesses significantly the reduced bunker costs of the specific bio-fuel that in comparison with the other fuel types is the cheapest on average. Prompted from our results there is a mismatch on the regions that will be mostly affected, with the Central and South America being placed at the third more negative position this time and Asia and Oceania region indicating adverse sign, by having export losses instead of export gains. This is a fact that cannot be justified from the existing literature, but there is no doubt that skepticism and premature and precarious steps that are being made nowadays can partially explain this difference on the outcome of the specific solution. China consists one of the biggest container markets and Chinese operators will probably lurk until they will be convinced before investing their money on changing their fleet to LNG. Figure 5-3 depicts the changes in output and appendix 11 summarizes the corresponding results.

Figure 5-3: Change in Output after implementing the LNG solution

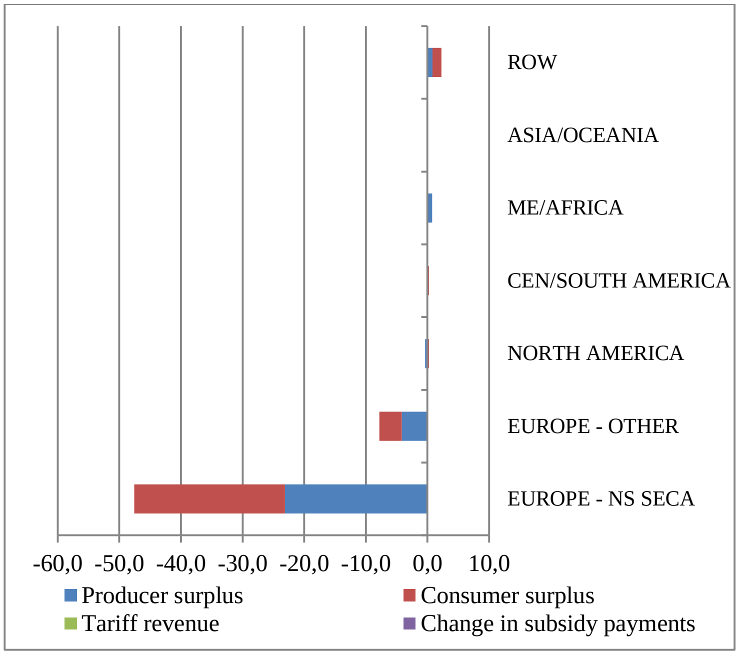


5.3 Change in Welfare Analysis

Figures 5-4, 5-5 and 5-6 depict the changes in net welfare, vis-à-vis the changes in produces' and consumers' surpluses, for each of the alternative solutions separately. In all scenarios the North Sea SECA area is the most affected region after the implementation of MARPOL Annex VI. The output of the net welfare in the North Sea is significantly lower than the changes on the output of the net welfare in all the remainder regions. Once more and as it is depicted the LNG solution causes the largest negative results in comparison with the other the MGO and the scrubbing technology solution. The total loss on welfare on the liquefied natural gas situation is approximately estimated to be around 61.52 million USD, while the second most negative effect is depicted at the MGO solution with 52.55 million losses. Once more the scrubbing technology causes the least negative net welfare loss with approximately 35.10 million losses. Producers' and consumers' surpluses in all occasions seem to follow the same directions and also they appear to be affected proportionally from IMO's regulation. Thus, their contribution on the total losses is almost identical. This fact could be justified by the relatively high elasticity of demand and supply as competition within the container sector is high and thus the producer has the opportunity to extend his choices regarding the company that he will cooperate with. Hence, losses seem to be burdened proportionally. The freight rates increases in the North Sea are the highest in all scenarios, because of the mandatory crossing of the containerships from the SECA, regardless the port of departure, incurring by that manner additional expenses to their operators.

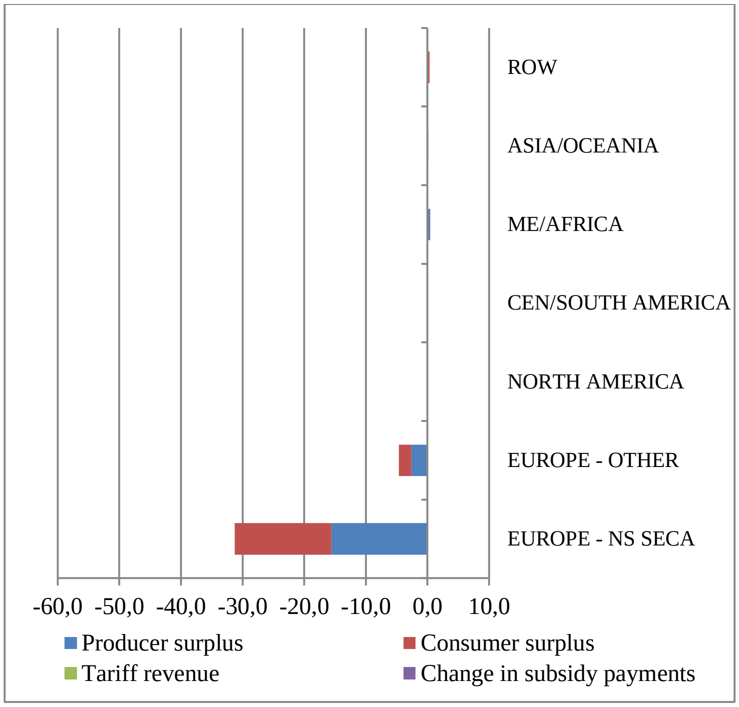
With regards to the MGO solution the European North Sea SECA and the remainder European territories contribute to the negative welfare both with a negative sign. In, contrast and with respect to the North America and Asia Oceania designated regions, producer and consumer surpluses are moving towards to each other with opposite signs. The negative producer surplus in the North America regions exceeds the positive consumer surplus, by 16 million USD, while on the other hand in the Asia/Oceania region the situation this situation is raveling conversely by leaving the net welfare of region with a negative sign of $750,000. The Central-South America region and the Middle East region, while the have a negative producer and consumer surplus respectively, they finally lay both positive net welfares of $90,000 and $710,000. Lastly, the Rest of the World are provides positive results for both consumer and produces surpluses, by leaving a final positive net welfare 2.27 million USD. Appendix 9 provides a table that demonstrates the aforementioned interactions. Figure 5-4 is the graphical representation of that table.

Figure 5-4: Change in Welfare after implementing the MGO solution (in million USD)



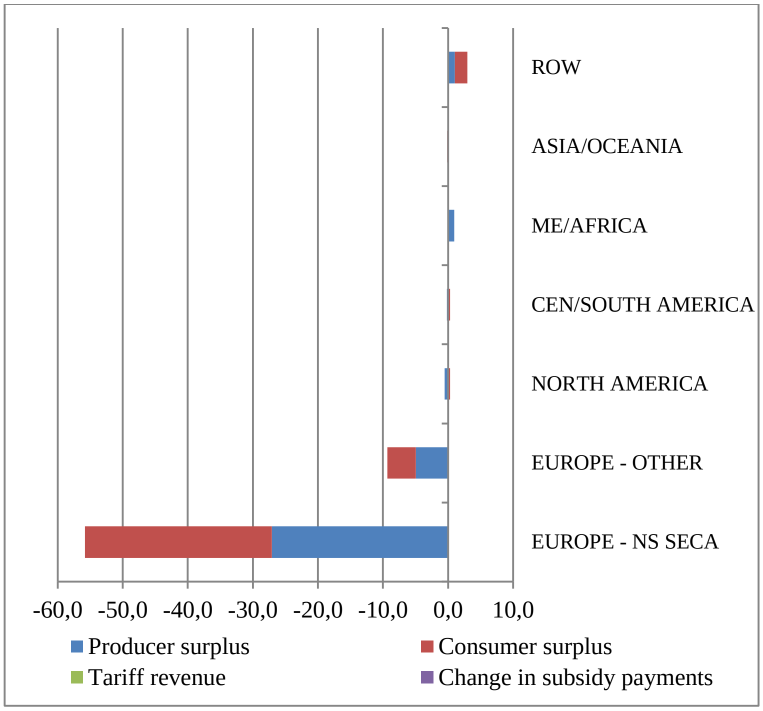
With regards, to the scrubbing technology implementation the North Sea SECA, the European-Other, the North America and the Central and South America regions fluctuate all with negative signs, leaving 31.27 million USD, 4.63 million USD, $93,000 and $14,000 losses respectively. Asia-Oceania region is moving with reverse signs of producers' and consumers' surpluses, by finally extracting a positive net welfare of $135,000. Lastly, Middle East-Africa and ROW regions are giving positive net welfares of $418.000 and $356,000 respectively, by both consumer and producer surplus moving positively. In total the scrubbing solution provides the least negative effects in terms of net welfare globally. Appendix 11 illustrates the above-mentioned fluctuations, while figure 5-5 provides the corresponding graphical representation.

Figure 5-5: Change in Welfare after implementing the Scrubbing Technology (in million USD)



The last examined solution was the usage of LNG. The specific choice provides the largest negative affect of 61.50 million USD reductions in the global net welfare and in parallel it consists the most costly solution for the North Sea SECA operators, by leaving them with a negative sign of 55.81 million USD that represents approximately 90% of the global losses. The Europe-Other region and the Asia-Oceania regions are also having negative impacts on their net welfares with 9.3 million USD and $130,000 respectively, by both providing negative producer and consumer surpluses signs. Three of the other regions are moving conversely, in terms of producer and consumer surpluses signs, viz North America, Central-South America and Middle East-Africa. The former is finally leaving a negative total welfare of $200,000, while the remainders are leaving both positive net welfares of $128,000 and $869,000 respectively. The ROW region contributes to the total net welfare by having a positive sign for both consumer and producer surpluses and finally lays a positive contribution of 2.9 million USD. Appendix 11 provides a consistent table of these amounts, while figure 5-6 is a graphical representation of these claims.

Figure 5-6: Change in Welfare after implementing the LNG solution (in million USD)



5.4 Conclusion

On this chapter, the results of the three alternatives have been discussed in depth. The outcomes of chapter four gave us the insight to empirically test our model three times over our proposed solutions. Through the implementation of the GSIM model we finally extracted the answers on our research questions. The most affected area after the implementation of the MARPOL amended regulation is the North Sea SECA region. The rest of the regions have a smaller decrease because only part of their exports are directed to the North Sea, as they also export large quantities to other regions of the world without sailing through the North Sea. The upshot of our examination displayed a total loss in both exports and net welfare globally for the maize commodity, regardless the alternative that will be chosen to be in force.

Besides the LNG solution seems to be the most costly for ship-operators that serve the North Sea SECA lane, while implementing a scrubbing abatement technology, appears to be the most cost effective solution, at least in terms of a short-run investment. All in all, the LNG solution affects the global trade of maize with the most negative manner, in terms of both global exports and global net welfare. The MGO solution is the second most expensive alternative, while in all of the occasions the usage of a scrubbing system consists the most harmless and profitable one. The percentage that both consumer and supplier are contributing to the total losses seem to be almost identical, as both elasticities of demand and supply are relatively elastic, especially due to the high competition that is engaged within the container sector.

6 Conclusion

The analysis based on previous literature of the various compliance alternatives to the MARPOL Annex VI sulphur limitation regulation starting from January 1st 2015 that limits a fuel's sulphur concentration to a maximum of 0.1% m/m in specific designated areas, called SECAs, has provided qualitative background to the issue that is under investigation. Thus, in chapter two an extensive discussion has been made on the compatible alternatives that ship-owners have at their disposal in order to align with the amended regulation. These elements were later used in order to fulfill our model and help us to extract the respective results. On chapter three possible methodological approaches have been evaluated with the usage of the GSIM model excelling as it aligns perfectly with the scope of our research. In order to estimate the economic impact on the global trade of maize, each of the three options that have been discussed in the literature review part, viz switching to MGO, usage of scrubbers and switching to LNG bio-fuel, have been tested. In chapter four the empirical conversion of the theoretical framework of the proposed model that had to be made, in order to comply with the scope of this thesis, is actually being presented. As we had to cope with initial and final bilateral tariffs we had to contemplate a non-tariff measure in order to offset this mismatch, by choosing freight rates as our lever towards this manner. Then, we calculated the extra costs, by using our information from chapter two, in order to extract the matrix of final bilateral tariffs. Then, the GSIM model has been run three consecutive times, for each of the three examined alternatives and finally provided us with the responding and requested answers towards our issue. After recalling our main research question that was*:*

"What is the impact on the maize market due to the increased costs associated with the vessels operating in the North Sea SECA region and having to comply with the MARPOL Annex VI sulphur limitation regulation in 2015?", we can extract the following results:

The analysis in chapter five indicates that a total loss in both imports-exports and net welfare will be imposed globally for the maize commodity, regardless the alternative that will be chosen to be in force. The most affected region in terms of reduced exports, net welfare, as well as consumer and producer surplus is the European North Sea SECA. Both imports and exports are affected since everything passes through the North Sea SECA and incurs additional costs. Exporters' welfare loss is due to decreased quantities exported. Importers' welfare loss is on account of the higher price which will be charged for transportation of maize. Both of these groups appear to participate equivalently on the total sum of net welfare as their elasticities have been judged as relatively inelastic. The second most affected area was the remainder of Europe region, especially due to the reason of the direct hinterland connectivity that has with the North European SECA. The rest of the regions seem to have positive signs with respect to export output. Finally, for the remaining regions producers' and consumers' surpluses seem to remain relatively unaffected, with slightly positive or slightly negative results, depending on each of the alternatives.

The LNG solution that according to the existing bibliography is being presented as the most volatile and hardly to be projected appears to be the priciest as it requires the most significant initial capital investment. The least expensive alternative is the usage of scrubbers as it does not require different bunker costs and the capital investment that has to be made is relatively low. The MGO solution is lying in the middle as it requires extensive additional bunker costs and relatively low capital investment. Overall, the decisions as to how they will address this issue are left to each private company by means of strategic management.

6.1 Limitations

In order to correspond with the research question of our study, specific limitations have been considered. At first, in order to calculate the freight rates per lane, it was assumed that all the containerized moving cargo is comprised only of maize commodities. Besides, the ships that have been considered represent a sample of the world fleet, as the total ship types cannot be segmented in only three vessel sizes. Moreover, and due to the proportional split of the world's container fleet, a bias of zero vessels operating within specific lanes has been noticed, a fact that was actually offset with one ship for each of these lanes. Neither the former nor the latter could be considered as identical occasions that reflect realistic circumstances. Lastly, general limitations that could be considered concern any other factors that have been left outside of this thesis, as the elements that affect the global picture of trade for the specific commodity, include also other socio-economic factors that have not been taken into account in this thesis.

All in all, recommendations for further research could be retrieved, in terms of the possible changes in demand, supply and the consequent imposed costs. There are several implications that are being arisen from the selection of each alternative, and thus, changes in supply capacity and changes in demand could be probably considered as the most significant and important areas for further study.

Moreover, cargo transferability could be also considered as another zone of interest, especially due to the probable changes on the selected mode of transport. No doubt, increased transfer costs will definitely imply changes in the existing routes. This is an issue that has to be addressed from the shipping companies, as necessary precautions need to be considered towards any kind of unfair competition.

Another matter of interest concerns the on-shore infrastructure for LNG, as till now both suppliers and users keep a silent behavior towards the future of this alternative. Thus, light must be shed on the circumstances under which establishing cooperation bonds is profitable for both groups.

Finally, individual subsidies towards these upcoming technologies are also a matter of concern that directly affect the outputs of the proposed model. Hence, further investigation in any state aid that will be available is also included on the variable parameters. Norway has already started to provide financial encouragement on the ship-owners that tend to comply with the proposed "green" techniques and it would be useful to weigh the respective outputs, with regards also to the remainder of the countries that consist the total European SECA, vis-à-vis both the North and the Baltic Sea.

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Appendices

Appendix 1: Definition of Regions

Europe-N.S. SECA		
BEL-Belgium	NLD-The Netherlands	SWE-Sweden
DEU-Germany	FRA-France	NOR-Norway
DNK-Denmark	GBR-The United Kingdom	
Europe-Other		
BLR-Belarus	GRE-Greece	PRT-Portugal
BGR-Bulgaria	FIN-Finland	POL-Poland
CZE-Czech Republic	IRL-Ireland	RUS-Russian Federation
CHE-Switzerland	HUN-Hungary	ROM-Romania
EUN-European Union	LTU-Lithuania	SVK-Slovak Republic
ESP-Spain	ITA-Italy	
North America		
USA-United States	CAN-Canada	MEX-Mexico
Central & South America		
ARG-Argentina	COL-Columbia	PER-Peru
BRA-Brazil	CHL-Chile	
Middle East & Africa		
DZA-Algeria	SAU-Saudi Arabia	LBN-Lebanon
JOR-Jordan	ZAF-South Africa	TUR-Turkey
ISR-Israel	PAK-Pakistan	

Asia & Oceania

CHN-China	KOR-Korea Republic	THA-Thailand
IND-Indonesia	KAZ-Kazakhstan	SGP-Singapore
AUS-Australia	NZL-New Zealand	VNM-Vietnam
HKG-Hong Kong	JPN-Japan	

Appendix 2: Import Data Summary

	Europe-N.S. SECA	Europe-Other	North America	Central & South America	Middle East & Africa	Asia & Oceania	ROW
Europe-N.S. SECA	1809604.372	874057.785	19446.074	125499.347	8561.863	10024.464	758620.25
Europe-Other	1019121.502	1530616.073	116194.163	473039.525	43884.345	8302.395	917961.29
North America	6970.85	6596.491	3211869.477	725597.112	369874.75	1150.1	1699267.13
Central & South America	5870.977	420.779	99471.246	1528538.718	29.888	1406.925	450897.52
Middle East & Africa	139046.692	467104.29	167676.797	1411846.073	24623.302	42538.818	250697.23
Asia & Oceania	21172.818	241690.369	6485617.956	1939029.412	65398.191	97954.809	403624.11
ROW	426285.75	907822.78	500890.36	748297.45	1046808.52	850963.12	1799783.56

Appendix 3: World Containership Fleet- Regional Breakdown of Vessels

WORLD FLEET			**50,000 Source: Total fleet-Keith,M**					
CONTAINERSHIPS as % of World Fleet			10% Source: Lloyd's List Intelligence 2014					
WORLD FLEET- CONTAINER VESSELS			5,005					
				Destination				
Origin	EUROPE-NS SECA	EUROPE-OTHER	NORTH AMERICA	CENTRAL&SOUTH AMERICA	MIDDLE EAST&AFRICA	ASIA&OCEANIA	ROW	TOTAL
EUROPE-NS SECA	267	129	3	19	1	1	112	532
EUROPE-OTHER	151	226	17	70	6	2	136	608
NORTH AMERICA	1	1	475	107	55	480	251	1370
CENTRAL&SOUTH AMERICA	1	1	15	226	1	1	67	312
MIDDLE EAST&AFRICA	21	69	25	209	4	6	37	371
ASIA&OCEANIA	3	36	479	287	10	14	60	889
ROW	63	134	74	111	155	126	260	923
TOTAL	507	596	1088	1029	232	630	923	5005

Appendix 4: Ship Types Operating in each Origin-Destination Lane

	Ship Sizes						
	Europe-NS SECA	Europe-Other	North America	Central&South America	Middle East & Africa	Asia&Oceania	Row
Europe-NS SECA	Feedermax	Feedermax	Panamax	Panamax	Post-Panamax	Post-Panamax	Panamax
Europe-Other	Feedermax	Feedermax	Panamax	Panamax	Post-Panamax	Post-Panamax	Panamax
North America	Panamax	Panamax	Panamax	Panamax	Post-Panamax	Panamax	Panamax
Central&South America	Panamax	Panamax	Panamax	Feedermax	Post-Panamax	Feedermax	Panamax
Middle East & Africa	Post-Panamax	Post-Panamax	Post-Panamax	Post-Panamax	Feedermax	Panamax	Panamax
Asia&Oceania	Post-Panamax	Post-Panamax	Panamax	Panamax	Panamax	Feedermax	Panamax
Row	Panamax	Panamax	Panamax	Panamax	Panamax	Panamax	Panamax

Appendix 5: Principal Containership Freight Rate Components

Freight Rate Cost Comparison for Different Vessel Sizes					
Source: Unctad 2013 Review of Marotime Transport					
Ship Size		Feedermax	Panamax	Post-Panamax
Costs per Day (in USD)		5,678.68	12,454.10	24,908.20
Operating Days	350			
Capital Costs				
Ship Financing	5%	99376.9	217946.75	435893.45
Ship Procurement	2%	39750.76	87178.7	174357.38
Additional Capital Investment				
Operating Costs				
Manning	10%	198753.8	435893.5	871786.9
Port Charges	5%	99376.9	217946.75	435893.45
Classification	1.99%	39552.0062	86742.8065	173485.5931
Repair&Maintenace	5%	99376.9	217946.75	435893.45
Registration	0.01%	198.7538	435.8935	871.7869
Insurance	3%	59626.14	130768.05	261536.07
Commissions	4%	79501.52	174357.4	348714.76
Management	4%	79501.52	174357.4	348714.76
Profit	5%	99376.9	217946.75	435893.45
Voyage Costs				
Bunker Costs	55%	1093145.9	2397414.25	4794827.95
Total Annual Cost per Vessel (in USD)		1,987,538	4,358,935	8,717,869

Appendix 6: Summary of Affected Lanes

Lanes affected from the new regulation							
	Destination						
Origin	Europe-NS SECA	Europe-Other	North America	Central/South America	Middle East/Africa	Asia/Oceania	ROW
Europe-NS SECA	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Europe-Other	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
North America	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Central/South America	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Middle East/Africa	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Asia/Oceania	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
ROW	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE

Appendix 7: Ship Engine Powers

Ship Type	**Feedermax (3,000TEU)**	**Panamax (5,000TEU)**	**Post-Panamax (10,000 TEU)**
Engine Power	3,897 kW	12,853 kW	29,632 kW

Appendix 8: Scrubber Installation Costs

Ship Type	Feedermax	Panamax	Post-Panamax
Total Installation Costs (€)	2,564,294	6,261,179	13,103,405

Appendix 9- Scenario 1: Switch to MGO

Losses in trade values after the MGO solution

N.S. SECA Initial Trade Values	N.S. SECA Final Trade Values
1,809,604.372	1,811,775.8972464
874,057.8	887,669.64046
19,446.074	19,455.797037
125,499.3	125,549.49972
8,561.863	8,564.4315589
10,024.464	10,028.4737856
758,620.253	759,075.4251518

Induced Effects

	Producer Surplus (in million USD)	Consumer Surplus (in million USD)	Net Welfare Effect (in million USD)	Output Change (%)
Europe-N.S. SECA	(23.14)	(24.43)	(47.57)	(0.12)
Europe-Other	(4.19)	(3.63)	(7.82)	(0.07)
North America	(0.39)	0.22	(0.16)	(0.05)
Central & South	(0.12)	0.21	0.09	(0.04)

America				
Middle East & Africa	0.76	(0.05)	0.71	(0.03)
Asia & Oceania	0.017	(0.092)	(0.075)	(0.04)
ROW	0.81	1.45	2.27	(0.06)
Total	(26.25)	(26.32)	(52.55)	

Appendix 10 -Scenario 2: Scrubber Technology

Losses in trade values after installing the scrubber abatement technology

N.S. SECA Initial Trade Values	N.S. SECA Final Trade Values
1,809,604.372	1,811,052.0554976
874,057.8	874,582.23468
19,446.074	19,455.797037
125,499.3	125,536.94979
8,561.863	8,564.4415588
10,024.464	10,028.4757856
758,620.253	758,999.5631265

Induced Effects				
	Producer Surplus (in million USD)	Consumer Surplus (in million USD)	Net Welfare Effect (in million USD)	Output Change (%)
Europe-N.S. SECA	(15.59)	(15.67)	(31.27)	(0.08)
Europe-Other	(2.59)	(20.39)	(4.63)	(0.06)
North America	(0.036)	(0.057)	(0.093)	(0.05)
Central & South America	(0.01)	(0.003)	(0.014)	(0.03)
Middle East & Africa	0.4	0.009	0.418	(0.03)
Asia & Oceania	0.15	(0.018)	0.135	(0.04)

ROW	0.14	0.2	0.356	(0.05)
Total	(17.53)	(17.756)	(35.106)	

Appendix 11 -Scenario 3: Switch to LNG

Losses in trade values after the LNG solution

N.S. SECA Initial Trade Values	N.S. SECA Final Trade Values
1,809,604.372	1,812,137.8181208
874,057.8	874,844.45202
19,446.074	19,457.7416444
125,499.3	125,587.14951
8,561.863	8,565.2877452
10,024.464	10,028.4737856
758,620.253	759,075.4251518

Induced Effects				
	Producer Surplus (in million USD)	**Consumer Surplus (in million USD)**	**Net Welfare Effect (in million USD)**	**Output Change (%)**
Europe-N.S. SECA	(27.063)	(28.754)	(55.817)	(0.14)
Europe-Other	(4.965)	(4.36)	(9.326)	(0.09)
North America	(0.519)	0.318	(0.2)	(0.06)
Central & South America	(0.16)	0.288	0.128	(0.07)
Middle East & Africa	0.937	(0.068)	0.869	(0.04)
Asia & Oceania	(0.013)	(0.118)	(0.13)	(0.04)
ROW	1.059	1.912	2.971	(0.06)
Total	(30.724)	(30.782)	(61.506)	