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The Economic Impact of Sulphur Emissions from Ships and MARPOL Annex VI

By

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Acknowledgements

This year has been a further step in understanding the importance and having the joy of gaining valuable knowledge. This challenging and demanding step wouldn't be as easy as it is without the presence of those who were always with me with their help.

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Abstract

In this paper the possible effects of MARPOL Annex VI revisions on the shipping industry have been analyzed with a focus on the impacts of the rising fuel costs on maritime freight rates. Requirements of the Marpol Annex VI and its applicability through time have been explained and specifications of marine fuels, bunker consumption of different ships and some technical applications are broadly analyzed in line with the annex.

Impacts of future fuel cost rises on maritime freight rates are analyzed in two different markets. Aframax, Suezmax and ULCC/ VLCC spot rates, dry bulk commodity spot rates, such as; iron ore, grain and coal spot rates are analyzed with multiple linear regression analysis under various models. The fuel switch cost increase estimations depending on timelines and different sulfur contents are made in line with the average results of the currently available relevant literature.

Although, there seems to be a significant cost increase, the reflections of the percentages on the freight rates are estimated to be slightly different on different markets. Dry bulk commodity spot rates are estimated to reflect the increase of the fuel costs on the freight rates with the highest levels up to 44%. Tanker spot rates are estimated to rise considerably lower with values varying between 0.9% and around 3%.

Keywords: Annex VI revisions, oil prices, freight rates

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CHAPTER 1: Introduction

1.1 Thesis outline and objectives

The revisions of MARPOL Annex VI which brings further requirements for controlling the sulfur content of the fuels used on board ships has implied considerable effects on the future concerns of shipping industry. While future supply and availability characteristics of such marine fuels are not clear yet, the possible cost changes increased many concerns in the industry. Although, not extensive, a few studies done by mostly international and national organizations focused on the future pricing of marine fuels, the impacts of the revision in the modal split change in Emission Control Areas (ECA), supply and availability of future marine fuels and some technical applications. The available studies are done in the regional level mostly focusing on short sea shipping. Many major possible impacts with high levels of uncertainty make the topic even more challenging.

In this study the consequences of MAPOL Annex VI revisions will be analyzed with a focus on the impacts of future fuel costs on maritime freight rates. Apart from a regional or sector specific approach, a more globally covering analysis will be carried out. The impacts of increasing fuel costs on the maritime freight rates, such as; tanker spot rates, dry bulk commodity spot rates namely, iron ore spot rates, grain spot rates, coal spot rates, will be analyzed. The reason behind the selection of these freight rates is the common usage of voyage charters in for example the bulk markets and in some bigger size tankers. In most of the time charter agreements, the fuel consumption cost is for the charterer's responsibility which doesn't reflect the impacts of fuel oil prices on the freight rates. Therefore, spot rates are considered for assessing the impacts of fuel oil prices on the freight rates.

The improved fuel oil quality used on board ships with the revisions of MARPOL Annex VI will cause an increase in the fuel costs. In this paper the impact of increasing fuel oil costs on the mentioned freight rates will be analyzed. The reflection of the effects of fuel oil costs on the freight rates will be assessed in line with related past data. While doing so, several models for different scenarios will be developed and tested with multiple regression analysis methods for developing linear equations and being able to estimate the future impacts.

The paper consists of seven chapters of which first and last chapters are introduction and concluding chapters respectively.

In chapter 2, MARPOL Annex VI regulations, its revisions and the future requirements of the annex are summarized based on the legislation. Some important graphical designs are brought to make it easy to understand the matter. A specific insight is given to the subject of the study namely as the revisions. Specific terms and definitions which will be used in the following parts of the study are explained. Lastly, own personal experience and interpretation of the legislation have been further guides in this part of the study.

Chapter three focuses on marine fuels and their specifications while discussing the issues relating on future availability and pricing. Bunker consumption of vessels are explained broadly with some technical examples. World fleet bunker consumption and estimation results are also included in the chapter. Chapter three is developed to be a guide in understanding the specifications of marine fuels, their price trends and bunker consumption of the vessels. These issues will be used and further developed in the following chapters.

Chapter four discusses the outcomes of a few relevant and available research carried out on investigating the consequences of MARPOL Annex 6 revisions. The reason behind the literature review to be included as a separate chapter is that, it supplies an overall understanding of the impacts of the Annex VI revisions and partially relates to some other chapters as some reference points for the estimations is also derived from the chapter.

Chapter five forms one of the main parts of this study where the mathematical analysis and modeling of the data is carried out. The impacts of increasing fuel costs on the maritime freight rates is modeled and analyzed in different scenarios. Relationships between fuel oil prizes are estimated for mainly two markets. Tanker spot rates, and dry bulk commodity spot rates are considered for the estimations. The approach is carried out by multiple regression analysis of the formed models to see the relationships between the independent and explanatory variables. After all the elasticities of freight rates to bunker prices are estimated by combining with chapter 6.

Chapter six is where we combine the data and give the final outcomes of the mathematical analysis. Firstly the future fuel oil cost increases are estimated for various scenarios in relation with the annex six revisions. The outcomes of the future fuel price increase estimations depend on the relevant studies. Many of the studies that are included in chapter four have estimated future prizes of fuel oils depending on reliable surveys carried out by governmental bodies, shipping operators, oil associations and refineries. Fuel oil cost increase estimations are done by taking the overall average of all relevant studies. After all we estimate the impact of fuel cost increases by combining the elasticities obtained in chapter five and the pricing models obtained in chapter 6.

Finally, chapter seven represents concluding remarks with an overall summary of the study and gives relevant recommendations.

1.2. Methodology of approach

The research on a very hot subject which may have considerable effects on the shipping sector globally has been very challenging as it is always very hard to analyze trends and possibilities of unknown future. Although, there is a high level of uncertainty in the matter, correct approaches taken in estimating the unknown future of shipping is worth to all efforts given. With personal ambition and experience on the matter, this study tries to combine many approaches such as;

- Academic knowledge through published books, articles, lecture notes of this year and the valuable information gained in this course;
- Relevant market reports and the data supplied by major shipping and ship broking companies published in both paper and electronic format;
- Mathematical modeling for statistical tests and obtaining the relationships between relevant variables;
- Personal in-depth in the matter improved by the valuable recommendations and ideas of many professionals.

The challenge of the approach mainly lay behind the high uncertainties and complex cost structure of some shipping markets.

Two main literature reviews are carried out. First is done to investigate the relevant research on the overall impacts of Annex VI revisions. Secondly, in the mathematical parts, the literature review for modeling the determinants of shipping freight rates is used as a guide and several models are developed with the guidance of the literature.

For estimating the impacts of fuel oil prices on freight rates, several linear models are developed using multiple linear regression analysis methods. The freight rates are considered as a function of variables such as; fuel prices, the volatility in fuel prices and the related indexes for different markets. By using the past data, models are tested for being statistically significant and the elasticities are estimated from the outcomes of the models. Possible price increases of marine fuels in regards with the revisions are estimated in line with the extensive surveys of the related literature and studies. With the help estimated elasticities and fuel price increase scenarios the impacts on the freight rates are calculated as the outcomes and guidance of various chapters are combined in assessing the results of the study.

Chapter 2 MARPOL Annex VI Requirements, Revisions, Coverage

2.1 *Introduction*

The International Maritime Organization (I.M.O.) which is an authorized agency of the United Nations was established in 1958 as an international regulating and promoting authority on maritime safety. After the foundation of I.M.O., many major cases and disasters leaded the organization to establish new conventions on maritime safety and maritime pollution. Consequently, International Convention for the Safety of Life at Sea (S.O.L.A.S.) and International Convention for the Prevention of Pollution from Ships, MARPOL 1973/1978 entered into force. Prevention of Air Pollution from Ships, Annex VI of MARPOL 73/78 was established in 1997 by the amendments to MARPOL convention. The annex which defined the first regulations under Tier I in 1997 after included Tier II and Tier III regulations by the amendments in 2008.

Unlike most of the other annexes, the reason for the establishment of Annex VI hasn't been a disaster but the increasing concerns of the society. It is a well known fact that, merchant ships are allowed to use one of the world's lowest quality fuel oil. These types of degraded fuel oils contain higher amounts of asphalt, metallic compounds, carbon residues, sulfur (up to 5% wt. (weight per cent), high viscosity and low volatility (Peng, Lin and Jong, 2005). Although, the bunker costs can amount up to 50% of the total operating costs of a ship (Lin and Chen 2004), high amounts of nitrogen oxides(NOx), sulfur oxides(SOx), carbon di oxide(CO2), particulate matters, ozone depleting substances etc., made I.M.O. establish an Annex regulating the emissions from ships.

The Annex mainly contains regulations for controlling the Nitrogen Oxide (NOx) and Sulfur Oxide (SOx) gases found in the ship exhaust emissions. After defining the ozone depleting substances, it requires no deliberate emission of those. In terms of emissions and bunker fuel specifications, the annex underlines measures both globally and regionally. While defining the emission control areas (E.C.A.s), it sets stricter regulations for those. Special technical requirements are set according to gross tonnage and ship type while different requirements are brought forward in regards with the construction date. From 1997 to 2008 the annex has been revised several times and the establishment of the rules has been set gradually for the related parties to cope with.

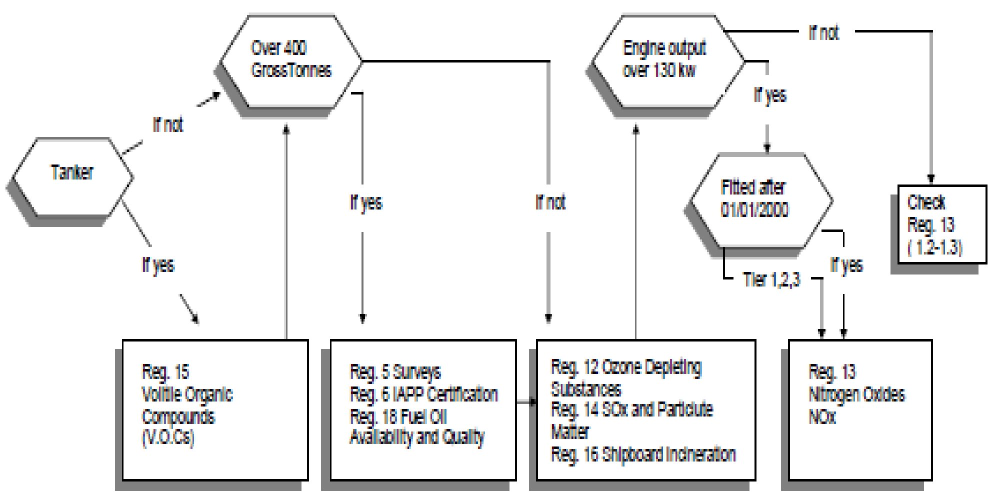
In this chapter, the requirements of MARPOL Annex VI, its coverage and emission control areas will be briefly explained. While mentioning certain legislations, gradual changes in the annex will be mentioned. Latest revisions will be analyzed and explained.

2.2 *Annex VI Requirements*

Annex VI of Marpol 1973-1978 Convention includes definitions and regulations for reducing and preventing the air pollution from ships. The annex brings regulations for mainly reducing the emissions of SOx gases, NOx gases and particulate matters. The applicability of the regulations depends on the specified ship types and building dates with their engine types and outputs.

Figure 1 illustrates a brief summary of the applicability and different regulations of Annex VI to different kinds of ships according to their types, gross tonnage and engine output. As it can be seen from the figure, if the vessels are not tanker vessels, 400 gross tones of capacity has been the bottom line for many applications. Moreover, 130 kw of engine output and the major conversion or new building dates for the engines as 1st of January 2010 have been other determining points for the applicability of different legislations.

Figure 2.1 Applicability of MARPOL Annex VI Regulations



Source: Own Preparation, Data derived from MARPOL Annex VI

A ship of 400 gross tones or above is required to pass under several surveys before she is put into service or with intervals not exceeding five years. The main aim of this application is to ensure that the arrangements, material, equipment, fittings etc. fully comply with the requirements of the annex. (*MARPOL Revised Annex VI, Regulation 5*) The pre-determined surveys include annual, intermediate and special surveys. As the surveys are done incompliance with the regulations, certification of the vessels and the related equipment is mandatory under regulation 6 of the annex. One of the main certificates known as International Air Pollution Prevention Certificate is issued for the vessels. Even the vessel is constructed before the establishment date of the annex, a survey and in following certification has been set mandatory if the vessel is subject to Annex 6 regulations.

Under regulation 15 of the annex, specific measures are brought for the control of the emissions of volatile organic compounds (VOCs). This regulation mainly covers and controls tanker vessels which can cause the emission of specific gases and compounds during loading, discharging or sea carriage of the cargoes. Since, the tankers carry liquid cargoes which may generate their own vapors and use special safety and line systems for safe loading, discharging carriage and storage of the cargoes; they may cause emission of volatile organic compounds. For the control of these emissions certain vapor emission control systems are being used by both tanker vessels and terminals. For tankers carrying crude oil, an onboard VOC management plan and its application is set mandatory for controlling the actions taken to comply with the regulation and for minimizing the amount of VOC emissions during loading, carriage, discharge of the cargo or crude oil washing procedures.

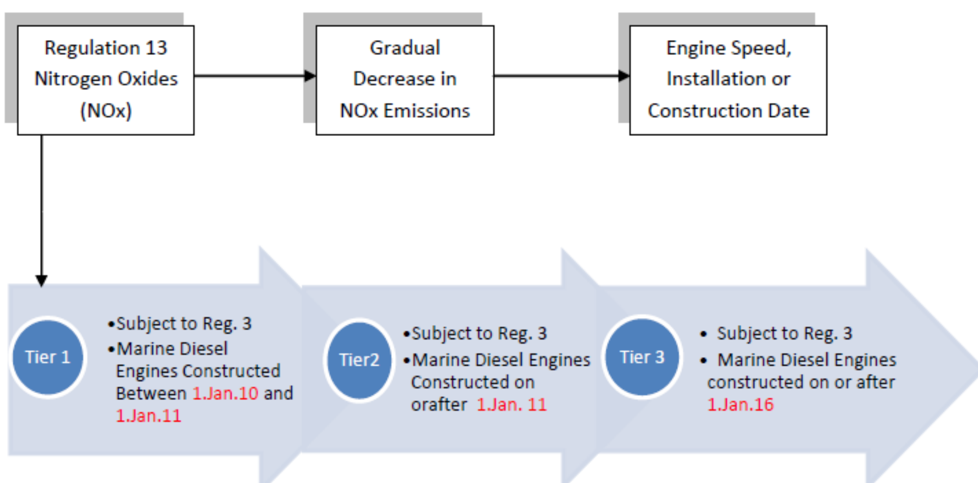
Shipboard incineration which is basically the burning process of certain materials on board the ship in certain types of incinerators is controlled under regulation 16 of the annex. While prohibiting incineration of certain materials such as those subject to Annex I, II, III, sewage sludge, heavy metals etc., it also sets standards for the incineration equipment and the responsible personnel. Moreover, the regulation bans the incineration of certain materials inside the port, harbor or terminal limits.

Apart from previously summarized regulations, the annex mainly sets regulations and standards for regulating the emissions of NOx, SOx and ozone depleting substances. The latest revisions bring new requirements in regulating the sulfur contents of any fuel oil used on board ships and bring gradual Tier regulations for controlling the NOx outputs from the engines of the vessels. The revisions to these certain regulations bring mandatory applications according to given time periods and require future actions to be taken.

2.2.1. Controlling Emissions of Nitrogen Oxides (NOx)

For controlling the Nitrogen Oxide (NOx) emissions, the annex states implementation of certified and standard equipments for vessels built with diesel engines with a power output of 130kW or more, constructed or went through major conversions on or after 1st January 2000. The Annex gives certain measures for the operation of the diesel engines to maintain the specified NOx emissions limits. For complying with NOx requirements, the personnel on board don't have much operational responsibilities. IMO requires standard equipment working within the given limits. All the equipment used, have a special IMO technical number. Once the company assures to comply with the requirements, the personnel on board are only responsible for maintaining the certified equipment.

Figure 2.2 Requirements for controlling NOx emissions and Tier I,II,III standards.



n = rated engine speed	Tier 1	Tier 2	Tier 3
n < 130 rpm	17.0 g/kWh	14.4 g/kWh	3.4 g/kWh
130 rpm ≤ n < 2000 rpm	$45 \cdot n^{(-0.2)}$g/kWh	$44 \cdot n^{(-0.23)}$ g/kWh	$9 \cdot n^{(-0.2)}$ g/kWh
2000rpm ≤ n	9.8 g/kWh	7.7 g/kWh	2.0 g/kWh

Source: Own preparation, data derived from MARPOL Annex VI

As it can be seen from figure 2, I.M.O. sets three tiers of which first one has been introduced in 1997 and the other two have been introduced in 2008. For reducing the nitrogen oxides emissions from ships, gradual time periods have been given with the allowable emission limits. Subject to Tier I, marine diesel engines constructed between 1st of January 2010 and 1st of January 2011are allowed to produce between 9.8 grams to 17.0 grams of total weighted emissions of NO2 per kWh depending on their crankshaft revolutions per minute. The engines which are constructed after 1st of January 2011 are allowed to emit NO2 gases within the given limits of 7.7 g/kWh to 14.4 g/kWh. The third and the last tier further reduce the limits to between 2.0 g/kWh and 3.4 g/kWh. All the limits in three tiers are set according to the construction or installation date depending on the rated engine speed grouped as less than 130rpm, between 130 rpm and 2000 rpm and more than 2000 rpm.

As the revisions set for reducing the NOx emissions will bring technological obligations on the related industry players, there is no doubt that there will be an economic cost and technological improvement process. The organization will therefore, review the standards and implementations, commencing by 2012 and ending no later than 2013. Although the time limits and technical measures are set in the tiers, they may be subject to changes depending on the review of the organization.

2.2.2 Controlling the Sulfur Oxides (SOx)

Emissions of sulfur oxides are mainly regulated by controlling the sulfur content of the fuel oil used on board the ships. Differentiating from the applications for the nitrogen oxides, rather than setting technical guidelines for marine diesel engines, the organization brings mandatory requirements for the fuel oil to be used. .

2.2.2.1 Emission Control Areas

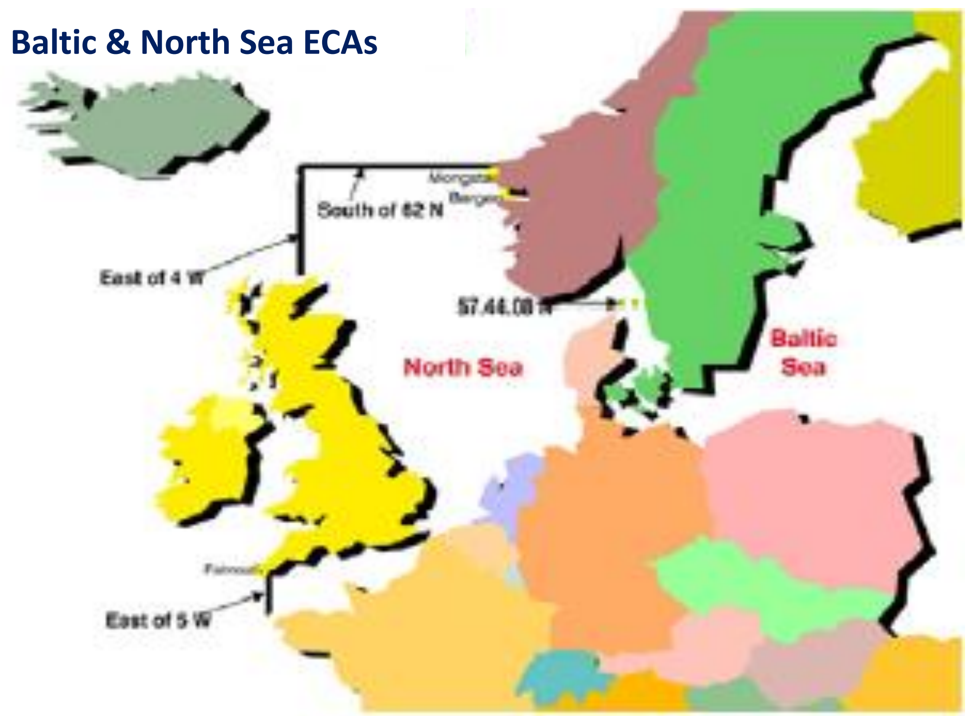
Emission control areas were firstly set as SOx emission control areas (S.E.C.As) and are called ECAs from 1st of July 2010. Emission Control Areas are defined as the special areas where the air pollution of SOx, NOx and particulate matter caused by ship emissions is prevented or reduced by certain regulations. The maximum sulfur contents are firstly set in two groups, which are for controlling the emissions globally and within the emission control areas (E.C.A.s). With the latest revisions, the maximum limits are required to be decreased gradually by the proposed time limits both globally and within emission control areas The allowed sulfur content of fuel oil used on board ships by MARPOL Annex VI has decreased to 1.0 % m/m[1] from 1.5

[1] m/m means by mass. 1% m/m means that the substance is 1% of the mass of the total solution

% m/m in 1st of July 2010 and will further decrease to 0.1 % m/m after 1st of January 2015.

Defined emission control areas cover the Baltic Sea, English Channel and the North Sea area. Moreover, the U.S. and Canada have requested from I.M.O. to establish further emission control areas covering 200 miles distance from East and West coasts of North America and Hawaii, if these requests are adopted, they can be in force from 2012.

Figure 2.3 Geographical Boundaries for Baltic and North Sea ECAs

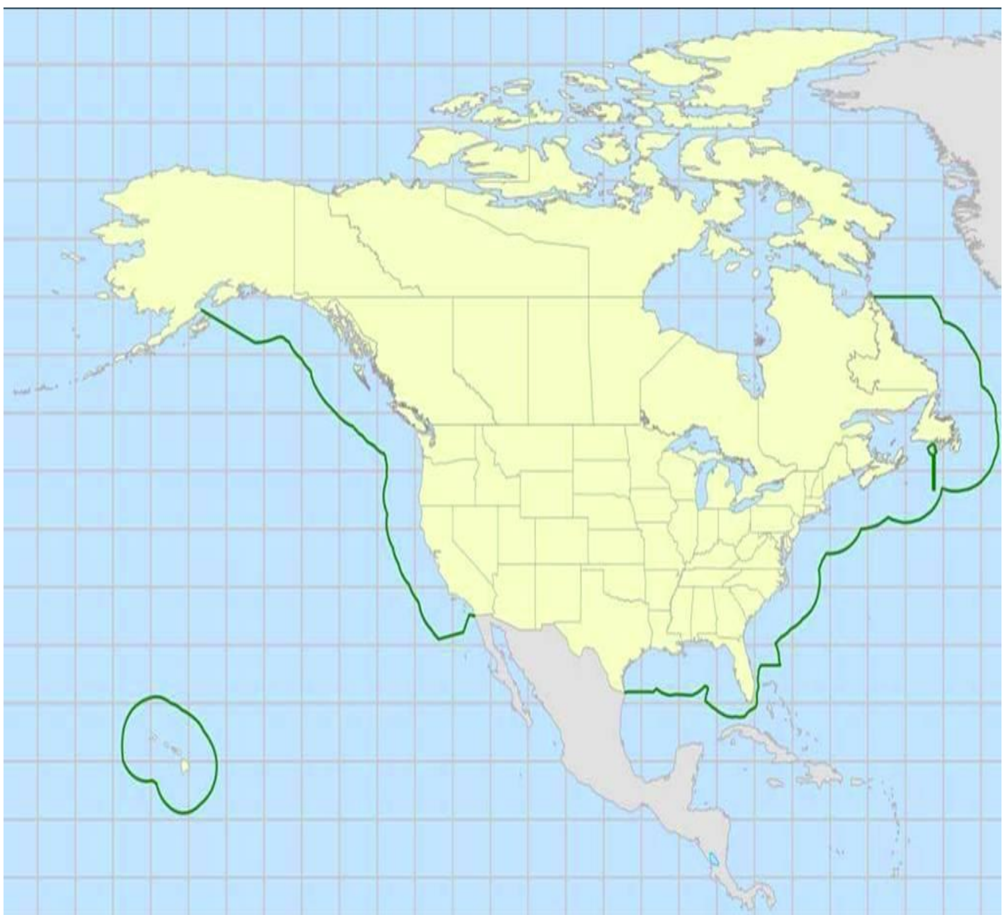


Source: *ECSA, (2010)*

As it can be seen from figure 4, the emission control areas consist of English Channel, North Sea area and the Baltic Sea. Starting from the east of longitude 005 W in south entrance of English Channel and East of longitude 004 W and south of latitude 62 N covers the North Sea Emission Control Area and includes the Baltic Sea Emission Control Area. A more detailed explanation can be found in Annex I and Annex V of MARPOL.

Since, the vessels are required to use low sulfur fuel oil (L.S.F.O.) in emission control areas, they have to switch to LSFO from HSFO. Depending on the engine and tank settling of the vessel, this process may be done in different forms. One of the most common applications is having two separate tanks which are the service and settling tanks. The process of changing over the fuel oil used is done by blending the different specs and flushing the system until it is reached to the desired low sulfur fuel oil. The time for the change over process depends on the difference between the sulfur contents, fuel oil consumption of the engine, and the volume of the blending from the storage tank to the service tank (Det Norske Veritas, 2010).

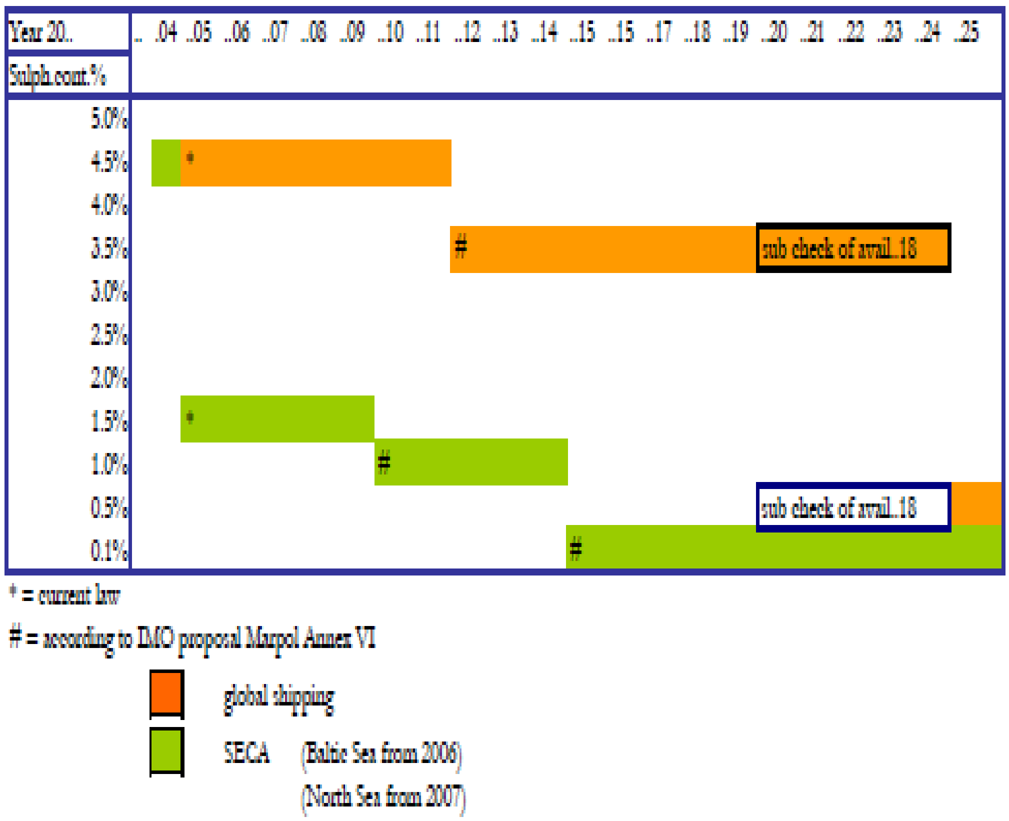
Figure 2.4 North America Emission Control Areas



Source: EPA (2010)

Figure 4 illustrates the proposed emission control areas by U.S. and Canada. The areas from the coasts to the green surrounding lines are the proposed areas and they may have the same requirements of LSFO usage as in standing ECAs. As mentioned before, if I.M.O. adopts the proposal, new legislation can be in force by August 2012.

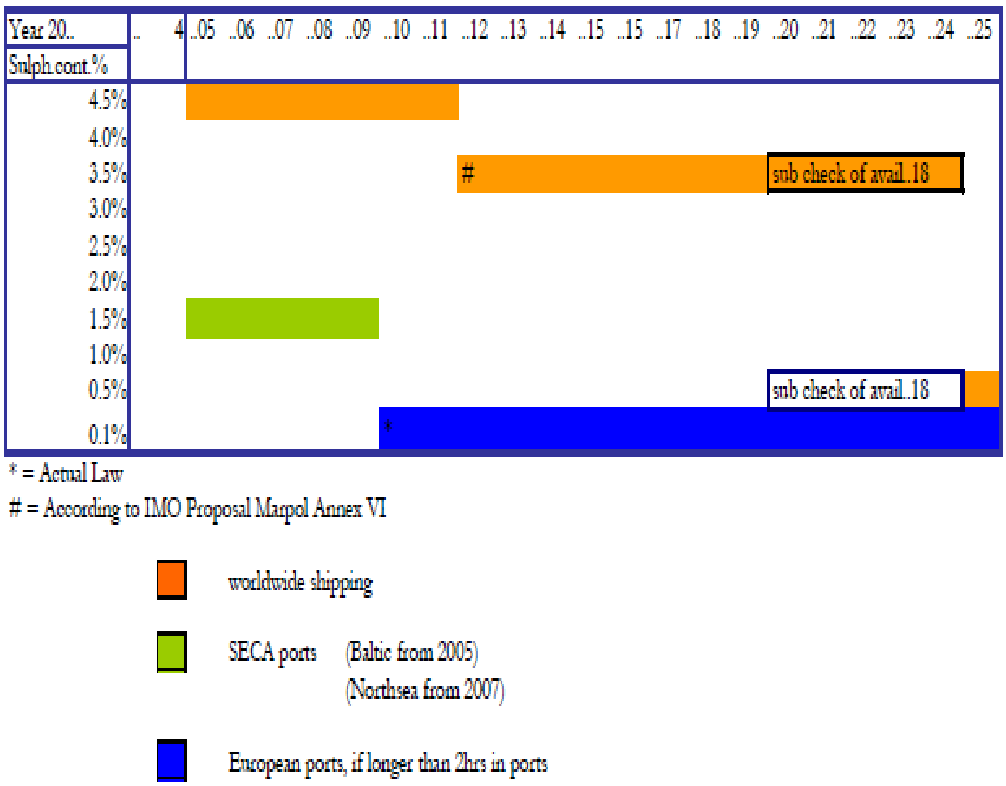
Figure 2.5 Required sulfur contents of marine fuels <u>at sea</u> according to IMO MARPOL Annex VI



Source: *ECSA.,(2010)*

Figure 4 and figure 5 shows the maximum allowed sulfur contents of marine fuels applied by IMO, MARPOL legislation. As mentioned before, the allowed limits differ from global coverage to ECAs. Maximum allowable limit in the global coverage will decrease to 4.5 % m/m to 3.5 % m/m in 2012 and it will further decrease to 0.5 % m/m in 2020 subject to the reviews planned for 2018. Maximum allowable sulfur content of fuel oil used in ECAs will decrease from 1.0 % m/m to 0.1 % m/m in 2015. Moreover, the requirements in the ports become stricter especially with the establishment of the provisions in E.U. ports. A sulfur content of 0.1 % m/m of fuel oil used on board ships is applicable from 2010 in all E.U. ports. The importance in this application is that, current heavy fuel oils used on board ships can't reach the given 0.1 % m/m. Therefore, the ships are obliged to use Marine Diesel Oil (MDO) or Marine Gas Oil (MGO) which are more expansive than the heavy marine fuel oil grades with higher sulfur contents.

Figure 2.6 Required sulfur contents of marine fuels <u>at ports</u> according to IMO MARPOL Annex VI



Source: ECSA., (2010)

Ship emissions and their polluting affects have been a major concern in the last decades and many studies have been done in the matter. Setting limits for marine fuel oils to be used on board ships both globally and in emission control areas is one of the main steps taken by IMO. Although, limits are set to reduce the air pollution and environmental hazards caused by the ships, there are many concerns in terms of economical, technological and environmental subjects. As the limits are to be reduced by 2020 with the new revisions, the organization has set a review time for better applicability.

2.3. Review of the revisions

As adopted by the 58th session of IMO's Marine Environmental Protection Committee (MEPC 58), Annex VI of MARPOL has been subject to revisions which concern many parties such as ship owners, fuel oil suppliers, ship building companies, governmental bodies etc. Previously mentioned regulations for controlling the NOX emissions (Regulation 13) and Sulfur Oxides and Particulate Matter (Regulation 14) are the ones subject to the revisions. Tier II and Tier III of regulation 13 and the marine fuel oil sulfur content limits of regulation 14 are the mentioned revisions.

For both regulations IMO has set a review process time for monitoring the applicability and effectiveness of the revisions.

- Regulation 13, Review; beginning in 2012 and to be completed no later than 2013.
- Regulation 14, Review Provision; no later than 2018, review for the availability of global fuel oil supply in accordance with the maximum allowable sulfur content of 0.5 % m/m for 2020. If the requirements are decided to be found not compliable by the ships, the standards shall become effective by 2025.

2.3.1 Future concerns for the revisions

The review process of IMO and the contents mainly shows the first matters of concern for future applications. For the revisions in the NOx technical code, the technological requirements are the main bottlenecks to be considered. For the revisions in regulation 14 including the Sulfur content of the fuel oils the availability of those becomes the major concern. Moreover, the economical costs of the improved fuel oil quality on board ships may bring and include further consequences. Some of them may include;

- Uncertainty in availability of fuel oil in required specifications and locations.
- Increased fuel oil costs for ship owners and ship operators.
- Higher operation costs depending on high fuel oil costs.
- Increased freight rates in regards with higher operation costs.
- Possibility of modal split change depending on higher shipping costs.
- Need of technological innovations.
- Increased external costs.

The possible consequences can considerably be expanded and may include many other subjects. High uncertainty in many points such as; future price and availability of fuel oil, respond of the industry to increased costs, increasing environmental cautions and needs make the issue related to many parties. It is not only the ship owners or ship building companies who can respond to the legislation. Involvement of governmental bodies, local authorities, fuel oil suppliers and producers, ship owners, ship building companies, academics, research and development departments and many more parties are primarily responsible for the better application of the new revisions. The amount of question marks in the matter is significantly high. It is why; the organization has set review provisions and deadlines for better applicability.

2.4. Conclusion

In this chapter the coverage, application and revisions of MARPOL Annex VI is briefly explained and the relative points of the legislation are summarized. Summarizing and explaining the applications of the legislation and the revisions is done to be a good guide in understanding the possible future outcomes. The gradual decrease in sulfur content of marine fuels both in global usage and in ECAs imposed by the revisions of Annex VI has been analyzed as one of the main points since it has been a major concern of the shipping industry. The possible price increase of the marine fuels in line with the improved quality as a result of the revisions is the main factor causing many future concerns. Uncertainty in the supply and demand of such marine fuels, their future pricing, response of the industry and the effects of these factors on the maritime freight rates are some of the other main concerns that arise as a result of the revisions.

Chapter 3 Marine Fuels and Future Trends

3.1 Introduction

From the very beginning of maritime transportation until now, many kinds of ships have been designed. While our oldest ancestors were using small wooden boats with paddles and simple sailing sheets, bigger sailing boats with many oarsmen on them had been further designs to serve the trade. Continuous developments in technology and the increasing demand for maritime transportation opened the way to even bigger vessels with engines consuming coal and running with the generated steam. Invention and application of diesel engines have been one of the main cornerstones in maritime sector. Although, the efficiency in fuel consumption of marine engines has improved, fossil fuels are still the main source of energy in marine engines.

As the needs of the industry have been changing dramatically, supply and demand of the energy sources have been evolving as well. The most significant change in the bunker supply, after the change from coal to oil, is the regulations brought forward by IMO for reduction of ship emissions. In terms of demand for marine fuels, desire to reduce sulfur oxides emissions has the greatest impact (EMC. 2010). Although, there are many market forces affecting the price of marine fuels, requirements for usage of different specs of marine fuels now and in the future have one of the most considerable impacts on prices and forming of supply and demand.

In this chapter, different types and specifications of marine fuels will be explained. The cost evaluation of certain fuel types will be given and the future projections for supply, demand and prices of certain marine fuels from several studies will be analyzed. Apart from giving information about marine fuels and future trends, this chapter can also be a guideline for further chapters where the future trends in the bunker markets will be considered.

3.2 Marine Fuels and Specifications

The specifications of marine fuels used on board and their worldwide supply standards have been developed by The International Standardization Organization (ISO) under the specifications of ISO 8217. Amongst the total 19 grades of marine fuels, four categories of fuels or grades have been most frequently supplied and used on board ships (SCG 2005). The main types of marine fuels and their specifications can be summarized as below;

- **Residual Oil** is the heaviest part of the distillation of crude oil. While it is the cheapest liquid fuel in the market, it also contains high amounts of pollutants. As the viscosity of the fuel is higher it needs to be heated for flowing efficiently. Residual oil is mostly used in large ships due to heating requirements.(ECSA 2010)

- **Intermediate Fuel Oil (IFO) 380** is the outcome of mixing 98% of residual oil and 2% of distillate oil.

- **Intermediate Fuel Oil (IFO) 180** is the outcome of mixing 88% of residual oil and 12% of distillate oil. As the distillate oil content is higher in comparison to IFO 180, IFO 380 is less expansive than IFO 180.

- **Marine Gas Oil (MGO)** is pure distillate oil and currently it has the lowest sulfur content in marine fuels.

- **Marine Diesel Oil (MDO)** stays between MGO and IFO 180 in terms of sulfur content. It is a mixture of higher percentages of distillate oil and may contain a trace of residual oil.

Table 3.1 Specifications of most commonly used four marine fuels

Industrial name	ISO name	Composition	ISO Specification sulphur weight %	World average
Intermediate Fuel Oil 380 (IFO 380)	MRG35	98% residual oil 2% distillate oil	5% (*)	2.67%
Intermediate Fuel Oil 180 (IFO 180)	RME25	88% residual oil 12% distillate oil	5% (*)	2.67%
Marine Diesel Oil (MDO)	DMB	Distillate oil with trace of residual oil	2%	0.65%
Marine Gas Oil (MGO)	DMA	100% destillate oil	1.5%	0.38%

(*) IMO regulation capping sulphur at 4.5% supercided ISO specification

Source: *ECSA, (2010)*

Further details for previously mentioned marine fuels can be found in table 3.1. As the sulfur content of IFO 380 and IFO 180 are in the range of the global sulfur content requirements of MARPOL Annex VI, they are the most common used ones. MGO and MDO are the ones which are used mostly in ECAs because of the lower sulfur content requirements. Their prices and availability differ regionally depending on the legislative usage in terms of sulfur content and emissions. More detailed explanations and characteristics for marine fuels can be found in ISO 8217.

3.3 Bunker Consumption

Propulsion of the vessels is the main concern in terms of fuel consumption. Vessel hull design, installed engine power and type, operating speed are some of the main characteristics which affect the fuel consumption. Apart from propulsion there are many other applications which are consuming the fuel on board. Bow and stern thrusters, hydraulic oil systems, heating and processing of fuel, navigation equipment, inert gas generator production purposes, air conditioning, cranes, pumps used on board tankers for loading and unloading of cargoes, reefer containers, air conditioning etc. can be given as examples of some other energy consumers on board vessels (Ce Delft *et. al*. 2006).

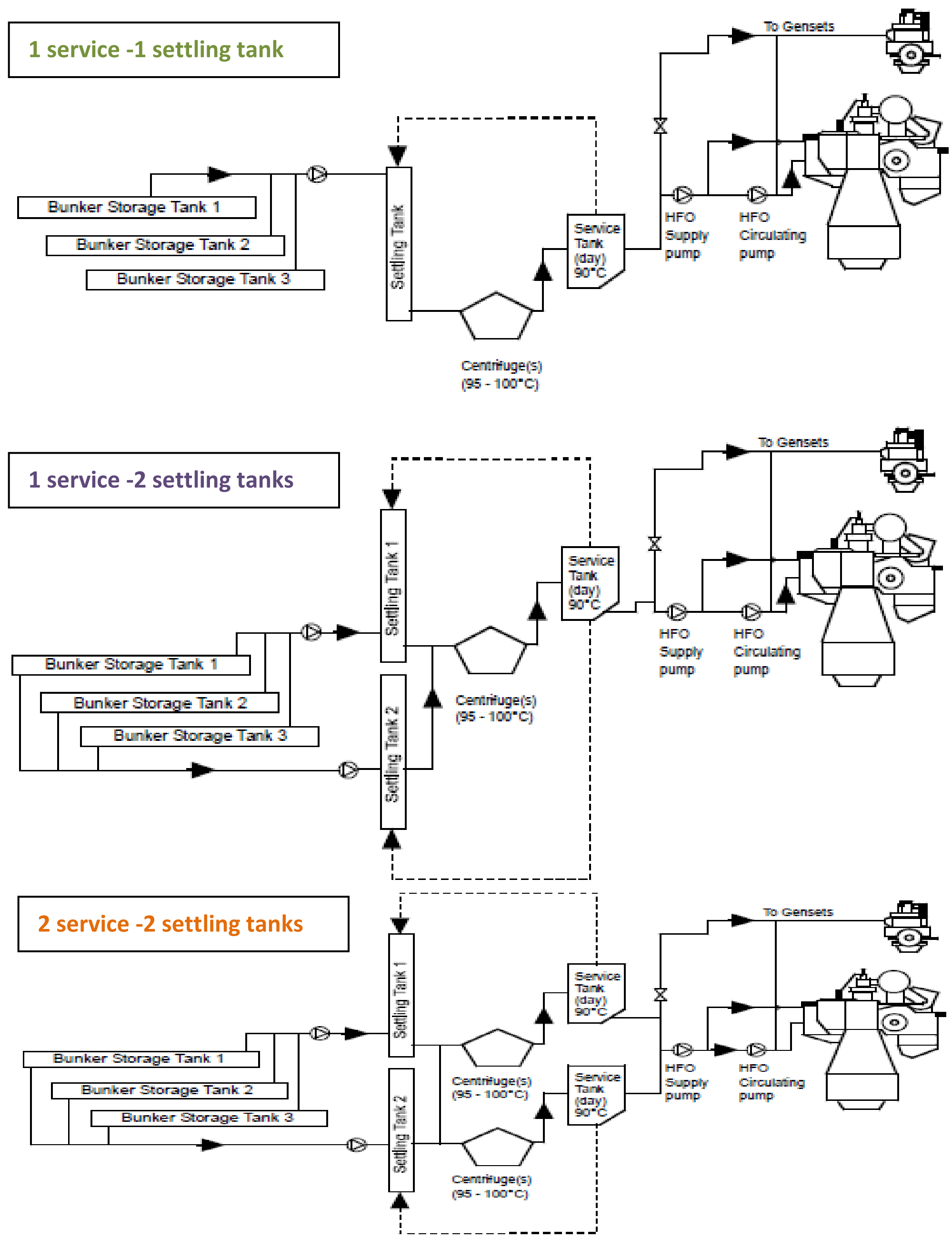
Consumption of different types of marine fuels mostly depends on the legislative requirements of the routes where the ships are sailing and the engine specifications. For example, a vessel sailing outside the emission control areas can consume IFO 380 or IFO 180 which are cheaper than other low sulfur content marine fuels. The same vessel has to use low sulfur content fuel in emission control areas. As the emission control areas are limited when considered in global coverage, higher demand and supply of high sulfur content marine fuels in comparison to low sulfur marine fuels become obvious.

3.3.1. Fuel Systems for Change-over Process.

Vessels sailing in the routes which require entrance to an ECA must do a change over for carrying out the requirements of the regulations. The changeover process from high sulfur content marine fuels to low sulfur content marine fuels is done in several ways depending on the fuel systems. One of the most common applications is mixing the higher content fuel oil with the low content fuel oil until the required level is reached. This is done through a combination of service and settling tanks. Different options and applications between the service and settling tank combinations are used in various vessels. Combinations of one service and one settling tank, one service and two settling tanks and two service and two settling tanks can be given as examples of different applications on board ships.

Mentioned tank combinations are the examples which are used and mainly developed after the ratification of Sulfur Emission Control areas. The systems are developed for coping with the requirements of the legislation while considering in mind the trade-off between the capital expenses and the time saved by the settlings for change over applications. Moreover, these settlings are also important while purchasing bunkers for the planned voyage. A voyage where the destination port is defined after departure can also be subject to these settlings as the tank capacities and change over abilities are important while planning the purchase of different grades of marine fuels.

Figure3.1 Fuel systems of ships, service and settling tank combinations



Source: *Ce Delft et. al.* (2006)

Figure 3.1 illustrates different fuel system applications with various service and settling tanks. The first technical drawing with one service and one settling tank carries higher operational risks when the blending of high sulfur fuel with low sulfur fuel is considered. As the blending process is done through one tank, failure of sulfur content compatibility may occur.

The second drawing with two settling and one service tank carries less risk in comparison to the first one. While the blending of different specs is done in the service tank, the other tank can be filled with low sulfur fuel oil and the other with high sulfur fuel oil. In case of any failure of blending to the required sulfur level, the fuel can be returned to the HFO tank.

The third drawing with two service tanks and two settling tanks is one of the optimum applications in terms of blending and operation. Since it minimizes operational deficiencies of blending the fuel, it has the highest operational efficiency. However, the cost of the three applications, their technical and space requirements forms the trade offs.

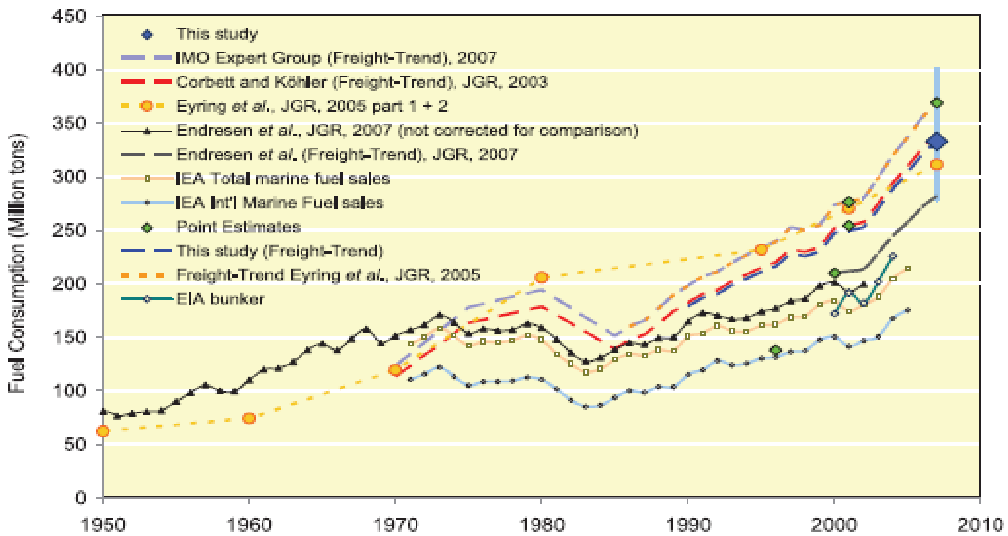
3.3.2. World Fleet Bunker Consumption

Bunker consumption of the world fleet can be directly related to many factors such as, engine powers of the vessels, operating days, service speed, vessel type, hull design etc. Moreover, international economic activity is one of the main macro factors affecting the activity of international seaborne trade, therefore, the fuel consumption of the world fleet. Although, technical innovations may seem to be one of the main determinants of the fuel consumption, the level of international economic activity is one of the main determinants of global bunker consumption as the demand for maritime transport is a derived demand from economic activity.

IMO, 2009, represents world fleet fuel consumption with two approaches, by considering activity based fuel consumption data and fuel statistics. First the fuel consumption of the ships is estimated depending on the ship type and the outcomes are added together for obtaining the global values. Also, the operational patterns of individual ship types are considered next to specific characteristics of different ship types.

Estimations of total fuel consumption of world fleet from different activity based estimates and statistics can be seen in Figure 3.2. While, the fuel consumption was around 60 and 75 million tons in 1950s, the total fuel consumption increased up to between 175 million tons and 375 million tons. The high variations in the figures depend on different estimations from different studies. However, the certain trends that can be observed from the graph are the similar fluctuations through time from 1950 to 2010. The similar dips and peaks in the trends in mid 1970s(oil crisis),1980s and early 2000s can also be realized in crude oil prices.

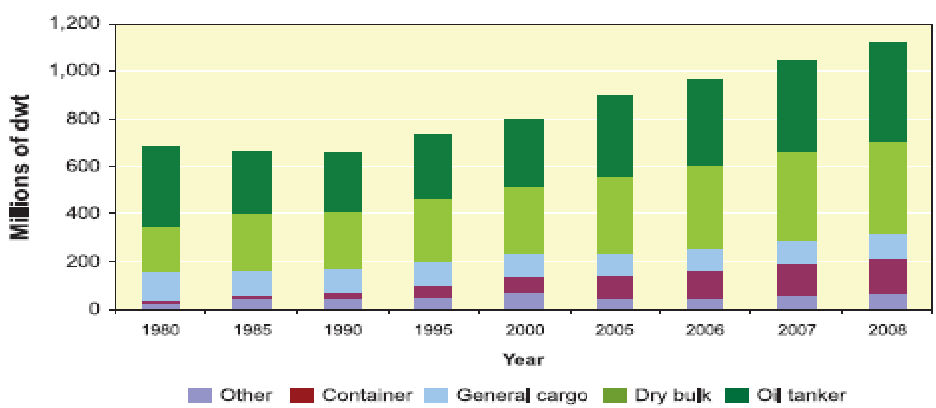
Figure 3.2 World fleet annual fuel consumption estimations.



Note: Naval vessels are not taken into account in the estimations. The representation with blue square (this study) represents IMO Green House Gas Study 2009. Dashed lines show the forecasts and back casts calculated from the evolution of freight ton miles through time with point estimations.

Source: IMO, (2009)

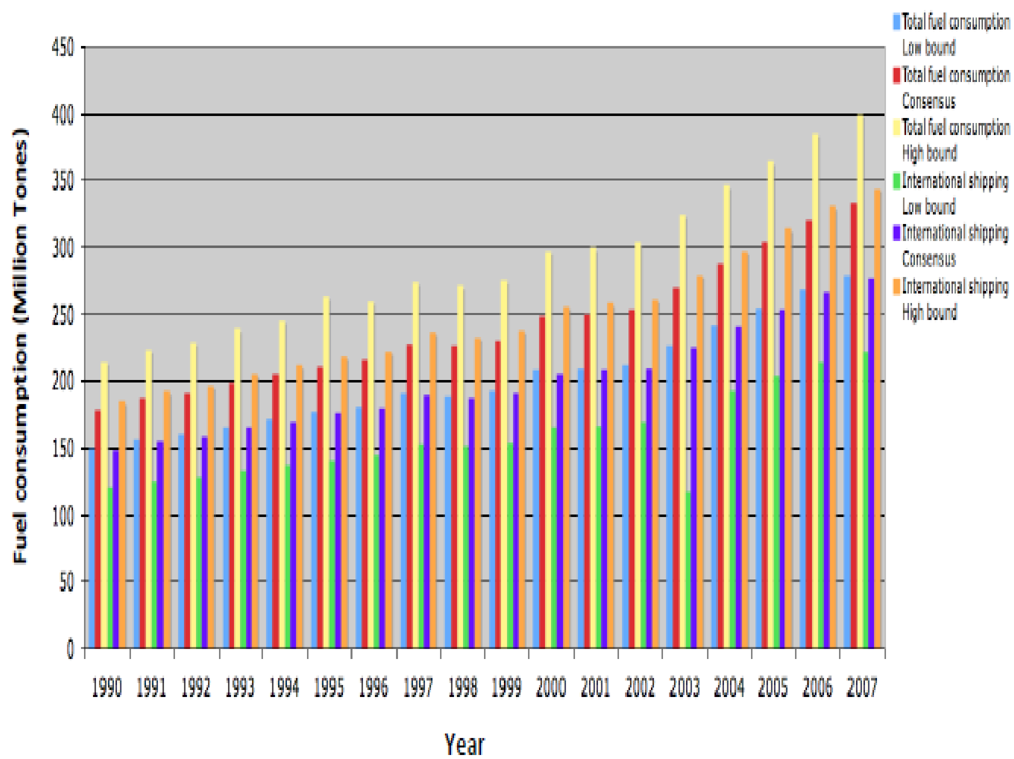
Figure 3.3 Fleet growths in millions of deadweight per major ship type from 1980 to 2008.



Source: *UNCTAD, (2008)*

Figure 3.3 reflects the world fleet growth from 1980 to 2008. A similar trend between world fleet fuel consumption and world fleet growth (figures 3.2 and 3.3) can be observed. The increasing amounts of tanker and container fleet contribute highly in world fleet growth and the fuel consumption accordingly. For both figures the effects of the latest economical downturn starting from mid 2008 must be taken into account. The increasing amount of lay ups, scrapings and the slow steaming strategies of many liner companies are the points which may affect the trends in both figures downwards from 2008 to 2010.

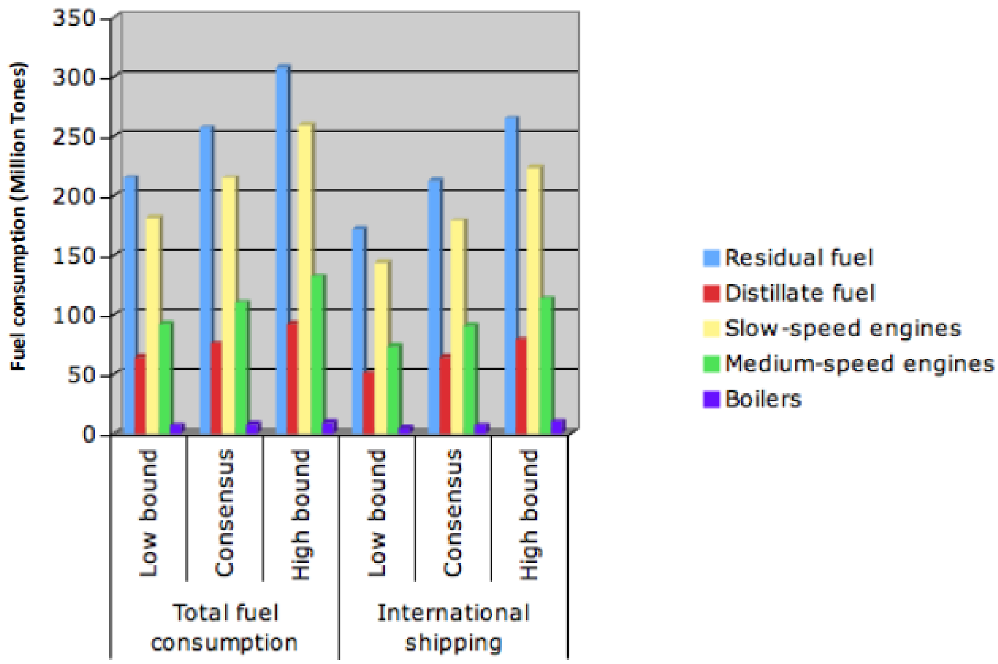
Figure 3.4 Shipping fuel consumption estimations from 1990 to 2007



Source: Own preparation, data derived from IMO GHG Study (2009)

Figure 3.4 illustrates the estimations of fuel consumption for total and international shipping. For estimations low, consensus and high limits are taken. Consensus fuel oil consumption for total shipping in 1990 is estimated at around 210 million tons. A slight increase in fuel oil consumption until 1995 leaves its place to a decrease in 1996. While the fuel oil consumption was stable around 300 million tons between 2000 and 2002, it has been estimated to rise dramatically from 2003 to 2007. As mentioned before the impacts if the global crisis in 2008 and the scrapping, laying up and slow steaming strategies of many shipping companies should effect the trend dramatically.

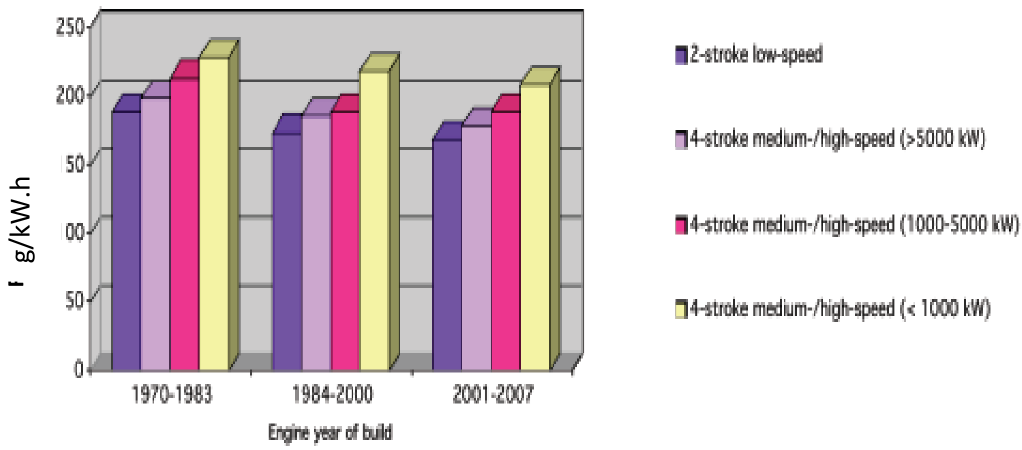
Figure 3.5 Fuel consumption according to fuel type and combustion source, 2007



Source: Own preparation, data derived from IMO GHG Study (2009)

Figure 3.5 shows the fuel consumption estimations for different types of fuel and combustion sources for the year 2007. Three intervals as low, consensus and high levels are considered for the estimations. As it can be seen from the figure, highest consumption is made in residual fuels. Amount of residual fuel consumption for international shipping has been estimated under the consensus scenario as 257 million tons while the distillate fuel consumption has been estimated as 76 million tons. The ratio of residual fuel consumption to distillate fuel consumption is around 3.3 for both total and international shipping. In terms of combustion sources, slow speed main engines consume nearly two times of the combustion of medium speed engines. Higher amount of slow speed engines in shipping is one of the main factors behind this figure. The fuel consumption of slow speed engines amounts up to 179 million tons while the same figures are 91 million tons for medium speed engines and 7 million tons for boilers in 2007 for the consensus estimations.

Figure 3.6 Values of specific fuel consumption for different kinds of main engines according to year of build in g/kW.h



Source: Own preparation, data derived from IMO GHG Study (2009)

Fuel consumptions of different main engines according to stroke numbers, output power and year of build are given in figure 3.6. In terms of fuel consumption, 2 stroke low speed main engines consume the least while 4 stroke medium – high speed engines with an output of less than 1000kW .The reduction in the fuel consumption of 4 stroke medium high speed engines with outputs between 1000 and 5000 kW build in the period of 1970 and 1983 and the ones build in the periods 1984 and 2000, forms the highest from 215 g / kW-h to 190 g / kW-h. Moreover, a continuous reduction in fuel consumption of 4 stroke medium-high speed vessels with outputs of less than 1000 kW can be seen from 1970 to 2007.

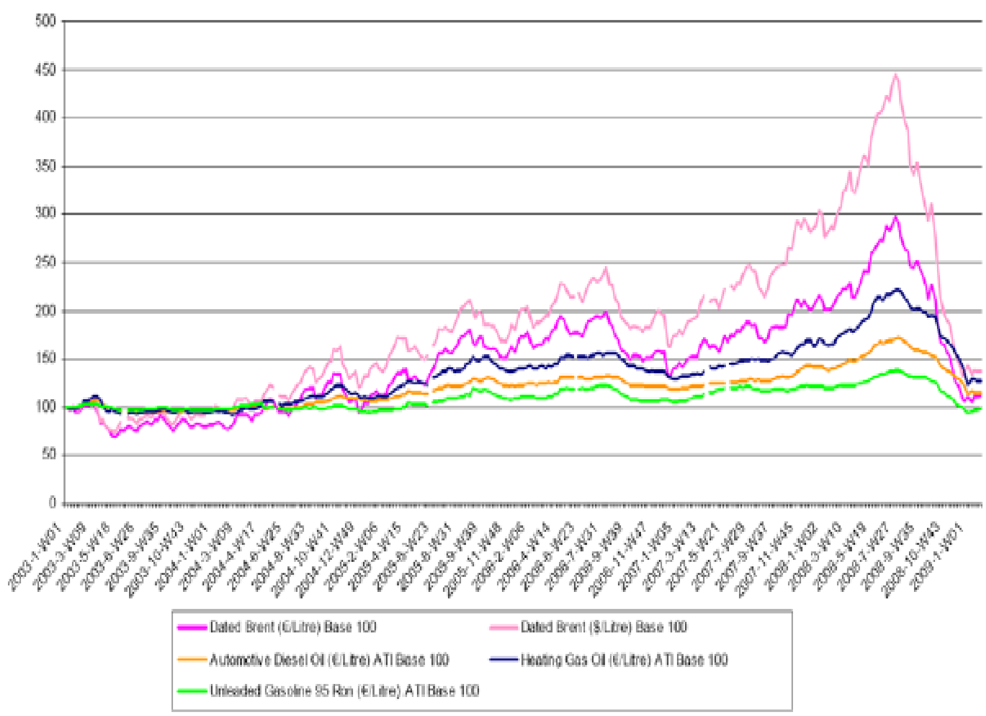
Figure 3.6 can be a good guide in understanding the increasing efficiency of ship main engines. Moreover, there are many factors which influence the innovation movements in international shipping. When the freight rates and demand for shipping is high, there are les innovations and full order-books in the ship building yards. When there is overcapacity, freight rates are considerably lower incentives for innovations takes place. Certain regulations concerning international shipping such as MARPOL and its revisions can be further triggers for ship building and design. Increased awareness of fuel consumption efficiency and reduction in shipping emissions seems the latest incentives for innovation.

3.4 Marine fuel prices and future estimations

Prices of marine fuels used on board ships depend on many factors such as crude oil prices, related supply and demand characteristics, sulfur content of the specific fuels, process cost of the marine fuel from crude oil, etc. As mentioned previously, high sulfur content fuel oils, in other terms residual fuels are consumed nearly three times more than distillate fuels by the ships. The sulfur content of residual fuels, HSFO, LSFO, are higher than the distillate fuels, MGO, MDO, while the latter groups prices are higher.

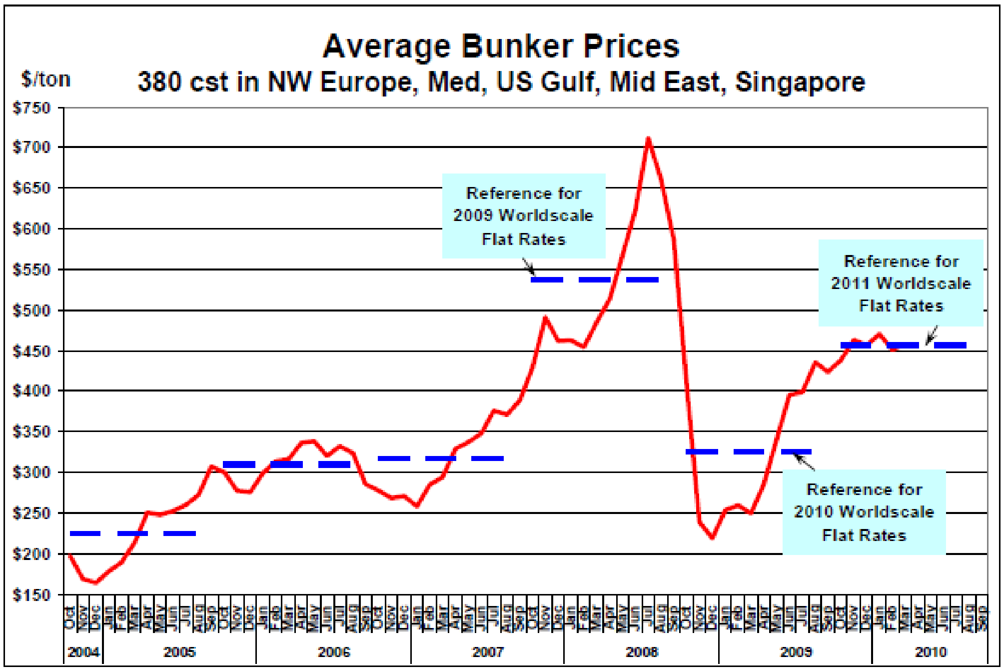
Dips and peak points of oil prices have been considerably moderate over time apart from the effects of several oil crises (ECSA 2010). In consideration with the recent past, oil prices have shown many fluctuations. With the high volatility, the prices rose considerably from the beginning of 2007 until mid 2008. A peak of 145$ per barrel of crude oil in July 2008 decreased sharply to 49$ per barrel in December 2008 and rather more stable oil prices have been experienced. A detailed trend of the evolution of crude oil, diesel oil and other products over time can be seen in figure 3.7.

Figure 3.7 The index evolution of crude oil, diesel oil and other oil products.



Source: *ECSA (2010), based on market observatory of energy (2009)*

Figure 3.8 Average bunker prices between 2004 and 2010



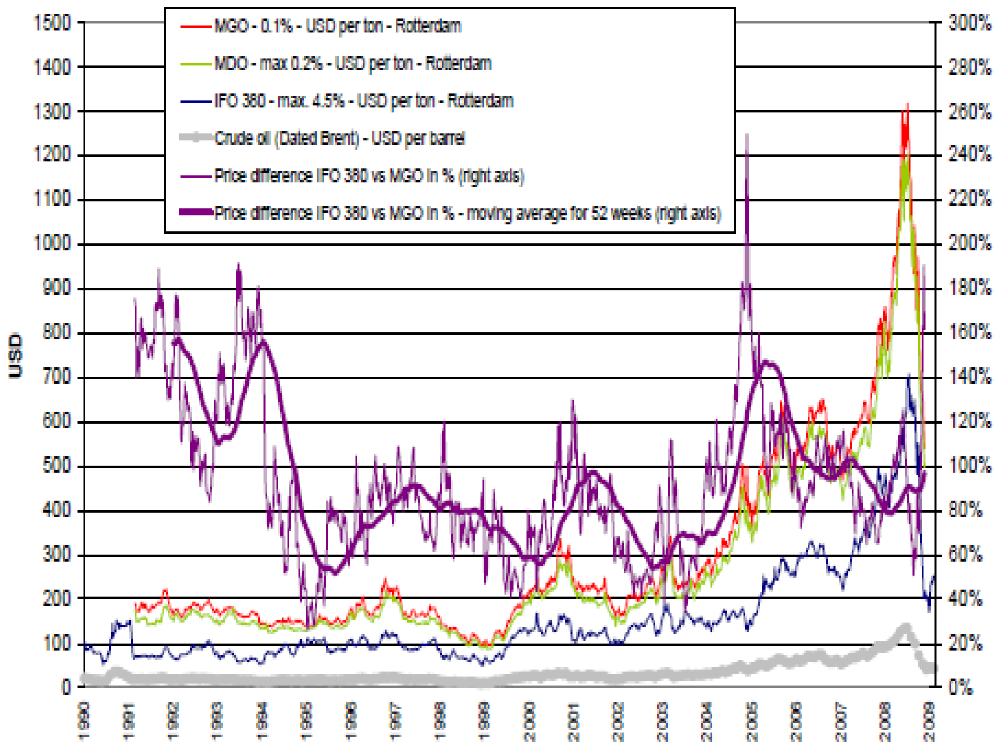
Source: Gibson (2010)

Figure 3.8 reveals the average bunker prices for the years 2004 to 2010 for Intermediate Fuel Oil (IFO) 380cst considering NW Europe, Mediterranean, Middle East, US Gulf and Singapore markets. When compared with figure 3.7, the effect of the volatility in crude oil prices on bunker prices can be observed. The peak in oil prices in July 2008 has pushed the average IFO 380cst prices from around 250$ per ton to around 700$ per ton. One of the main reasons behind the big price difference with an increase of around 450$ was the global economic growth in 2008 and the increasing demand of oil which is close to world production limits (Gibson, 2010). As the economic growth has pushed the bunker prices to rise, the downturn in mid 2008 has reversed the situation by causing a sharp decline resulting by around 225$ per ton of IFO 380cst.

Reduced production of oil by OPEC, slightly increasing economic activity and the positive expectations, has made the oil prices stable as the bunker prices around 450$ per ton.

World-scale flat rates are calculated according to historical data on the prices of bunkers. October prices of last year to the September prices of the current year are taken on average to determine the flat rates of the next year. As the reference point for 2010 world-scale flat rates have been highly affected from the volatility and dips of 2008 and 2009 it stayed around 325$ per liter. However, slightly increasing prices of 2009 and stable prices of 2010 may increase the reference of world-scale flat rates in 2011.

Figure 3.9 Price Evolution of IFO 380, MDO, MGO and crude oil



Source: ECSA (2010) based on Clarkson data

Figure 3.9 reflects the price evolution of IFO 380, MGO, MDO and crude oil. The correlation between crude oil prices and marine fuels has been mentioned before. One of the main points that can be drawn from the figure is the evolution of the price difference between IFO 380 and MGO. As it can be seen the price difference fluctuates from 1990 to 2009. While the price difference dips at around 30% in mid 1995, it peaks at around 250% in 2004. Observing these fluctuations can be a further guide in examining the future trends of price differences between MGO and IFO 380 as MGO may be the only fuel type that can be used to cope with MARPOL Annex VI requirements with sulfur content of 0.1% Moreover, as the demand is one of the main factors in determination of the prices, the price of MGO may rise considerably in case of no substitutes.

3.4.1 Future estimations

Like many other goods, price of marine fuels depend on their availability, in other terms supply, demand for different bunker types, market forces, political issues, legislations, etc. One of the main factors affecting the future trends of marine fuels will be the regulations of MARPOL Annex VI. Apart from the crude oil prices and international supply and demand forces, future requirements related to sulfur content of the marine fuels will be a main determinant in the bunker market.

Currently a sulfur content of 4.5% globally and a sulfur content of 1.0% in ECAs for marine fuels are the requirements. In 2015 the content of the marine fuels will drop to 0.1 percent in ECAs and in 2020 the global content will drop to 0.5% subject to IMO's reviews. Residual fuels and distillate fuels are being mixed to achieve the sulfur content requirements of today. However, when the limits become tighter, for example, in case of 0.1%, having this spec will not be possible by mixing the residual fuels with distillates.

When the consumption of marine fuels is considered under global regulations, the 0.5% sulfur limit legislation will require a mixture of higher amounts of distillate fuels with residuals. With current technology, the trend seems to shape in two ways. Either the ships will use pure distillate fuels to meet the future global requirements or as mentioned before high amounts of distillate fuels will be blended with residual oils.

In consideration with the first scenario, where only distillate fuels are being used, the demand for those will increase dramatically and there won't be any marine outlets for residual fuels in the refineries. The second scenario will also require high amounts of distillate fuels to reach the sulfur limits. In both estimations the demand for distillate fuels will dramatically increase and the price difference between residual oils and distillates will increase even more.

One of the main considerations in the future availability of marine fuels is the decisions of the refineries. It is a fact that producing low sulfur marine fuels will require costly investments. This decision of individual refineries will influence the availability and supply of marine fuels. The estimations made by European Commission may reveal the ideas for the extra costs to refineries in European Union[2]. The estimations are as follows:

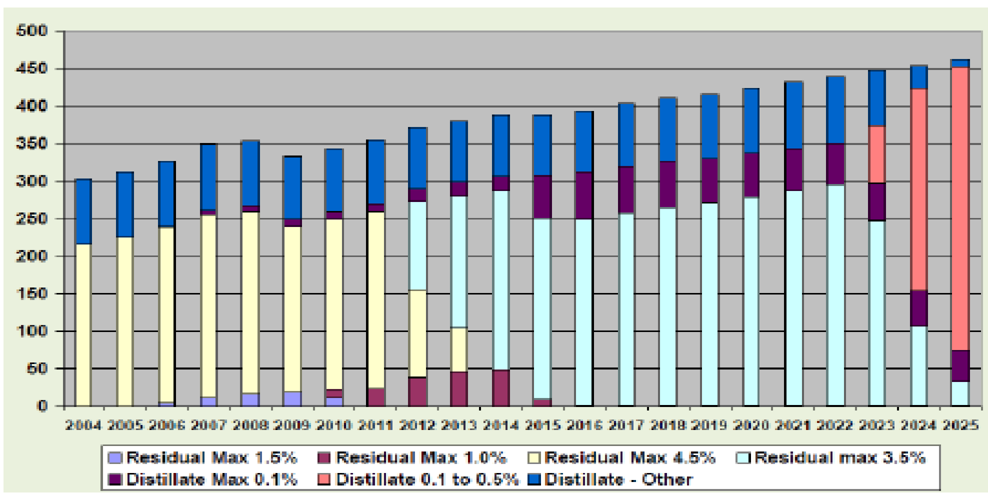
- Additional cost in 2015 for refineries in European Union, 13.2 billion USD.

[2] http://ec.europa.eu/environment/air/transport/ships.htm

- Additional cost in 2020 for refineries in European Union, 16.7 billion USD.

Although these figures are the future estimations on the costs for refineries in European Union there are many factors that have to be kept in mind. The environmental outcomes of the further production process of low sulfur fuels, demand for specific types and the location of demand, future investment requirements, possible technical developments and innovations in shipping industry may shape the decisions of the producers and suppliers of marine fuels.

Figure 3.10 Future demand estimations for marine fuels



Source: MTCF (2009)

Future demand estimations of marine fuels are given in figure 3.10. Demand for residual fuel with a maximum sulfur content of 4.5 % has been sharing the highest proportion from 2004 to 2010 fluctuating between around 200 and 250 million tons. Beginning in 2006 with the introduction of the SECAs until 2010, the demand for residual fuels with a maximum sulfur content of 1.5 % has the lowest share with an average of around 20 million tons per year. One of the considerable trend changes in the demand for marine fuels can be observed from 2010 as the required sulfur limit has reduced to 1.0 % from 1.5 % in ECAs. While, the demand for 1.0% sulfur content residual fuels is increasing from mid 2010 to 2015, the demand switches to distillate fuels (MGO) with a sulfur content of 0.1%. As the global requirements for maximum sulfur content is reducing to 3.5% in 2012 demand for residual fuels max4.5% sulfur leaves its place to residual fuels with a maximum sulfur content of 3.5%. Consequently, a continuous increase in the demand for marine fuels can be observed from the graph and the effects of the revised MARPOL Annex VI requirements can be analyzed as the demand for residual fuels with a maximum sulfur content of 1.5 % and 4.5 % disappears and leaves its place to lower sulfur content residual fuels and distillate fuels.

3.4.1.1 Price estimations from studies

Future prices of marine fuels depend on so many variables and price trends are not definitely based on facts depending on future beliefs and expectations *(MTCF, 2009).* Even the past fluctuations and the volatility of bunker prices experienced in the past can be a good reference to show the hardness of making an accurate estimation. Depending on many variables and scenarios, including total switch to MGO and using higher proportions of distillate fuels, various organizations and studies have estimated future prices of marine fuels for different years.

- Ministry of Transport and Communications Finland (MTCF,2009) have analyzed the price variations for different types of fuel. The assessment has been done by asking Finnish Oil and Gas Federation about their estimates for price increases for marine fuels. Rather than giving a future reflection of prices, they have assessed the differences by giving variances to the current prices. They first estimated price differentials for the years 2006 to 2008 and with reference to that they have estimated the cost of fuel switching. No future projections are made, further cost calculations are made with reference to the price differentials by using them in the model. Summary of the outcomes from the study can be seen in table 3.2

Table 3.2 Estimated price differentials for low sulfur fuel grades in relation to the fuel grade currently in use (2009)

Fuel grade	Price € per tone	Differential € per tonne	Differential ex-pressed as a percentage
Current heavy fuel oil (1.5%)	271		
Heavy fuel oil (1%)	290–330	+19–59	7–22 %
Heavy fuel oil (0.5%)	305–350	+34–79	13–29 %
Light fuel oil (0.1 %)	470–500	+199–229	73–85 %

Source: MTCF (2009)

- European Community Ship-Owners Association (ECSA, 2010) reflects future price projections of marine fuel prices especially for MGO. Firstly the price differentials of different marine fuels are considered in connection with the historical data. After examining the fluctuations of price differences between LS 380 (%1.5) and MDO for the period 1990 to 2008, they find a long term average of 87%. The price average long term price difference between IFO 380 and MGO for the same period has been found as 93%.

Based on historical data they compare the effects of future price increases of MGO, IFO 380 and LS 380. Use of MGO instead of IFO 380 has been calculated to imply a cost difference between 80% to 90% and use of MGO instead of LS 380 has been calculated to imply a cost difference from 70% to 90%. A shift from 1.5 % sulfur content to 0.5 % sulfur content is estimated to have a cost increase of 20% to 30%. The price increase while switching from 0.5% to 0.1% sulfur content is calculated to be 50% to 60%.

In the study three scenarios are developed for MGO prices. Low, base and high scenarios corresponds to 500$, 750$ and 1000$ per ton of MGO respectively. The authors defend that the average price of MGO will not exceed 1000USD per ton over several years of time at least in the medium term. Moreover, they argue that, the price of MGO will mostly fluctuate around the base scenario which is 750$ per ton.

- Swedish Maritime Administration, (SMA, 2009) forecasts the future prices of marine fuels for 2015. The authors assume that, the increase in crude oil prices will be fully reflected in bunker prices for 2015. The study takes the forecasts of the International Energy Agency (IEA) for crude oil price to be 100 USD per barrel (159 liters) in 2015. The example of the full reflection of the increase in crude oil prices is given as; the increase in crude oil prices from 60USD per barrel to 100USD per barrel will cause an increase of 70% in the price of marine fuels by 2015.

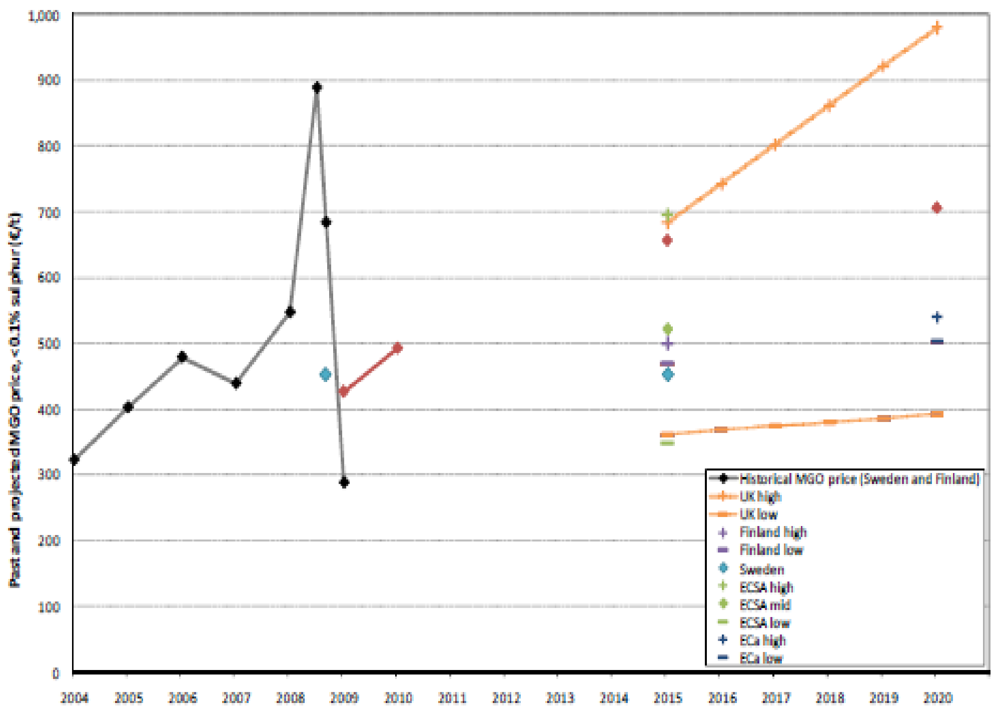
  They assume three scenarios for the models. In scenario 1, the price of crude oil is assumed to be 60 USD per barrel and in scenario 2 it is assumed to increase by 75% and set at 100 USD per barrel. Scenario 3 considers a further increase of 150% in bunker prices in comparison to scenario 1.The price of MGO is set to be at 662 USD per ton in scenario 1 and approximately 1158 USD per ton in scenario 2. The price of MGO is assumed to be 1650 USD per ton considering a 150% increase according to scenario 1.

- Environmental and Engineering Consultancy (Entec, 2009) supplies price reflections for 2020 depending on the 2009 prices of crude oils. Like other studies, because of the uncertainty in the future prices of marine fuels, estimations done under three scenarios.

  By assuming the price of crude oil in 2009 as 50 USD per barrel they form three scenarios. They assume the base price as 50USD in accordance with IEA historical data, interviews with shipping companies and fuel price experts. In the first scenario price of fuel oil is estimated to be 60 USD per barrel in 2020. In the second and third scenarios, the prices of crude oil in 2020 are estimated as 80 USD per barrel and 150 USD per barrel.

Summary of the historical and projected MGO prices by different studies can be found in figure 3.11. The historical prices for MGO are available for only the studies MTCF (2009) and SMF (2009). Further projections from different studies for future prices of MGO prices for 2015 and 2020 can be seen in the figure.

Figure 3.11 Historical and projected MGO prices from different studies used in the studies over time



Source: Entec, (2010)

The mentioned studies estimate the future prices of marine fuels by looking at the past data and relying on the extensive surveys carried out. One of the common points used in the estimations in that they all set different price scenarios for reflecting the uncertainty. Low, medium and high scenarios are presented where the medium or base scenarios are the ones most likely to happen. While the base scenarios for the estimations don't differ in high amounts the high scenarios differ considerably. Some authors use the crude oil prices as a starting point while the others directly use MGO prices for future price estimations.

3.5. Conclusions

Types and specifications of marine fuels are briefly explained for a better understanding of bunkers. In terms of bunker consumption, reductions in certain types of marine engines by increased efficiency can be visualized. However, an overall increase in the total bunker consumption through time is also analyzed mostly depending on the increased economic activity therefore the maritime transport. The price volatility of such marine fuels have been analyzed depending on mostly macro factors such as the supply demand and global or regional crisis.

In assessing the future prices of marine fuels, firstly past price trends of several types are analyzed. A high volatility in the prices have leaded to many factors which makes it hard to estimate an overall reason. On the other hand, while defining the future price estimations in regards with the Annex VI revisions, surveys and estimations of relevant literature and studies are considered. The high amount of uncertainty in the future price of marine fuels is also reflected by the studies as they mostly set different scenarios with a large gap between the low and high scenarios. Moreover, the demand characteristics of certain marine fuel types are analyzed in line with the set timelines by MARPOL Annex VI revisions. An increasing demand through lower sulfur content marine fuels is observed for the period until 2025.

Chapter 4 Literature review for the consequences of MARPOL Annex VI Revisions.

4.1 Introduction

Latest low sulfur requirements brought by I.M.O. MARPOL Annex VI were adopted in October 2008. By the time of the writing of this thesis, although there are several ongoing studies, lack of many available reports and studies makes the topic more challenging and interesting. It is not possible to find extensive individual studies at the moment. The ones which have been finalized are mostly drafted by academics and industry professionals for legal and commercial organizations such as International Maritime Organization, European Commission and some ship owners' associations. Since, the studies are carried out for special organizations; most of the outcomes are researched according to the needs of those.

4.2. Literature Review

- Notteboom T., Delhaye E. and Vanherle K., 2010 mentions various outcomes for the impacts of the new low sulfur directives in the report drafted for the European Community Shipowners' Association (ECSA). The authors deal with subjects such as; the impacts on the costs and prices of short sea shipping traffic in ECAs, the impacts on the modal split in the ECAs and the influence of the revisions on the external costs. The authors use experts' information and survey results for defining impacts on the costs and prices of short sea shipping in ECAs. For the rest of the research questions, they use stated reference technique for assessing the outcome of the surveys, detailed cost analyzes and simulation models.

For analyzing the impacts of low sulfur fuel requirements on costs and prices of short sea shipping the authors firstly set three scenarios for the increase in fuel cost named as low medium and high scenarios. While, analyzing different grades of fuel in two parameters first in terms of distance and second in terms of sub markets, they find several outcomes. From the survey results(2008) they obtain average usage of different fuel oil grades for short sea shipping in the selected routes as : HFO ≤ 1.5% - *69.6%*, HFO ≤ 1% - *10.9%*, HFO ≤0.5% - *13.0%*, MDO(0.2%-1.5%) – *1.2%*, WRD(0.2%-1.5%) - *1.6%*, MGO (≤0.1%) – *3.8%*. Furthermore, they analyze the cost increases for the shift between different grades and types of fuel in relation with the past data and studies. A cost increase of 20% to 30% for the shift from 1.5% to 0.5% sulfur content, 50% to 60% for the shift from 0.5% to 0.1% sulfur content is estimated. A total combined cost increase of 70% to 90% is estimated in comparison to LS380 (%1.5).

The authors obtain different cost increase estimations for defined low, medium and high scenarios for short sea shipping. While having an average cost increase of 25.5% increase for vessels with an average operating speed of 18.5 knots in the base scenario, they obtain 30.6% increase in the high scenario. These numbers change from 29% to 40% for faster vessels.
In determining the effects on the freight rates the authors first look at the share of the bunker costs in vessel operating costs. In the selected 15 routes mostly covering ECAs, the percentages of bunker costs differ from 16.2% to 64.4% depending on the route and the bunker grade type to be used on board. Referring to this data, the expected increases in the freight rates are obtained. An estimated increase ranging from 7.0% to 39.6% is estimated depending on route, bunker consumption and vessel speed.

- Swedish Maritime Administration (SMA,2009) examines the impact of the new revisions with a focus on modal split change, impact on industrial costs and impact on the shipping industry. Moreover, they analyze the economical consequences in line with both environmental and technical implications in relation with Swedish industries.

Differing from most of the other studies, Swedish Maritime Administration has analyzed the economical consequences not directly relating to the end product as marine fuel oils but relating it to the assumed crude oil prices for 2015. Two scenarios where crude oil prices are estimated to rise by 75% and 150% are run. Moreover, three scenarios where the increase and decrease in road, rail and sea transportation is kept in different levels is run to see the outcomes of the change in the modal split.

Firstly, the administration examines the future availability of 0.1% marine fuel oil and explains the refinery process. Although, it is not possible at the moment to decrease the level up to 0.1 percent in heavy fuel oils the report concludes that there will be sufficient amount of supply for 0.1% marine fuel oils recommending different technologies and methodologies for the refineries and they also mention the use of natural gas and scrubber technologies for the ship owners.

Analyzes in modal split change and the impacts on shipping, rail and road transport give various outcomes. In terms of shipping a transfer of freight transport from Sweden’s east coast to west coast is estimated. For the modal split, a decrease in marine transport operations equal to around 2 percent of total combined marine transport is estimated while a marginal increase in road and rail is reflected within Sweden.

The estimation in the impacts on fuel costs increase reflects 20% to 28% higher shipping transport costs. These outcomes have been reached by indicating an average share of 40% to 50% of fuel costs in vessel operating expenses in terms of transported freight a cost increase of 20 to 100 SEK per ton is calculated. The reason for the mentioned increase rate to be highly variable mainly depends on the load factors of different ships.

- United States Environmental Protection Agency (US. EPA, 2010) has drafted a report in 2010 for indicating the costs and benefits of reducing ship emissions in the proposed North American emission control area. While mentioning the procedures in ECAs for reducing ship emissions, the reports estimates separate reductions in NOx, Sox and particulate matter (P.M2.5). In 2020 the emissions of SOx in the ECA are estimated to be reduced annually by 920,000 tons where further annual reductions of 320,000 tons for NOx and 90,000 tons for PM2.5 are expected.

The total cost of the proposed American ECA is estimated to be around 3.2 billion $ in 2020 while it is estimated to prevent 14,000 premature deaths and respiratory problems of 5 million people. The benefits of the reduction in health and death problems is estimated as 110 billion $ in 2020. The cost of reducing a ton of SOx, NOx and PM is estimated as 1,100$, 2,400$ and 10,000$. The cost for a ship to comply with the requirements in the emission control area is estimated to increase by 3% while this operational cost difference may cause an increase of 18$ in transport cost of a 20 foot container.

- International Maritime Organization has given outcomes and recommendations dealing with ships emissions and green house gases in second IMO GHG Study 2009. Rather than an economical study, general information about ship emissions and covering legislation has been mentioned. While, total international ship emissions and the role of MARPOL Annex 6 in reducing those has been underlined, future estimations of NOx, Sox and particulate matter emissions of international shipping have been given.

Although, the report mostly deals with green house gas emissions of international shipping and modeling of those, it gives technological and political recommendations for being able to reduce the emissions and cope with the covering legislation. In the technological and operational recommendations, improving energy efficiency, usage of renewable energy sources and usage of bio-fuels and natural gas are discussed. For emission reduction technologies, the report underlines various methods. Some of the emission reduction methods for NOx are given as; fuel modification, modification of the charge air, modification of the combustion process and treatment of the exhaust gas. For reduction of Sox, scrubber technologies are mentioned. Improved vessel and engine designs and fleet management policies are further methods recommended for less emissions and better energy efficiency.

- Kalli J., Karvonen T., Makkonen T.,(2009), examine the consequences of MARPOL Annex 6 revisions in various subjects in their report prepared for Finnish Ministry of Transportation and Communications. They analyze effects of the fuel price changes in day to day running costs of the vessels with an investigation of fuel availability. By doing so, they supply a forecast in future fuel oil grades' demand and underline the impossibility of getting 0.1% sulfur content by the method of mixing different grades with current technology. While, estimating the costs of the consequences of low sulfur requirements they develop a cost model to be used on the issue.

In the cost model they calculate the allocation factor for obtaining share of total fuel oil consumption of significance for Finland for specific types of vessels depending on number of visits to Finland, total engine power, time spent in Baltic and the engine output. Three scenarios are taken for running the cost model which are the low scenario, high scenario and average (expert's opinion) scenario. In high scenario the prizes of different fuel grades such as MGO and heavy fuel oil and travel times in the North Sea and Baltic are estimated higher than the low scenario. Moreover, previously mentioned values are taken between first and second settings in the average scenario.

The authors estimate an additional cost of around 564 million Euros from all ships paying fairway dues to Finland under the high scenario. The results for low scenario and average scenario are around 341 million Euros and around 430 million Euros respectively. The report also deals with the impacts on freight charges and certain industries.

While, the costs for maritime transport are estimated to rise between 25.58% and 44.9%, they estimate the highest increase in forest industry exports with 51.5%. The impacts on the freight charges are estimated separately depending on freight categories and sulfur contents of the fuel to be used. Container freight is expected to have the highest increase while steel products and oil freight are the ones which are affected in minimum. The total freight transport costs are estimated to rise between 2% and 7% and the effect per transported ton of freight is estimated between 2 Euros and 10 Euros.

- Feng M. (2010) examines the impacts of Marpol Annex 6 regulations on marine fuels supply. The author mentions that, the new SECA regulations may cause tighter constraints on the volume of available low sulfur bunker fuels. Especially in the case of 0.5% sulfur limit, addition of low sulfur distillate fuel in larger quantities to meet the required standards is underlined. Two ways of achieving the requirements are mentioned as: using low sulfur distillate fuel or mixing and blending the heavy fuel oil with larger extents of distillate fuel until reaching the required limits.

Solutions, one and two are mentioned to be requiring additional fuel processing in refineries while creating considerable amounts of CO2. This application may impact national strategies for reducing the green house gas emissions while it requires larger capital investments. Mentioning the disadvantages of these two processes the author also gives examples of other environmental friendly fuel types such as; bio-fuels, ethanol and LNG.

Requirement of considerable upgrade of additional capacity fur cleaner fuels to meet the regulations is one of the points that can summarize the study. Another point given in the study is that, the disadvantage of fuel switching causing increased costs may prompt larger vessels to use alternative fuels as marine fuel.

- SKEMA. (2010), determines the impact of MARPOL Annex VI on the relative competitiveness between short sea shipping and road haulage. They assess the impact of MARPOL Annex VI by modeling of routes in the North Sea and Baltic emission control areas. The study also determines the cost impacts of sulfur utilizing technologies such as scrubbers.

The study analyzes the impacts modal shift between short sea shipping and road haulage in certain routes under several scenarios. Selected 10 routes consists of destination arrival pairs such as; Gothenburg to Dortmund,

Dortmund to Manchester, Klaipedia to Harwich etc. In the selected 6 scenarios, current MARPOL legislation, Eurovignette infrastructural toll and environmental toll, reduced wages of truck drivers and different contents of sulfur contents of marine fuels are considered separately. For combining the short sea shipping and road haulage several RO-RO and LO-LO vessels are used in the model.

The highest probability of modal shift in the selected route including Klaipedia, Hamburg, Rotterdam and Harwich is estimated under two scenarios which are covering current MARPOL Annex 6 requirements and plus truck drivers on reduced wages. Furthermore, the TAPAS model used in the study which predicts the highest probability of being selected for the transportation of goods under a certain route, gives different outcomes for different years as the requirements of the legislation change. While the highest possibility in 2009 is for the route Klaipedia to Frederica by ship, Frederica to Esbjerg by truck and Esbjerg to Harwich by ship, in 2025, it changes to Klaipedia to Rotterdam by truck and Rotterdam to Harwich by ship.

Consequently several outcomes for short sea shipping in the ECAs are given. Increase in transportation costs for all routes with sea legs is one of the main estimates of the study. A lower impact on change in the cost difference over longer distances is mentioned.

- Entec. 2010, has made a study to review the assessments which are undertaken of the revised MARPOL Annex 6 regulations. Some of the previously mentioned literatures and studies done by European organizations are reviewed and compared in the study.

While giving the overview of the reports key assumptions are brought forward by the study. The assumed starting point of the analysis for the impacts of the new revisions on MARPOL Annex 6, shipping sector response, analysis of availability and cost of low sulfur fuels, estimations through modal shifts, emission reduction technologies and associated environmental benefits are summarized in the report.

The study draws several conclusions on price reflections of future marine fuels, modal shift expectations in ECAs, external costs etc. Total cost of assuming only fuel switching for compliance in 2015 has estimated to be between 3.0 billion Euros and 3.6 billion Euros. The additional fuel cost of shifting from 1.5 % sulfur content heavy fuel oil(HFO) to 0.1 % sulfur content Marine Gas Oil (MGO) is estimated to be between 155 Euros and 310 Euros per metric ton of fuel oil by representing an increase of around 80% in fuel oil prices. The modal shift is expected to vary between 3% and 50% in volume differing largely in relation with routes and price projections. In the matter of external cots, the study not only points out the reviews done in favor of benefits caused from the shift to 0.1% sulfur content marine fuels but also, mentions the possible reverse effect of modal shift from sea to road and its increased external costs.

4.3. Summary and Conclusion

The impacts of MARPOL Annex VI revisions have been analyzed by a few studies which are mostly carried out for governmental or commercial organizations. While, some studies deal with the environmental aspects of the matter, others also investigate the economical impacts. Impacts of the revisions on costs of short sea shipping, maritime freight rates, modal split change, future pricing and the supply demand characteristics of marine fuels are some of the economical research done in the relevant literature. Environmental impacts and costs and benefits of the legislation are other areas researched.

Short sea shipping and vessels operating in the Emission Control Areas are the main focus of some studies. Firstly, the price estimations are done in order to estimate the economical impacts of increased fuel prices on the costs of short sea shipping. The authors find considerable cost increases for different vessels operating in ECAs in line with the future bunker price estimations. While doing so, some authors imply the share of fuel costs on the total cost structure of different vessel types for future estimations. The outcomes of the increased costs are also considered for the effects on the modal split as the cost for transporting the goods by sea will increase more in consideration to road or rail transport. Moreover, the matter is also analyzed on an industry specific level in consideration to certain cargoes and manufactured goods.

The price estimations are done in accordance with the surveys carried out by the authors having intervals which reflect the high uncertainty. The cost increases are modeled through simulation models or cost models structured in accordance with the share of the fuel costs on the total costs. Maritime freight rates are reflected as an outcome of the cost increases and in many of the studies, the matter is not defined and analyzed with clear methodologies. Technical innovations, such as scrubbers, their application and cost analysis are also other topics which are dealt in assessing the outcomes of the revisions.

Consequently, despite the high variation, considerable increases in fuel costs and freight rates are estimated by the studies. The possibility of modal split change and its impact on external costs are also other subjects researched which have significant results. Rather than a global coverage sector, geography specific estimations are done in order to answer the concerns of specific industries and legislative bodies.

Chapter 5. Impact of MARPOL Annex VI Revisions on Maritime Freight Rates

5.1. Introduction

Ratification of the latest revisions of MARPOL Annex VI has brought many obligations for the present and future of the shipping industry. Although, structured differently by many authors, fuel costs always take a considerable share in the total shipping costs[3]. With the fact of the fuel costs, the future price increase of the marine fuels in relation with the higher qualities and less sulfur contents has been one of the main concerns of the industry and many organizations.

High dependency of maritime transport on low quality fossil fuels with today's limited technology and standards increases the importance of marine fuel costs. Any regulation changing this balance such as MARPOL Annex 6 revisions further increases the relevance of the matter. Although, there have been many approaches in researching the impacts of the revisions, the studies have mainly investigated the matter in regional or industry specific terms.

By considering the freight rates as the earnings, fuel costs are one of the main components structuring the expenditure of the ship owners or operators. Depending on vessel specifications, types, sizes, and market structures, the effect of fuel costs on the freight rates vary dramatically.

In this chapter the effect of increasing bunker prices on maritime freight rates will be analyzed under different models. Tanker spot rates and dry bulk commodity spot rates and the impact of bunker costs on these will be analyzed considering different trade routes, vessel sizes, commodities and periods. Moreover, future estimations of marine fuel oil prices will be made with the light of current studies and approaches of organizations. After estimating elasticities for different markets and scenarios, future freight rates estimations will be given.

[3] See for example; Branch (1998), Stopford (2004), Hummels(1999), Humels(2001), Limao and Venables (2001), Mirza and Zitouna (2009).

5.2 Review of the relevant literature

There have been many research carried out in determining the cost structure and the determinants of maritime transport. With the increasing understanding of the importance of international shipping, many factors determining the market have been studied and examined both in micro and macro levels. Importance of port infrastructures and superstructures, ship financing, policy measures, sub markets of shipping, maritime cost structures have been well understood and examined. However, the effect of oil prices in other words bunker costs and their impact on the freight rates haven't been analyzed extensively. Some of the few studies that deal with the matter and a brief outlook to the literature are as follows;

- Mirza and Zatouni, (2009), have studied the effect of oil prices in concern with international trade. They analyze the effects on trade in dependence with the distance while using US bilateral imports and transportation costs data and considering trade between close and far countries. They consider the transportation costs as an outcome of fixed and variable costs. The authors also defend that oil prices may affect the variable costs of transportation and shape the trade between US and its partners.

Firstly, they develop a cost model where they argue that the technology function of transport costs is positively related to oil prices and on board factor prices. They develop a model for calculating the elasticity of transportation costs to oil prices depending on the share of variable costs to total transportation costs, technology function and price of oil. The distance is estimated to be a determining factor in the equation as it highly effects the variable costs, where for example, the bunker costs increase accordingly.

Secondly, they develop an equation for estimating the freight rates where the freight rates depend on the price of the good, premium charged on the price, total cost of transporting on ton of merchandize and the proportion of fixed costs to quantity of merchandize shipped. Thirdly, they develop an equation for calculating the proportional change in freight rates as a function of changes in fixed and variable costs and the changes in the price of the good.
Moreover, the authors estimate a further equation between a proportional change in the freight rates and consecutive change in oil prices.

Consequently, Mirza and Zaotuni (2009), obtain a low elasticity of freight rates to oil prices changing in accordance with the distance of the countries. The numbers differ between 0.088 (for countries closer to US) and 0.103 for countries far away from US

- Poulokidas and Joutz (2008), have examined the weekly spot tanker prices and the oil market for the periods 1998 to 2008. They analyze the

West African Us Gulf tanker rates, West Texas intermediate spot rates and three months future contracts and US weekly petroleum inventories with using Granger casualty analysis and using co-integration methods for examining the relationship between oil prices and tanker freight rates.

They firstly, employ a general to specific econometric modeling which can be used for characterizing the sample data in simple parametric relationships which remain reasonably stable over time. The properties of the time series of individual data series are analyzed and then a vector auto regression system is formed. After, the authors carry out Granger tests to look at the relationships between the previously mentioned four variables. According to the outcomes of the tests, futures contracts are estimated to be affected from tanker rates and inventories at the levels of 1% and 5% respectively. Spot prices are explained by all other three series and the results of the inventories appear to be affected by other three series at the 5% level individually and jointly.

With using the co-integration analysis, they defend the possibility of the idea that the demand for tankers is a derivative for the demand for oil. They also underline the possibility for the tanker companies to raise rates when there is a high demand for oil and it is pushing the demand for tankers accordingly.

- Hummels (2007), has examined determinants of transport costs both for air shipments and ocean shipments. The author uses historical data from 1974 to 2004 based on US imports and merchandise. He measures elasticity of ad valorem freight costs in relation to weight/value of the commodity, distance, fuel costs, distance and containerized share of trade in the ocean shipments.

At 1% significance level, the author estimates elasticity of freight costs with respect to fuel costs at 0.232 and with respect to weight / value of the commodity at 0.374.

- UNCTAD (2010), examines the effect of oil prices on container freight rates on three main routes as the transpacific, the transatlantic and the Asia – Europe. Quarterly container freight data for the years 1993 and 2008 are used. Moreover they assess the impact of oil prices on two main commodities, namely as iron ore and crude oil. For iron ore the analyze is done on the data from 1993 to 2008 on eight main trade routes and for crude oil the data from 1996 to 2008 is used.

For assessing the effect of oil prices on container freight rates, the organization has developed a model where the freight rates and the elasticities are estimated depending on six variables. Dependent variable is the average freight rates and other variables used in the model consists of; price per barrel of Brent crude oil prices, standard deviation of price per barrel of Brent crude oil prices, flows of containers on the expressed route for the specified time, measure of imbalance of container trades on the expressed route for the specified time and Harpex, index of charter rates. The standard deviation of oil prices is used to test whether the fright rates respond to fluctuations in oil prices. The flows of containers are used to measure the degree of economies of scale. A negative coefficient on this variable would show that , the larger the trade flows, the lower the transport costs per TEU.

For the container freight rates model, the authors find point estimates interpreted as elasticities with ordinary least squares method. They find that in all models the estimated elasticity of container freight rates to Brent oil prices is significant and changing between 0.137 and 0.291 with 0.45 and 0.50 R squares respectively. A non significant effect of variation in the oil prices and the flow of containers is found in the model while the trade imbalances have a statistically significant effect on freight rates with estimated elasticities ranging between 1.365 and 1.373.

For estimating the impacts of crude oil prices on iron ore freight rates a similar model is developed for eight main iron ore trade routes. The spot rate of iron ore is the dependent variable while the price per barrel of Brent crude oil, the standard deviation of the prices of crude oil, iron ore prices, trade volume of iron ore on the expressed route and time and the Baltic dry index (BDI) are the explanatory variables used in the model. With ordinary least squares method a point elasticity between iron ore freight rates and Brent crude oil prices is found to be 0.149. The author tests the model including and excluding the BDI. The results show that excluding BDI increases the explanatory power of crude oil prices significantly.

The effect of crude oil prices on crude oil spot freight rates is estimated with a model where the spot freight rates is the dependent variable and the price per barrel of Brent crude oil, standard deviation of the price per barrel of Brent crude oil and the trade flow are the explanatory variables. When the price volatility of the crude oil prices is excluded from the model, in the VI-GMM estimation the effect of the crude oil prices is estimated to be statistically significant and positively correlated with the spot freight rates, however, when the price volatility is included in the model, the coefficient foe the Brent crude oil prices remain positive but it no longer stays statistically significant.

- Notteboom and Verminen (2008) have examined the impacts of increasing bunker costs on the design of liner services on the Far East – Europe trade. They have assessed how shipping lines have arranged their service schedules in accordance with the increased bunker costs. A cost model which is stimulating the impact of bunker cost changes on the operational costs of liner services is also included in the study.

They develop a model where the minimum required service speed is calculated as an outcome of given frequency, number of ships, number of port calls and roundtrip distance. The cost model developed for liner services, ship costs, container costs, administrative costs and cargo handling costs are included. By testing different sizes of ships at different speeds they find a share of bunker costs in total costs varying between 20 % and 28 %.

- Lundgren (1996) reviews the changes in the transportation costs in maritime trade for the periods 1950 – 1993. While examining the decline in the maritime trade rates, he connects this outcome with the increasing technology in shipping in other words the increasing bunker efficiency.

The author also examines the freight rates for iron ore, coal and grain on selected route by employing them dependent variables in the ordinary least squares method. He uses, the percentage of lay ups, bunker prices, effects of main political events and crisis such as Korean War, closure of Suez Canal etc. according to the results of the model, the author estimates that an increase of 1 % in the bunker prices (at the mean) causes an increase of 0.39% in coal and grain freight rates.

- Bridgman (2003), has examined the relationship between energy prices and the expansion of world trade with an outlook into the 1970s oil shocks. He presents a trade model with an energy using transportation sector. He argues that the oil price increase following the oil crisis in 1970s has increased the transport costs and reduced the trade levels and the come backs of the prices in 1980s to their pre crisis values have declined the transportation costs and increased trade levels.

5.3 Impact of marine fuel prices on tanker spot rates

Tanker trade serving for the transportation of liquid bulk cargoes accounted for over one third of world seaborne trade in 2008. Worldwide shipments of liquid bulk cargoes have reached up to 2.75 billion tones of which nearly 65% were crude oil (UNCTAD, 2010). The importance of tanker shipping in serving the trade of world's oil market is obvious as it moves the oil from producers to consumer markets. Moreover, as the fuel consumed on board can be the commodity transported at the same time, which increases the complexity of the relationship.

Tanker spot rates are strongly influenced by the crude oil market, future contracts, petroleum inventories and spot prices. As one of the main determinants is the crude oil market, the pricing of the crude oil reflects further impacts on the tanker spot rates. The trade and pricing of crude oil is subject to many factors such as; relative demand changes from economic growth globally and regionally, the volatility which is leaded by supply disruptions and shocks in oil exporting countries, including the impacts of special entities namely OPEC and Russia (Poulakidas and Joutz 2008).

Both the cost component and the commodity traded can be the same product, for example crude oil or oil products, for tanker vessels. In determining the spot rates, the bunker cost component of the vessels carry a big importance while the volatility, supply, demand and the trade imbalance of oil and oil products have a cross effect on the spot rates. Moreover, political crisis, wars, global and regional oil shocks even speculations have a considerable effect on tanker spot rates.

Recovery of increasing fuel prices from the customers is a challenge when we consider that the vessel utilization is not always 100% (WSC 2008). Geographical trade flows play a considerable role in shaping the tanker spot rates. While the main loading area for crude oil stayed as Western Asia, other exporting regions included South America, Central Africa and North Africa. The main importing regions have been Europe, North America and Japan (UNCTAD, 2009).

The relevant value of different cargoes and their supply demand characteristics also shape the spot freight rates. A further point is the concentration of different markets, which can be interpreted from perfect competition to oligopoly in economical terms, may affect the behavior of the ship owners and operators. Although, there are many components of which some of them are impossible to obtain correctly, an empirical analysis with mathematical modeling can give a sight in obtaining the effects of fuel oil costs and their volatility on the tanker spot rates.

5.3.1 The data

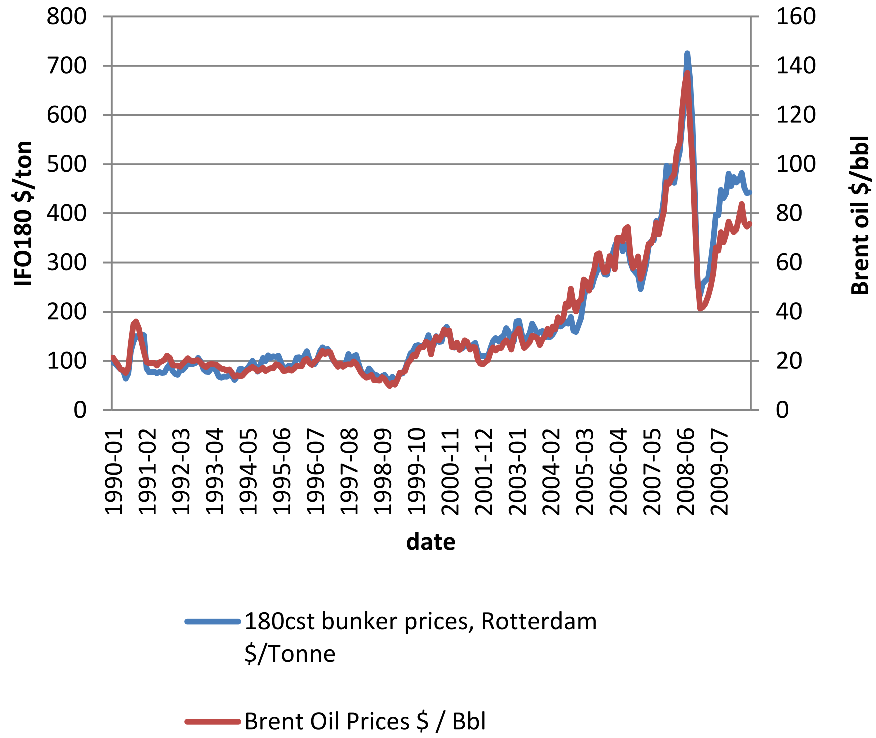
In this section, the relationship between oil prices, their volatility and the tanker world scale rates will be analyzed. The world scale rate is a unit of establishing payment of freight rate for a given oil tanker's cargo. This rate is used as a more convenient way of negotiating the price of the freight rate for transporting per barrel of oil on many trade routes(Stopford,2004). Specific freight rate for a given voyage and a given ship is reflected as the percentage of this index and reflects the demand for the transport of oil. The table published by World-scale Association gives details for many routes and many ships carrying oil. The rates written for transporting one barrel of oil on the specified route is referred to as WS100 meaning exactly the same amount as in the table. If the parties for example agree on the half price of the set price then it is referred as WS50.

In this section, tanker freight rates from 1998 to 2010 including world scale rates for aframax, suezmax, ULCC-VLCC type tankers will be analyzed in regards with the volatility and the price evolutions of the oil prices. Data on freight rates are taken from Clarksons research 2010, including dirty and clean world scale rates on different routes for different type of vessels. The crude oil prices and marine fuel prices and the Baltic dirty and clean tanker indexes for specific scenarios are also taken from Clarksons research services. The price evolution and the volatility of the price of IFO 180 (Intermediate Fuel Oil 180cst) is taken as the fuel cost variable to use in all the models.

As the marine fuels are the processed versions of crude oil, their price evolutions over time and their volatility highly correlates with the crude oil prices. Figure 5.1 shows the price evolutions of Brent crude oil and IFO 180. High correlation between the two series can easily be observed from the figure. Moreover, outcomes of a single linear regression test with 99% confidence level shows the high correlation of IFO 180 prices to Brent crude oil prices with an R square value of over 0.99. With the guidance of these statistics, we will take the price of IFO 180 as one of the references for all the scenarios. The reason behind using regression analysis is to observe if there is a relationship between the chosen dependent and independent variables, see the level of the relation and for a linear function in which we can analyze how much each of the independent variables effect the independent variable under different circumstances. This method have been used by various studies, for example: UNCTAD 2010, for assessing the relationship between the freight rates and their determinants.

The data for the tanker spot rates consists of two main categories as spot rates for the carriage of dirty cargoes such as crude oil, and spot rates for the clean cargoes such as clean products. Rates for various trade routes namely; North Sea to Continent, Russia, cross Mediterranean, Arabian Gulf – Northwest Europe, Arabian Gulf- Gulf of Mexico, North west Europe – Northwest Europe, etc. have been considered.

Figure 5.1 Price evolution of Brent crude oil and IFO 180 between 1998 and 2010.



Source: Own preparation, based on Clarksons data.

5.3.2 The models

Availability and accuracy of such data plays the utmost important role in creating a model for the relationship between freight rates and its determinants. There are many determinants which may affect the tanker rates such as; price data of marine fuels, price volatility of the marine fuels, economic activity in the specific routes for the selected cargoes, regional and global supply and demand characteristics for the service, seasonality effects etc. As it is not very easy to reach all the reliable data the model has been developed purely to investigate the effect of bunker prices and their volatility on tanker spot rates.

To investigate impacts of oil prices and their volatility on tanker spot rates, the below models have been developed.

Model 1

$$SFR_{imy} = \lambda_i + \beta_1\ IFO_{my} + \beta_2\ VLT_{my} + \beta_3\ BDTI_{imy} + \varepsilon_{imy}$$

Model 1.1

$$SFR_{imy} = \lambda_i + \beta_1\ IFO_{my} + \beta_2\ BDTI_{imy} + \varepsilon_{imy}$$

Model 2

$$SFR_{imy} = \lambda_i + \beta_1\ IFO_{my} + \beta_2\ VLT_{my} + \beta_3\ BCTI_{imy} + \varepsilon_{imy}$$

Model 2.1

$$SFR_{imy} = \lambda_i + \beta_1\ IFO_{my} + \beta_2\ BCTI_{imy} + \varepsilon_{imy}$$

- The definitions for the equation variables are as follows:

$\mathbf{SFR_{imy}}$= Related world scale rate for selected tanker vessel serving on route *i* in month *m* of year *y*;

$\mathbf{IFO_{my}}$ = Price per tone of IFO 180 in $ for month *m* of year *y*;

$\mathbf{VLT_{my}}$ = Standard deviation of the price of IFO 180 for month *m* of year *y*;

$\mathbf{BCTI_{imy}}$ = Related Baltic Clean Tanker Index for the selected tanker vessel on route *i* in month *m* of year *y*;

$\boldsymbol{\lambda_i}$ = Fixed effect;

$\boldsymbol{\varepsilon_{imy}}$ = Stochastic error term;

$\boldsymbol{\beta_n}$ = Coefficient for the related variable;

The models 1 and 1.1 are developed for controlling the impacts of the oil prices and their volatility on tanker rates for vessels carrying dirty cargoes mainly crude oil. Model 2 and 2.2 are developed for investigating the relationship between oil prices, their volatility and the tanker rates for vessels carrying clean cargoes such as clean oil products, naphtha, etc. Between models 1 and 1.1, 2 and 2.2 the variable, volatility of IFO 180, has been excluded for investigating only the effect of the IFO prices on the tanker rates.

To check the results of the models, multiple linear regression method is used to look at the correlation [4]between the explanatory and dependant variables. The data is tested with 90% and 95% confidence levels and the outcomes are analyzed accordingly to be statistically significant. Elasticities are calculated depending on the means of the samples and the coefficient of the independent variable. Following formula is used to estimate the elasticity[5] of the dependant variable in respect with the independent variable, i.e. elasticity of tanker spot rates to IFO 180 prices.

$$\mathbf{Ex} = \frac{\Delta \mathbf{x}}{\Delta \mathbf{y}}\, x\boldsymbol{\beta}_1$$

where; the mean of the sample of the independent variable is divided by the mean of the sample of the dependant variable and multiplied by the coefficient of the independent variable.

5.3.3 Results of the model for the impact of bunker prices on aframax tankers spot rates.

The regression analyses for all models are carried out by using Microsoft Excel Regression Analysis tool. All models are tested with 95% significance level and the outcomes are tested to be statistically significant.

The first analyze is done according to model 1 and 1.1 for investigating the effects of the bunker prices on dirty cargo carrying aframax tankers world scale rates. The corresponding data are available from 1998 to mid 2010. After testing the model at 0.95 significance level, the following results are obtained. The R square of the regression analyze has been found to be 0.773 meaning nearly 77 percent of the relations is explained by the linear equation. The coefficients for all explanatory variables are positive. The elasticities are calculated accordingly. The elasticity of world scale aframax tanker rates to bunker prices is found to be particularly small with a number of 0.018. Moreover, the elasticity of world scale aframax tanker rates to the volatility of the bunker prices is found as 0.043. Although, elasticities are close to zero the results are statistically significant. The oil prices and their volatility have effects on the freight rates in the levels of the given elasticities. When the volatility explanatory variable is taken out of the regression analysis (model 1.1), the outcomes are still statistically significant having nearly the same R square level with the previous estimate. The elasticity of the tanker rates to

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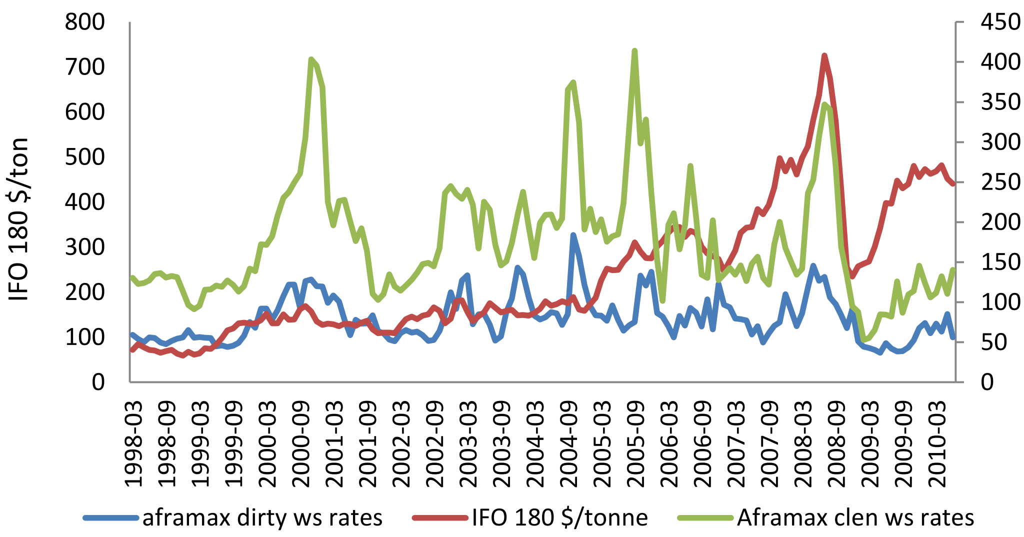
[4] The correlation is a measure to the extent which two variables vary together. The correlation coefficient varies between -1 and 1.

[5] The elasticity refers to the percentage increase in the dependant variable caused by a 1 percent increase in the explanatory variable.

bunker prices increases to a value of 0.05 when we exclude the volatility variable. Taking out the BDTI makes the results statistically insignificant.

The second analyze is carried out according to model 2 and 2.1 for estimating the impacts of bunker prices and their volatility on the related world scale tanker rates. The outcomes of the regression analysis run according to model two gives an R square of 0.62. Although, very small the coefficient for the fuel prices is found to be negative[6], this means a negative correlation with the freight rates. On the other hand, the volatility of the bunker prices and the BTCI are positively correlated with the related freight rates. No significant reason could be found for the negative correlation between bunker prices and the freight rates. As the model is tested for clean cargoes, the low relationship between bunker price growth and rates for clean oil products (Glen and Martin, 2005) can be one of the reasons.

Figure 5.2 Evolution of IFO 180 prices, aframax clean world scale rates and aframax dirty world scale rates from 1998 to 2010.



Note: the axis on the right relates to Aframax clean and dirty world scale rates and the axis on the left relates to IFO 180 prices.

Source: Own preparation, based on Clarksons data.

Figure 5.2 reveals the evolution trends of aframax dirty and clean world scale indexes and the price of IFO 180. Between the dirty and clean tanker rates

[6] Glen and Martin (2005), have found a negative correlation between the growth in real oil prices and growth in spot rates for tankers of 250,000 DWT.

similar dips and peaks can be observed from the figure. The peaks in early 2008 and the dips in early 2009, reflecting the high demand for bulk liquid transportation and effects of global downturn respectively, can be seen in all three series. We can see that, on average aframax clean world scale rates are higher than the dirty world scale rates. As the clean oil products are more expansive than crude oil, the value – volume ratio can be the main reason in this observation.

5.3.3.1 Sample Statistical Results

Below are the sample statistical results for interpreting the linear relationship between the dependant and explanatory variables. For example if we were to include all variables and define the freight rates in a linear equation it would be;

$$\mathrm{SFR}_{\mathrm{imy}} = \lambda_{\mathrm{i}} + \beta_1\ \mathrm{IFO}_{\mathrm{my}} + \beta_2\ \mathrm{VLT}_{\mathrm{my}} + \beta_3\ \mathrm{BDTI}_{\mathrm{imy}} + \varepsilon_{\mathrm{imy}}$$

$$\mathrm{SFR}_{\mathrm{imy}} = 21.6042 + 0.01060\ \mathrm{IFO}_{\mathrm{my}} + 0.53535\ \mathrm{VLT}_{\mathrm{my}} + 0.82500\ \mathrm{BDTI}_{\mathrm{imy}} + \varepsilon_{\mathrm{imy}}$$

Sample Statistical Results for first analyze model 1

Regression Statistics	
Multiple R	0.879654
R Square	0.773791
Adjusted R Square	0.76911
Standard Error	23.88425
Observations	149

	Coefficients
Intercept	21.6042
IFO 180	0.01060
Volatility	0.53535
BDTI	0.82500

	Elasticities
IFO 180	0.01794
Volatility	0.04363

Sample Statistical Results for first analyze model 1.1

Regression Statistics	
Multiple R	0.876159
R Square	0.767655
Adjusted R Square	0.764472
Standard Error	24.12298
Observations	149

	Coefficients
Intercept	20.89871
IFO 180	0.029807
BDTI	0.831454

	Elasticities
IFO 180	0.050441

5.3.4 Results of the models for the impact of bunker prices on suezmax tankers spot rates.

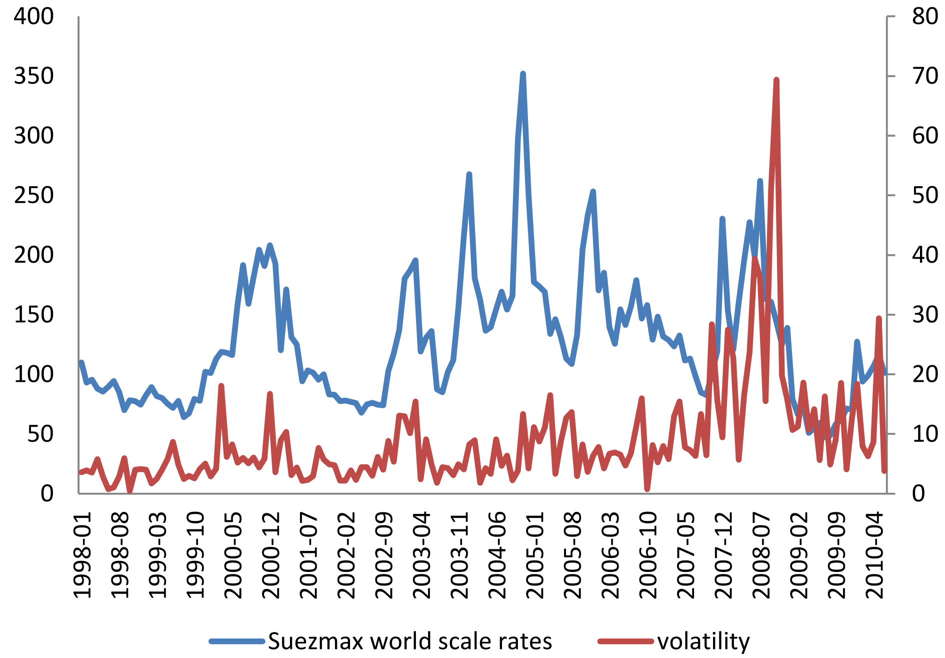
The third analysis is done for estimating the impact of bunker prices and their volatility on suezmax tanker world scale rates. Since the suezmax tankers are mostly carrying dirty cargoes in other terms crude oil the analysis is done according to dirty world scale index. Models 1 and 1.1 are used to investigate the relationship between the dependant and explanatory variables. The outcomes of the regression analysis are not strongly significant in statistical terms. The R square of the linear regression is around 0.51 meaning nearly half of the relations between the variables are explained by the equation. The correlation coefficient for the bunker prices is negative while the coefficients for the volatility and related BTDI are positive.

Calculated elasticities for bunker prices and volatility of bunker prices to suezmax tanker world scale rates are - 0.053 and 0.022 respectively. The results reflect the fact that the increase in oil prices affects the suezmax tanker rates negatively while the increase in volatility affects positively. When we test the data according to model 1.1, excluding the explanatory variable of volatility in bunker prices, the coefficient of bunker prices stays negative with a similar R square. Only the elasticity of suezmax world scale rates to bunker prices decreases to - 0.014.

Although, not very significant in statistical terms, the model shows a negative correlation between the increase in bunker prices and increase in tanker rates. As crude oil is one of the main commodities, mostly the only commodity transported by large tanker vessels, further supply and demand trends of crude oil can be one of the reasons to explain the outcomes of the analysis. For example, rising prices of the oil can be subject to production cuts and reductions in the main suppliers. When considered in economical terms, price as a function of supply and demand may explain the case. While, the price is increasing because of low supply, the demand for the transport may also decrease. When the demand decreases, the related spot rates also decrease.

The positive correlation between suezmax world scale rates and volatility of bunker prices may also depend on the supply and demand characteristics of crude oil. Figure 5.3 shows the evolution of the suezmax tankers dirty world scale rates and the volatility of the bunker prices for the period 1998 – 2010.

Figure 5.3 Evolution of suezmax dirty tanker world scale rates and price volatility of IFO 180 for the period 1998 – 2010.



Note: the axis on the left corresponds to suezmax tankers world scale rates and the axis on the right corresponds to volatility.

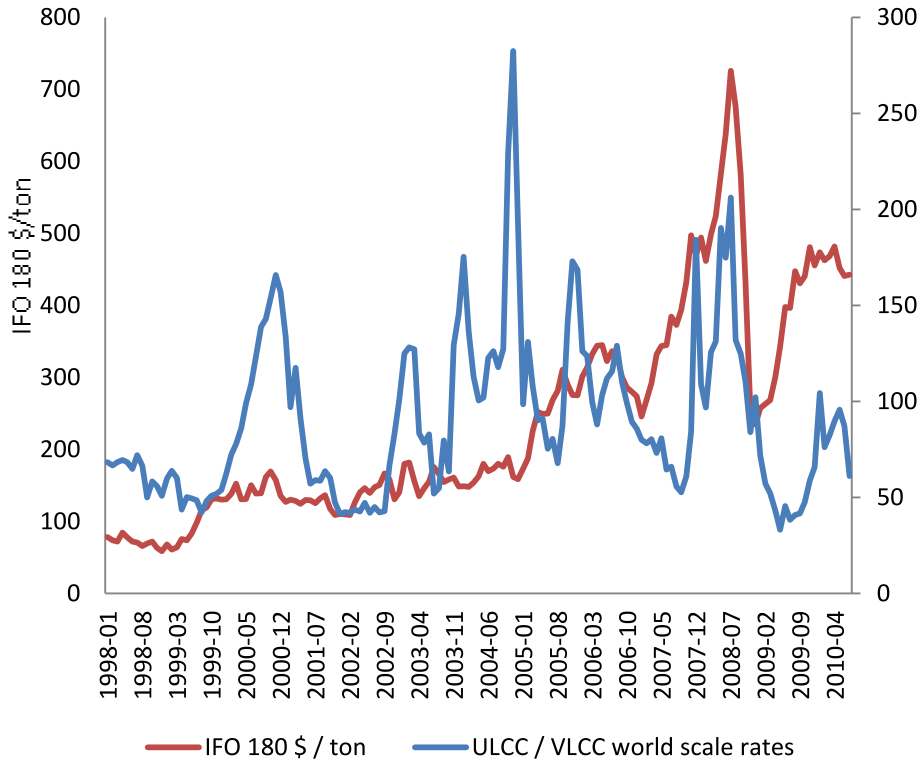
Source: own preparation, based on Clarksons data.

5.3.5 Results of the models for the impact of bunker prices on VLCC / ULCC tankers world scale rates.

Models 1 and 1.1 are used to investigate the impact of bunker prices and their volatility on VLCC / ULCC tanker world scale rates. The data are tested including and excluding the explanatory variable bunker price volatility. When the regression analysis is done according to model 1, the correlation coefficient for the bunker prices stays negative while the correlation coefficient for the volatility in bunker prices and VLCC / ULCC tanker world scale rates are positive. The equation is explained with an R square of 0.55. The estimated elasticity of the tanker rates to bunker prices is calculated as – 0.027. When the data is tested according to model 1.1 by excluding the effect of the volatility in bunker prices, the model still stays statistically significant with an R square of 0.53. Moreover, the bunker prices correlate positively when tested in model 1.1. The estimated elasticity of VLCC / ULCC world scale rates to bunker prices is calculated as 0.046. From the results of the models it is hard to estimate a very significant relationship between bunker prices and freight rates. Excluding the effect of volatility changes the correlation between the bunker prices and VLCC / ULCC freight rates. The pre determined reasons depending on the supply and demand characteristics of crude oil which is the main commodity transported by these type of vessels can be one of the reasons enlightening the results.

Figure 5.4 shows the evolution of IFO 380 prices and VLCC / ULCC world scale rates between 1998 and 2010. Similar to figure 5.2 and 5.1 it is not very easy to observe a high correlation in the graph. Some of the few similarities in the time trends are the peaks and the dips following by the boom times of 2008 and the effects of the global crisis. One interesting to note is that, between 2004 and 2005 VLCC / ULCC tanker rates peaks its highest while the bunker prices shows small fluctuations at the same levels. On the other hand in 2006, the world scale rates for VLCC / ULCC tankers world scale rates fall more than the bunker prices percentage wise. These opposing trends can be a guide to show the complexity of this market and its dependency on supply, demand and price characteristics of the crude oil market.

Figure 5.4 Evolution of IFO 380 prices and VLCC / ULCC world scale rates for the period 1998 – 2010



Note: the vertical axis on the left refers to IFO 380 prices $ / ton and the vertical axis refers to selected ULCC / VLCC world scale rates.

Source: Own preparation, data derived from Clarksons.

5.4 Impact of marine fuel prices on dry bulk spot rates

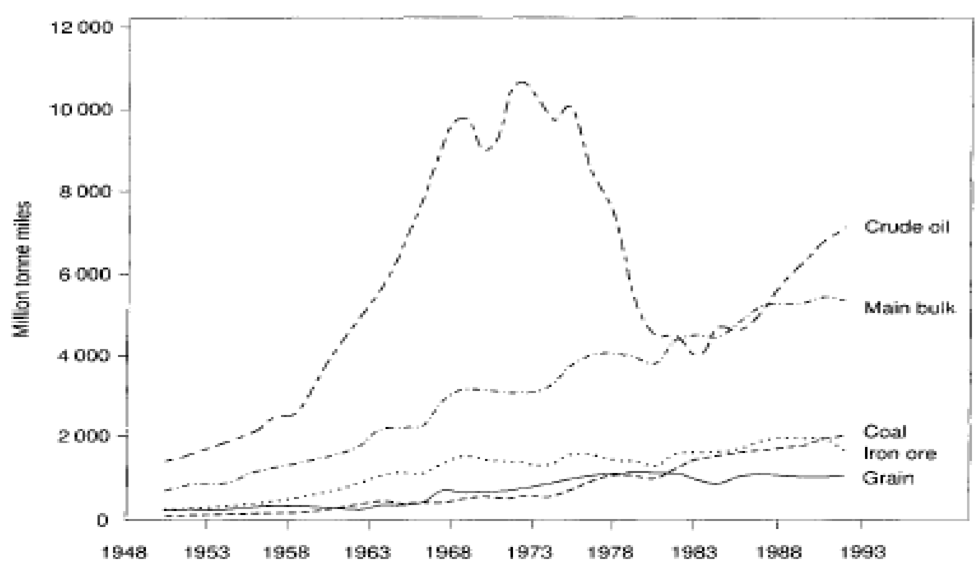
Dry bulk shipping market has been found to be the least concentrated amongst other shipping markets. The market is known with high degrees of competition where the players are price takers (Haralambides, 2010). With these characteristics dry bulk shipping sector is heavily dependent on the trade of main commodities such as iron ore, grain, coal, etc. In 2008 iron ore transportation has shared a value of over 10 % in terms of volume of the global trade with Australia and Brazil being the main exporters sharing two over third f the total iron ore exports and China being the main importer due to its growing steel production sector (UNCTAD, 2010). These statistics show

how , main commodities' trade, their demand and supply trends may have a determining effect in dry bulk shipping.

Spot rates of main dry bulk commodities depend on many factors apart from their own supply and demand characteristics. Cost of transporting the dry bulk commodities consists of determinants such as, fixed costs (e.g. ship capital costs, administration costs, insurance costs, etc.), varying maintenance and mainly fuel costs. The changes in the supply demand and pricing of crude oil by being a source of marine fuels have considerable effects in the dry bulk spot rates.

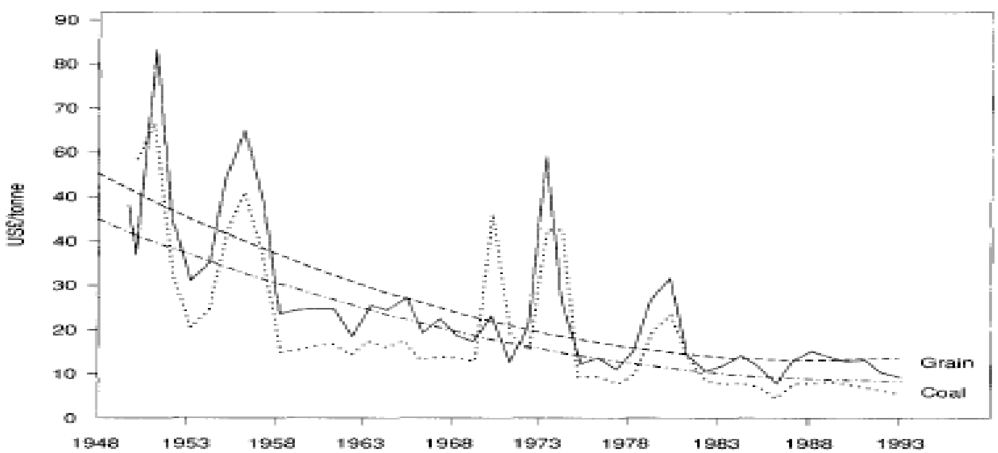
Figure 5.5 and 5.6 shows the world seaborne trade of main commodities such as crude oil, iron ore, coal, grain, main bulk and the freight rates for coal and grain respectively for the period 1950 – 1992. The figures can be a good reference to show how the freight rates are affected by the major political and global crisis, cutbacks in the oil production therefore the oil prizes. As it can be seen from figure 5.6 the Korean war crisis in 1951 – 1952, closure of Suez Canal in mid 1950s cause the freight rates to fluctuate sharply. The cutbacks of the OPEC in 1973 – 1974 and 1979 – 1980 shows a considerable impact on the freight rates as they increase sharply during these periods. This analyze can be a good guide to show the dependency of dry bulk freight rates to supply and price trends of crude oil.

Figure 5.5 World seaborne trade of crude oil, iron ore ,coal ,grain and main bulk in ton miles for the period 1950 – 1992



Source: Lundgren, (1996)

Figure 5.6 Freight rates of coal and grain from U.S. to European continent for the period 1950 – 1993



Source: Lundgren, (1996)

5.4.1 The data

The data used to assess the impacts of fuel oil prices and their volatility on the spot rates of iron ore, coal and grain is available from 1990, 1991 and 1999 to 2008 and 2010 depending on the variable. The iron ore spot rates taken for the period 1990 – 2010 for main routes and Australia – Rotterdam is taken as reference. The grain spot rates are available from 1991 to 2008. Grain spot rates for the route U.S. – Rotterdam is taken as reference. The data for coal spot rates is available from 1991 to 2010 and the route U.S. – Antwerp Rotterdam Amsterdam (ARA) is taken as reference.

The bunker prices included in the related models for the periods mentioned above and the Rotterdam price of IFO 180 $ / ton is taken as the fuel oil price variable. Monthly standard deviation of the IFO 180 Rotterdam price is calculated for including the volatility of the fuel oil prices in the models. Capesize bulk carriers are considered for iron ore transportation and Panamax type bulk carriers are taken for grain and coal transportation and related spot freight rates are included in the models accordingly.

As the Baltic Dry Index (BDI) is available from 11th month of 1999, this data is included in the models from the respective period until 2010 as a further explanatory variable.

For mentioning again the importance of the relevant data for assessing the relationships between freight rates and its determinants, availability of such correct data plays the most important role. An analysis including the price and trade volumes of each commodity, the regional and global effects on the route, shocks of the crisis etc. can be further explanatory variables apart from those included in the models. The hardness and sometimes unreliability of obtaining these kinds of specific data forms a challenge. However, the models give statistically significant outcomes with the presence of the mentioned variables that are included in the data for testing the relationships.

5.4.2. The Models

The models are developed for investigating the relationships between spot rates of selected main dry bulk commodities, the fuel oil prices and the volatility of the fuel oil prices for the selected time periods. The explanatory variable BDI is excluded from the equation to further investigate the effect of bunker prices on the spot rates for the selected commodities.

To investigate the impact of bunker prices on spot freight rates of iron ore, coal and grain cargoes, the following models are developed.

For iron ore spot rates;

Model 3

$$\mathrm{ISR}_{\mathrm{imy}} = \lambda_{\mathrm{i}} + \beta_1\,\mathrm{IFO}_{\mathrm{my}} + \beta_2\,\mathrm{VLT}_{\mathrm{my}} + \beta_3\,\mathrm{BDI}_{\mathrm{imy}} + \varepsilon_{\mathrm{imy}}$$

Model 3.1

$$\mathrm{ISR}_{\mathrm{imy}} = \lambda_{\mathrm{i}} + \beta_1\,\mathrm{IFO}_{\mathrm{my}} + \beta_2\,\mathrm{VLT}_{\mathrm{my}} + \varepsilon_{\mathrm{imy}}$$

For grain spot rates;

Model 4

$$\mathrm{GSR}_{\mathrm{imy}} = \lambda_{\mathrm{i}} + \beta_1\,\mathrm{IFO}_{\mathrm{my}} + \beta_2\,\mathrm{VLT}_{\mathrm{my}} + \beta_3\,\mathrm{BDI}_{\mathrm{my}} + \varepsilon_{\mathrm{imy}}$$

Model 4.1

$$\mathrm{GSR}_{\mathrm{imy}} = \lambda_{\mathrm{i}} + \beta_1\,\mathrm{IFO}_{\mathrm{my}} + \beta_2\,\mathrm{VLT}_{\mathrm{my}} + \varepsilon_{\mathrm{imy}}$$

For coal spot rates;

Model 5

$$\mathrm{CSR_{imy}} = \lambda_i + \beta_1\ \mathrm{IFO_{my}} + \beta_2\ \mathrm{VLT_{my}} + \beta_3\ \mathrm{BDI_{my}} + \varepsilon_{imy}$$

Model 5.1

$$\mathrm{CSR_{imy}} = \lambda_i + \beta_1\ \mathrm{IFO_{my}} + \beta_2\ \mathrm{VLT_{my}} + \varepsilon_{imy}$$

- The definitions for the equation variables are as follows:

$\mathbf{ISR_{imy}}$= Related iron ore spot rate ($ / ton) for selected dry bulk carrier serving on route *i* in month *m* of year *y*;

$\mathbf{GSR_{imy}}$= Related grain spot rate ($ / ton) for selected dry bulk carrier serving on route *i* in month *m* of year *y*;

$\mathbf{CSR_{imy}}$= Related coal spot rate ($ / ton) for selected dry bulk carrier serving on route *i* in month *m* of year *y*;

$\mathbf{IFO_{my}}$ = Price per ton of IFO 180 in $ for month *m* of year *y*;

$\mathbf{VLT_{my}}$ = Standard deviation of the price of IFO 180 for month *m* of year *y*;

$\mathbf{BDI_{my}}$ = Related Baltic Exchange Dry Index Clean for the month *m* of year *y*;

$\boldsymbol{\lambda_i}$ = Fixed effect;

$\boldsymbol{\varepsilon_{imy}}$ = Stochastic error term;

$\boldsymbol{\beta_n}$ = Coefficient for the related variable;

5.4.3 Results of the models for the impact of bunker prices on iron ore spot rates.

The analysis for investigating the effect of bunker prices on iron ore freight rates is done according to models 3 and 3.1. The dependant variable iron ore spot rates ($ / ton) is considered for Australia – Rotterdam with capesize bulk carrier vessels. Model 4 is tested for the periods 1999 and 2010 as it includes the BDI and BDI is not available for the dates before 11th month of

1999. The model excluding the BDI is tested for the dates between 1990 and 2010.

When the regression analysis is done according to model 3 including all variables for the period between 11 / 1999 and 07 / 2010, with a confidence level of 0.95, statistically significant outcomes with an R square of 0.958 is obtained. All the coefficients of the explanatory variables such as, bunker prices, volatility and BDTI are positive.

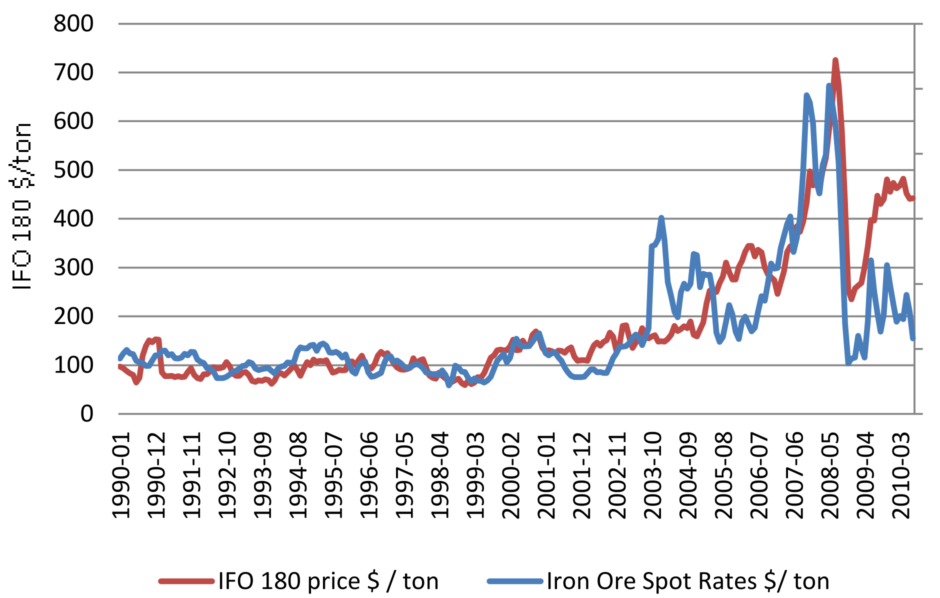
The elasticity of iron ore spot rates to bunker prices is 0.1249 and the elasticity to volatility of bunker prices is 0.055. In other terms, when we interpret the elasticity to bunker prices, a 1 % increase in bunker prices causes nearly a 0.12 % increase in the iron ore spot rates while the volatility shows a lower effect on the spot rates.

When we test the data by excluding the BDI explanatory variable, the R square reduces to 0.60 and the outcomes stay statistically significant. This test is done for both 1999 – 2010 and 1991 – 2010. The same timeline with model 4 was used to see if the similar R squares can be obtained. The R square level for the analysis between 1999 and 2010 is 0.45 while the R square for the analysis of 1991 – 2010 is 0.60. Elasticities obtained from the two are close to each other. Therefore, the data for 1991 – 2010 are taken for considering a larger sample and having more significant results.

The increase in the elasticity of iron ore spot rates to bunker prices is considerable when we exclude the BDI as an explanatory variable from the model. The elasticity with respect to bunker prices increases up to around 0.73, which means a considerable impact of bunker prices on iron ore spot rates.

Figure 5.7 reveals the evolution of iron ore freight rates and IFO 180 prices for 1991 – 2010. Nearly the same trend over time periods between the two variables shows a high degree of correlation. The increasing trend of iron ore freight rates from early 2005 can be related to the increasing demand of Asian countries, mainly China. The economical downturn of 2008 also shows how the iron ore markets and bunker prices are hit to a dip. After the dip in 2008 continuing and increasing iron ore demand of steel producing Asian countries have pushed the levels up causing a moderate increase in iron ore freight rates.

Fugure 5.7 evolution of iron ore spot rates ($ / ton) and IFO 180 prices ($/ton), 1991 - 2010



Note: The vertical axis on the left corresponds to IFO 180 prices ($ / ton) and the vertical axis on the right corresponds to iron ore freight rates ($ / ton)

Source: own preparation, based on Clarksons data.

5.4.4 Results of the models for the impact of bunker prices on grain spot rates.

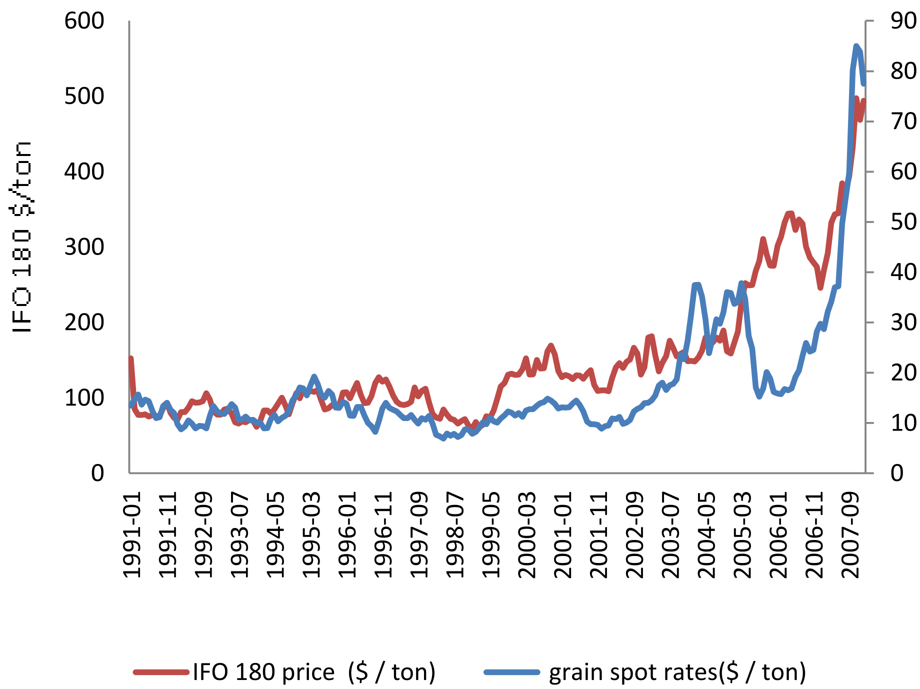
For estimating the effects of bunker prices on grain spot rates, same methods used for iron ore spot rates are used. Model 4 and model 4.1 are employed for the regression analysis. Firstly all variables such as bunker prices, volatility of bunker prices and BDI are included for the period 1999 – 2008. The grain spot rates are taken for panamax vessels serving in the route U.S. – Rotterdam until 2008 as it is the latest available date for the data.

The results of the regression are statistically significant with an R square of 0.89 and all explanatory variables are positively correlated with grain spot rates. The estimated elasticity with respect to bunker prices is found as 0.095 with including the BDI in the regression. This number is smaller than the elasticity of iron ore spot rates to bunker prices.

Secondly, the regression analysis is done by excluding the BDI. According to the results the R square reduces to 0.56 while the mathematical explanations stay statistically significant. Like the one in iron ore spot rates elasticity of grain spot rates to bunker prices increases nearly 10 times, when we exclude the BDI, resulting with a value of 0.94. This value again implies a high correlation between dry bulk spot rates and bunker prices.

Figure 5.8 shows the evolution of grain spot rates ($ / ton) and IFO 180 prices ($ / ton). As in iron ore rates the grain spot rates correlate highly with bunker prices and show a similar trend in most of the periods. The same trends as in iron ore rates and the peak of the rates causing from the boom of late 2007 in can be observed from the figure. Differing from figure 5.7, this figure doesn't contain the date for 2008 as the grain spot rates were available up to 2008.

Figure 5.8 Evolution of grain spot rates ($/ton) and IFO 180 prices ($/ton) for the period 1991 – 2010.



Note: the vertical axis on the left corresponds to IFO 180 prices ($ / ton) and the vertical axis on the right corresponds to grain spot rates ($ / ton)

Source: Own preparation, based on Clarksons data.

5.4.5 Results of the models for the impact of bunker prices on coal spot rates.

The approach which has been employed for determining the relationship between the previous two commodities and bunker prices is used for assessing the impacts on coal spot rates.

Models 5 and 5.1 have been used for the regression analysis. The coal spot rates are available from 1991 to 2010. Moreover, panamax type vessels serving in the U. S. – ARA route have been taken as a reference.

The results of the model including all variables shows statistically significant results with an R square of around 0.94 and the coefficients of all variables are positive. Elasticity of coal spot rates to bunker prices is estimated as 0.39 which is considerably higher than iron ore and coal easticities to bunker prices.

When the regression analysis is done by excluding the BDI, the coefficient of volatility of bunker prices is estimated to be negative. The elasticity of coal spot rates to volatility is very small and equal to – 0.007. The elasticity of coal spot rates to fuel oil prices increases considerably like in the iron ore and grain cases. The elasticity is estimated as 0.95 which is very close to unity. The result that can be drawn from the outcomes in comparison to iron ore and grain rates is the amount of the increase. In other cases the elasticity increases nearly 9 times while in the coal spot rates it increases nearly three times. Finally we can conclude that coal spot rates have the highest elasticity (very close to 1) to bunker prices in comparison to previous two commodities.

5.5. Summary and Conclusion

In this chapter, the impacts of bunker prices on tanker and dry bulk shipping freight rates have been investigated. While many of the estimations are inline with previous literature, some are different than the previously estimated ones.

Firstly, the impacts of bunker prices on liquid bulk shipping have been investigated including three types of tankers namely aframax tankers, suezmax tankers and ULCC/ VLCC tankers. Low elasticities are obtained for all of the estimations.

- For aframax tankers, elasticities of spot rates with respect to bunker prices are obtained as 0.018 and 0.043.
- For suezmax tankers, elasticities of spot rates with respect to bunker prices are obtained as -0.053 and – 0.014

- For VLCC / ULCC tankers, elasticities of spot rates with respect to bunker prices are obtained as -0.027 and 0.046

The reason behind the low and sometimes even negative correlation between tanker spot rates hides behind the fact that the cost component namely as bunker prices and the commodity traded depends on the same source. Supply and demand characteristics of crude oil, decisions of major oil producers, political events, several oil crisis and other factors play a considerable role in shaping the tanker spot rates. for example a cutback in one of the main suppliers may increase the price of oil in other terms bunker price while the demand for transporting crude oil decreases causing a decrease in related tanker spot rates.

Secondly, the impacts of bunker prices on main dry bulk commodities spot rates such as; iron ore, grain and coal spot rates have been estimated. Elasticities varying considerably have been obtained for all of the variables.

- For iron ore, elasticities of spot rates with respect to bunker prices are obtained as 0.125 and 0.73.
- For grain, elasticities of spot rates with respect to bunker prices are obtained as 0.095 and 0.94
- For coal, elasticities of spot rates with respect to bunker prices are obtained as 0.39 and 0.95.

Higher degrees of positive correlation of dry bulk commodity spot rates to bunker prices reflect the considerable effect of increasing fuel costs on the dry bulk industry. As the cost and earning component is not the same good like in case of tanker markets, and the market is not as sophisticated and concentrated as the liner market, the highest estimated elasticities can show the significant reflection of the bunker costs in the freight rates.

Chapter 6 Future maritime freight rates estimations

6.1 Introduction

One of the main considerations rising because of the revisions in MARPOL Annex VI is the possible increase in the marine fuel prizes and therefore in the fuel costs of the shipping industry. The characteristics of the marine fuels and their cost differences in regards with the sulfur contents have been discussed in details in chapter 3. The need of gradual change to lower sulfur content fuels both globally and in ECAs as a result of MARPOL Annex VI revisions increases the concerns about availability and pricing of such bunkers and the future freight rates accordingly.

While doing a future price estimate depends on many determinants, rapidly changing global economy and supply demand characteristics of the related goods may change suddenly by affecting the validity of the estimates.

For estimating the impact of future marine prices, average of different pricing scenarios which have been developed by previous studies will be taken as a guide. As nobody knows what will happen in the future of marine fuels, because of the future costs, applications and availability of marine fuels and the supply decisions of the refineries, extensive surveys carried out by national and international organizations will be considered in the approach for the switch in the emission control areas (1.5 % to 1.0 %, 1.0% to 0.1 %). And for the global reduce in the sulfur content up to 0.5 % will be estimated based on historical trends and price averages between

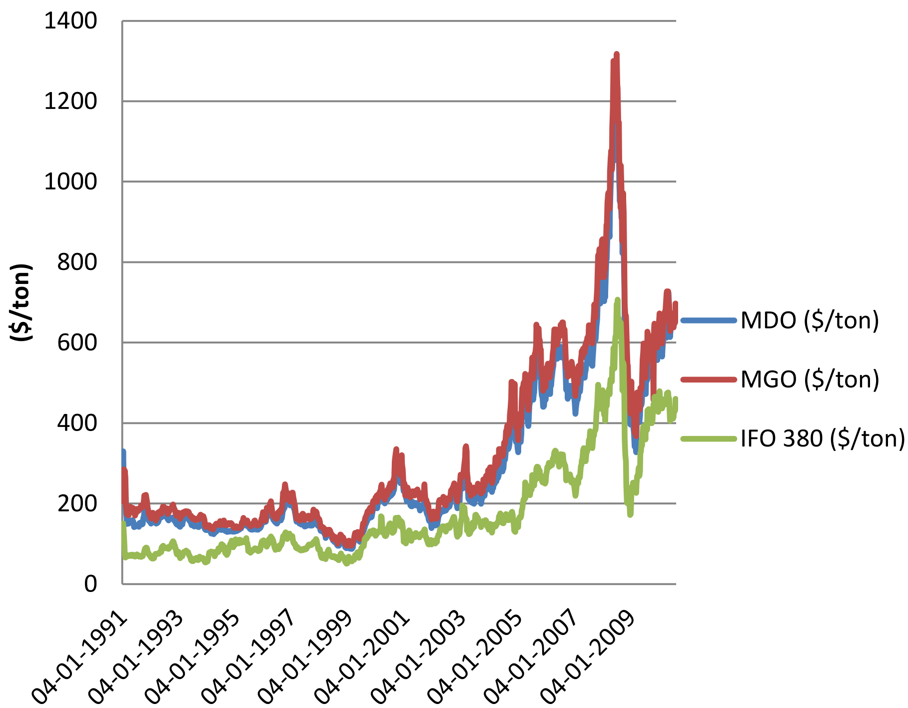
The estimated average price increase of marine fuels in regards with their sulfur content corresponding to the limits set by IMO will be calculated. These results will be employed with the elasticities of freight rates to bunker prices (which are obtained in chapter 5) to estimate the impact on future freight rates.

6.2 Future price estimations of marine fuels for the study

Annex VI of MARPOL requires various shifts in regards with the sulfur contents. Shits from 4.5 % to 3.5 % and 3.5 % to 0.5 % sulfur content marine fuels is required globally and shifts from 1.5 % to 1.0 % and 1.0 % to 0.1 % sulfur content marine fuels is required in ECAs.

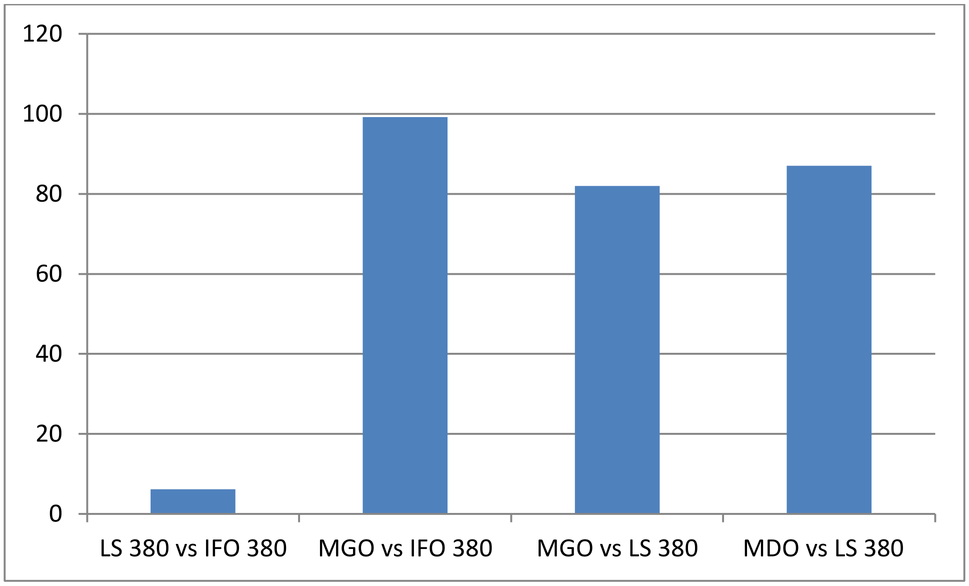
None of the surveys carried out by the previously mentioned studies in section 4.2 considers the price increase in the shift from high sulfur content marine fuels with a max sulfur content of 4.5% to 0.5 % globally. The surveys include the average price reflections for the shifts from 1.5 % to %1.0, %1.5 to %0.5 and %1.5 to %0.1. For estimating the price increase from high sulfur content to 0.5 % content long term average difference between LFO 380 and HFO 380 will be added to the estimations.

Figure 6.1bunker price evolutions of IFO 380, MGO and MDO



Source: Own preparation, based on Clarksons data

Figure 6.2 Long term average price difference of various bunker fuels in percentages, 1990 - 2008



Source: own preparation, data based on ECSA 2010.

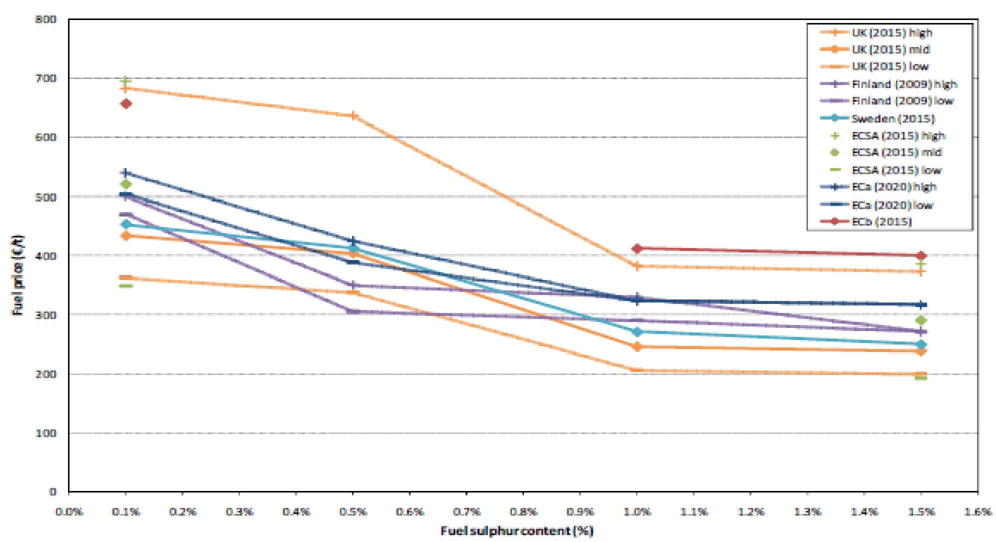
Figures 6.1 and 6.2 illustrate the price evolution of various marine residual and distillate fuels and their long term average price differences. As it can be seen from 6.1 the prices of MDO, MGO and IFO 380 fluctuates very highly over time. These trends bring a further challenge in estimating the future bunker prices. Although, there is a high degree of volatility, the long term average price differences can be a good guide in estimating the fuel cost increases while switching from one fuel to another. As it is shown in figure 6.2 the average price difference between LS 380 and IFO 380 was around 9 % between 1990 and 2008. For the same period long time average price difference between MGO and IFO 380 was 99 % while the difference was 82 % between MGO and IFO 380. These price differences can be a guide in assessing the outcomes of the various studies done on the future price increase of marine fuels in regards with MARPOL Annex VI revisions.

To recall the literature review in chapter 4, various organizations and authors have investigated the possible outcomes of MARPOL Annex VI revisions. While doing so, they have presented future increases of marine fuel prices in regards with the shifts to lower content sulfur fuels. Some of the examples from the studies are as follows;

ECSA 2010 has estimated a cost increase of 20% to 30% for the shift from 1.5% to 0.5% sulfur content, 50% to 60% for the shift from 0.5% to 0.1% sulfur content fuels. A total combined cost increase of 70% to 90% is estimated in comparison to LS380 (%1.5). Moreover, they employed three scenarios where the MGO prices are 500 $/ton, 750 $/ton and 1000 $/ ton taken in low medium and high scenarios respectively. This numbers indicate a 50 % and 100 % increase in the assumptions.

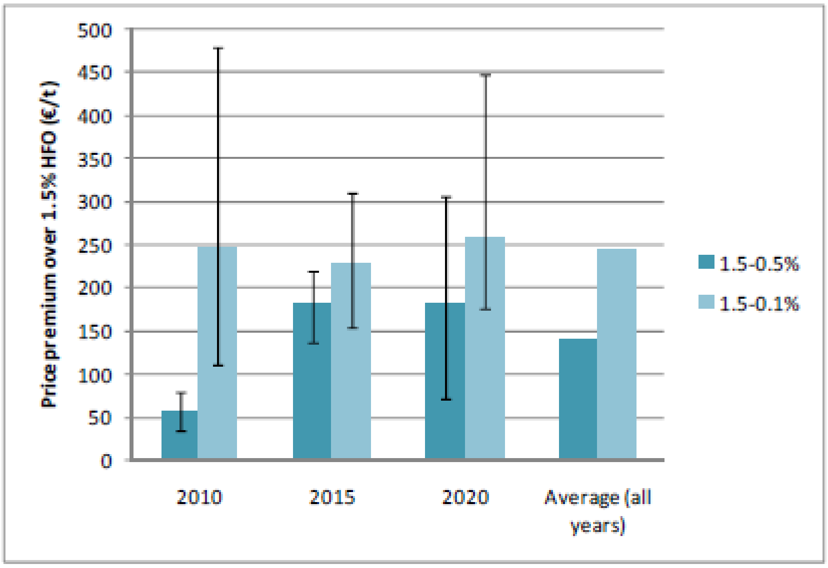
Swedish Maritime Administration (2009) has analyzed the economical consequences not directly relating to the end product as marine fuel oils but relating it to the assumed crude oil prices for 2015. Two scenarios where crude oil prices are estimated to rise by 75% and 150% are used for fuel pricing .The results of the all relevant studies assuming fuel prices in regards with sulfur contents can be seen in figure 6.3

Figure 6.3 Assumed fuel prices (€/ton) as a function of sulfur content



Source: Entec, (2010)

Figure 6.4 average price premium of low sulfur fuels (0.5 % MDO/LSFO and 0.1 % LSFO) over 1.5 % HFO



Source : Entec,(2010)

Figure 6.4 shows the average price premia used on the set price premiums by the relevant studies for estimating the cost impact of switching from 1.5 % fuels to 0.5% and 0.1 % fuels. The lines shows the maximum and minimum values used in the studies.

With all above data we can conclude an average cost increase of 80% while switching from 1.5 % to 0.1 % and an average increase of 56% while switching from 1.5% to 0.5%.

The average increase while switching from IFO 380 to 0.5% hasn't been considered in the studies as the average long term price difference between IFO 380 and LSO 380 is small in comparison to others with a number of 9%. Therefore, this amount will be subtracted from 56 % (average increase for switching from 1.5 % to 0.5 %) for investigating the global requirement of 0.5 % outside the ECAs and will be taken as 56%-9% = 47%.

6.3. Estimation results of the impact of increasing fuel oil prices on maritime freight rates.

The analysis of the impacts of increasing fuel oil prices in accordance with MARPOL Annex 6 revisions will be done with estimated elasticity outcomes obtained in chapter 5 and the estimated marine fuel price increase outcomes obtained in this chapter. With the requirement of switching from 1.5 % to 0.1 % in other terms switching to MGO from 2015 is applicable for estimating the results for short sea services including ECAs.

Selected tanker vessels and dry bulk commodity spot rates are not affected intensively from the sulfur content reductions of marine fuels to be used in the ECAs as they are moving globally, and mostly between continents. All estimations will be considered for the analysis done to estimate the impact of increasing fuel prices (switch to 0.5 % globally) on maritime freight rates in 2020.

Only the estimated elasticities which are positive will be considered in the analysis because of higher significance levels and market structures of different markets as defined previously.

With the guidance of the basic definition of elasticity, we will estimate the future increase in related container freight rates.

As the elasticity[7] of Y (dependent variable) to X (independent variable) is the percentage change in Y caused by a 1 % change in X, we can simply calculate the impact of increasing fuel prices on the freight rates.

6.3.1 Estimated impacts of MARPOL Annex VI revisions for global application in 2020 on the tanker and dry bulk freight rates.

To recall the previously estimated values;

- For aframax tankers, elasticiy of spot rates with respect to bunker prices are obtained as 0.018 and 0.043.
- For VLCC / ULCC tankers, elasticity of spot rates with respect to bunker prices is obtained as 0.046

[7] In the elasticity estimation, for increases more than 1 per cent there is an approximation error.

- For iron ore, elasticities of spot rates with respect to bunker prices are obtained as 0.125 and 0.73.
- For grain, elasticities of spot rates with respect to bunker prices are obtained as 0.095 and 0.94
- For coal, elasticities of spot rates with respect to bunker prices are obtained as 0.39 and 0.95.
- Estimated average cost increase of switching from HFO to 0.5 % is estimated as 47 %.

6.3.1.1 Estimated impacts on the tanker spot rates

The impact of increasing fuel costs corresponding to the global requirement of a reduction to 0.5% sulfur content in the marine fuels is estimated between **%0.818** and **%2.162.** These results are obtained as defined previously by multiplying the obtained elasticities summarized in section 6.3.1 and the price increase estimations summarized at the end of section 6.2. The previously defined characteristics of tanker spot rates by being dependant on many factors such as supply and demand of crude oil can be a guide to see the low reflection of the increased fuel costs in the freight rates.

6.3.1.2 Estimated impacts on the dry bulk commodity spot rates

Dry bulk commodity spot rates specified as iron ore spot rates, grain spot rates and coal spot rates are those which are the highly affected because of the increased fuel costs. The increases in the related spot rates are estimated as follows;

- Iron ore spot rates are estimated to rise between 5.875 % and 34.31 %.
- Grain spot rates are estimated to rise between 4.465 % and 44.18 % .
- Coal spot rates are estimated to rise between 18.33 % and 44.65 %.

6.4. Summary and conclusions

The estimated increases in the freight rates show the impacts of the increasing fuel prices due to a gradual change to lower content sulfur fuels in accordance with MARPOL Annex VI revisions. According to the estimated numbers, we can conclude that with the current market structures of all three groups, dry bulk shipping reflects the impact of increasing fuel costs at the highest levels. Conversely, container and tanker markets don't reflect the increase of fuel costs in the freight rates as much as dry bulk markets.

One may easily defend with a straight logic that the increase in the costs must be reflected in the earnings. However, previously analyzed trends between the two variables also show the hardness to investigate the matter. Different characteristics of bigger size tankers namlely, aframax, suezmax and VLCC / ULCC are determined not only by the cost structures of the market but also the demand and supply of the cargo which is the same commodity to be transported and to be consumed.

Chapter 7 – Conclusions and Recommendations

The latest revisions of MARPOL Annex VI have increased concerns of many sectors such as the shipping industry, fuel suppliers, and governmental bodies. With the new requirements in the gradual decrease of the sulfur contents of marine fuels, considerable increases in fuel costs are forming a main part of the concerns of the shipping industry. Various challenges are present in the matter as it widely relates many sectors globally.

While an increase in the fuel costs may cause an extra cost passed through the consumers, it may also change the levels of competition between sea transport and various modes, especially in routes taking part in the Emission Control Areas. The supply, availability and pricing of marine fuels are further issues which include high levels of uncertainty. As an increase in the fuel costs will be faced for the representative years in line with the Annex, these costs will put a pressure on maritime freight rates.

In this study, the impacts of increasing fuel costs on maritime freight rates are analyzed. The study is carried for two main shipping sectors including the tanker market and the dry bulk market. Rather than investigating the bunker cost shares and employing the related costs on the freight rates a mathematical analysis considering the past relationships between the variables is done. The limited scope of the approach in defining the impacts of increasing fuel oil prices on maritime freight rates should be noted. As our analysis is done in relation with the past data, any change in the shipping and related market structures can easily limit the viability of the estimated outcomes Many of the relevant studies on the matter calculate the cost increase due to the fuel oil requirements. Our approach shows how the increase in the fuel oil prices is reflected on the related freight rates.

Although, there seems to be a significant cost increase, the reflections of the percentages on the freight rates are estimated to be slightly different on different markets. Dry bulk commodity spot rates are estimated to reflect the increase of the fuel costs on the freight rates with the highest levels up to 44%. While the tanker spot rates are estimated to rise considerably lower with values varying between 0.9% and around 3%.

Several conclusions can be drawn from the results and highly different values for some sectors. When we consider the dry bulk markets, the highest impact of increasing fuel costs on spot freight rates can be observed. This can be meaningful when we compare the cost structures and market characteristics of different sectors. One of the less complex sectors among all is the bulk shipping, as the vessels are less sophisticated depending on considerably simple and cheaper infrastructure and having a market with high degrees of competition.

For the tanker market bigger size vessels which are mostly transporting dirty cargoes are considered. The estimated increases in the freight rates due to fuel cost increases are considerably small in comparison to bulk shipping. This may be resulting from the dependence of the market on the supply and demand trends of crude oil. While there is an increase in the prize of crude oil, a downward trend in the spot rates can be observed in these types of vessels. For example when there is a shortage of supply, the price of crude oil increases, while the demand for the transportation decreases causing a drop in the spot freight rates.

One of the future researches that must be carried out in dealing with the matter should be for determining the characteristics of the fuel oil suppliers and their pricing strategies. This matter is due to some confidentiality problems as many oil producers are not willing to share their future estimations or just waiting for the market to form accordingly. One can assume that the demand will form the supply accordingly. However, technical applications and innovations may limit the viability of the revisions. Therefore, this can be a further point for the refineries to wait before doing extensive investments.

The determinants of freight rates include many key factors such as the price of the commodities, route characteristics, vessel operating costs, supply and demand characteristics of the markets, political factors, etc. Although it is very hard to access and employ such data, this issue must be considered widely while investigating all extensive data with the participation of all players providing data and spending efforts on the matter. Rather than sector or industry specific research a more global study must be carried out.

The cost impacts of the Annex VI regulations are obvious. One of the main points to be considered in reducing these impacts must be technical applications and further innovations in the shipping sector. Rather than accepting the cost burden of the new regulations, extensive research in alternative fuels, cheaper scrubber applications, more efficient engine designs must be done. As mentioned earlier, innovations and improved technology may not only solve the problem but also can make the revisions unnecessary if they can reach up to a level enabling an application creating zero air pollution.

The matter must be researched further by governmental bodies in terms of external costs and the outcomes of possible modal shifts. Environmental costs and benefits must be researched in global coverage with the participation of all related bodies. While trying to improve the air quality, transport from the most efficient mode in terms of ton / mile may shift up to the roads by polluting the air more and creating more external costs.

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