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Container freight rates in the automotive sector: developing a model assessing the impact of IMO 2020.

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Contents

List of Figures

List of Tables

Introduction

Globalization is one of the most relevant economic and social phenomena occurred in the last fifty years. In fact thanks to the always improving connection between countries it has became easier for manufacturers to increase their competitiveness and to reduce manufacturing costs exploiting the lower wages in the developing countries. Of course the impact on the transportations industry has been and it is huge. In particular the most cost efficient way to move goods among continents for long distances is by sea. As explained hereinafter the maritime shipping industry to adapt to the ever increasing demand for shipments has evolved trying more and more to optimize costs, above all trying to exploit the economy of scale as much as possible. One of the markets that certainly uses and makes use of maritime shipping both upstream and downstream of production is the car market. In this work, the technical and business aspects of maritime transport linked to the world of car manufacturers will be described in detail. Then, this study will address one of the most discussed aspects in the transport world in recent years, which is the environmental aspect. In particular, the new standard of the International Maritime Organization, which will come into force on January 1, 2020, known as IMO 2020, will be discussed. This standard has the noble goal of substantially reducing the emission of sulphides contained in the gases of discharge of products from merchant ships, and consequently to improve the quality of the air of the plant and of the life of all people connected to maritime transport and not only. Obviously a policy of this impact brings with it considerable technical problems that will be discussed. In particular, the strategy that the shipping companies will adopt to comply with the standard is of great interest. Three different strategies will be discussed and one of them, which in the opinion of the experts is the most effective, will be analyzed in detail. In particular this last strategy refers to the use of fuels with a reduced sulphide content. These new compliant fuels will have higher costs, which according to industry experts may even be twice as high as the current bunker cost. It is therefore interesting to try to predict how much the increase in the cost of the fuel just mentioned may impact the actual rates of shipments. Since the price of the bunker and the shipping rates values recorded over time and depending on each other, an approach for the aforementioned study is the analysis of the historical series of these variables and the use of forecasting methods, in particular the use of conditional forecasting methods. The work in fact provides a forecast model developed in the Matlab framework. In particular this thesis begins discussing the maritime shipping market with a particular clue for the automotive sector, this discussion covers topics from the operation, the pricing method and to the environmental issues. Then the work gives an overview of forecasting methods, starting with time series analysis and concluding with the related forecasting methods. The the above mentioned model will be discussed and applied to the data. At the end a result analysis is provided with the related conclusions. A benefit of this study is to is to provide a quantitative analysis of the increase in shipping rates.

Chapter 1

Maritime shipping in the automotive sector

The world economy growth has been dragging the development of the global automotive industry for the last decades, continuously driving the demand for maritime transport of vehicles from the manufacturer plants to the final markets. Globalization has played a major role in the the development of those trades. See, as an example, figure 1 showing the evolution of cars importation in the US. When producing in developing countries has became ways cheaper and convenient for car manufactures the shipping industry became to play a center role for the automotive trades, in fact in many countries the imports of cars has raised. This chapter will provide an overview on the actual situation of the shipping industry as today and, moreover, an explanation of the technical aspects regarding the shipping activity with respect to the automotive sector.

1.1 Ocean Market situation Highlight

The last three decades have brought enormous changes to the naval transport market. The first years are characterized by low rates, and no profit for shipping companies. Furthermore, this period has also been characterized by huge investments in megaships which, combined with low profitability, have brought enormous debts to maritime companies [21]. Analysing the maritime shipping market, it is understood that it has huge costs and most of it is fixed. Despite this, there are low barriers to entry

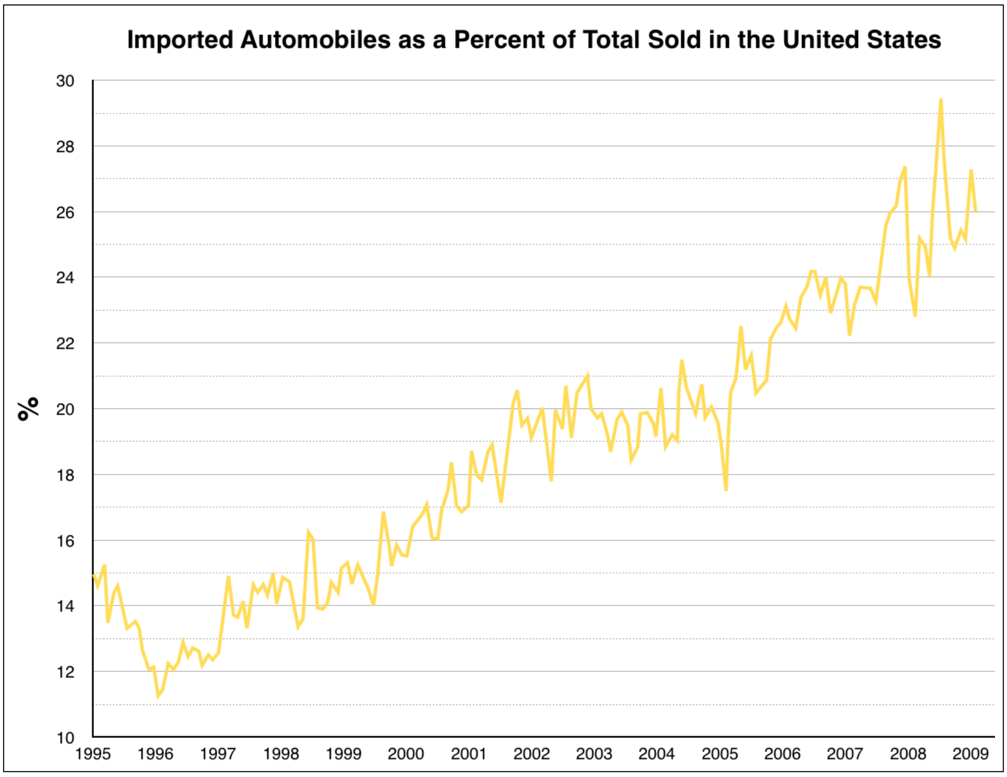

Figure 1.1: Imports of cars in the US [14]

and high barriers to exit, high costs in the sector and the tonnage supply is inelastic, so the price is greatly affected by the variation in demand. All this makes the market very competitive, with companies intent on lowering freight prices to obtain a greater quantity and thus be able to sustain high costs [22]. This situation leads carriers to act in some way to avoid bankruptcy. The solution found was to create strategic alliances capable of controlling the greatest number of ships. From 2016 to 2017 the market passed from having 4 alliances to have 3. This led to a process of mergers and acquisitions whose start is attributable to the acquisition, in 2002, by Maersk of the Danish Dampskibsselskabet TORM. Later in 2005 Maersk also acquired P & L Nedlloyed. In 2014, Hapag announced the acquisition of Chilean-based CSAV. Then in 2016 CMA acquired APL that is a Singaporean company. At present, the two Chinese companies owned by the state, China Shipping and Cosco, have announced their willingness to merge into what it's called China Cosco. In addition, Maersk announced its intention to acquire Hamburg Sud and Hapag-Lloyd announced about a possible merger with the container shipping operations of UASC. Between the 2016 and 2017 the number of alliances went from 4 to 3 reinforcing even more the oligopolistic character that the industry has developed. In the figure 1.2 the situation at present is showed.

Figure 1.2: Past and current alliances in the seaborne transportation industry

To better understand the current market structure and how it has changed over the years, it is interesting to pay attention to the figure 1.3. As you can see, the TOP

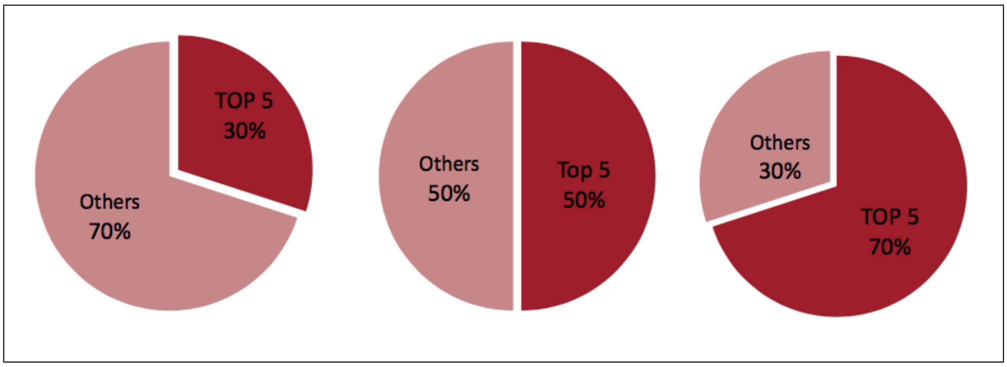

Figure 1.3: Market structure: 1997, 2016, Est 2020

5 took about 20 years to go from 30% to 50%, while it is estimated that in 2020 they reach 70% of the market. It is therefore evident that the market has moved from a very competitive framework to a quasi-oligopoly situation.

Figure 1.4 instead highlights the structure of the market, in 2017, among the various alliances mentioned above. As can be seen, 76% of the market is managed by 3 alliances. it is therefore possible that, thanks to this new arrangement, and to all the mechanisms for sharing the noses, the shipping companies will return to profit.

All this projects the market of shipments by sea in a situation of great uncertainty. From a point of view, shipping companies need to find ways to make operations more efficient, from the packaging of goods to innovative scheduling systems, with the aim

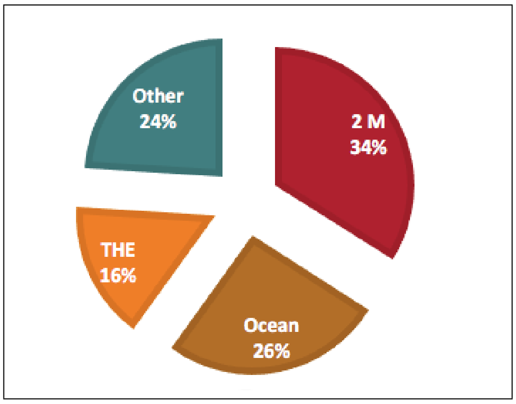

Figure 1.4: Market structure among alliances

of filling ships as much as possible so as to reduce costs and increase their margins . From the customer's point of view, however, this quasi-oligopoly situation can lead to an increase in shipping rates and the low competitiveness situation can reduce the choice of routes. This can lead customers to review their own booking and scheduling operations or in the most extreme cases it may even lead them to consider alternative transport methods such as on rail or air.

1.2 The automotive case

From 1996 to 2007 the global automotive trades has grown by 179% [7].

Talking about the logistic of a car manufacturer the process can divided in two main parts. The first one is the inbound shipping which regards all the components that are going to be assembled together to complete the final product. The second one is the outbound logistic. In this part the object to be shipped is the final product its self. The inbound transportation it is in general scheduled to follow the demand expectation. Engines, transmission, tires, interior parts, air-bags devices and other parts manufactured abroad are generally shipped into containers. The car manufacturers can generally chose between two services, Full Container Load (FCL) and Less than Container Load (LCL). FCL is a service that provide to the costumers the entire volume of the container and it is up to the costumer to fill the entire volume, of course the price is fixed. LCL is the second type of service and, in this case, given the volume and weight of what you want to ship, is up to the shipowner or to the freight forwarder to fill the container with other costumers stuff. In this case the rate is computed on the volume and/or weight of the parts to be shipped. Given its volumes a car manufacturer in general opt for FCL services [7]. In general the container is filled at the supplier plants, then it is transported to the port for its shipping. Maritime companies con also provide services as truck transportation or transportation on rails in order to pick up the container from the supplier plant and get it to the port. Of course this mechanism can works also on the other way around and they can offer also trucks or rail transport from the destination port to the recipient. The business terminology for this type of services is **door to door** for the complete pack in which the maritime company will pick up the container from the supplier plant and will deliver it to the recipient location, **door to port** instead is from the supplier plant to the destination port, **port to door** is from the port of loading to the recipient location then with **port to port** is meant only the transport by ocean from the port of loading to the port of destination. On the other hand there is the outbound transportation, for which it is intended the transport of the built up vehicle.

Roll on - Roll off (Ro-Ro): when talking of seaborne car shipping the first methodology for ship a car is to use the service of the so called Pure Car Carries (PPC). PCC are vessels properly designed to carry vehicles be they car or trucks

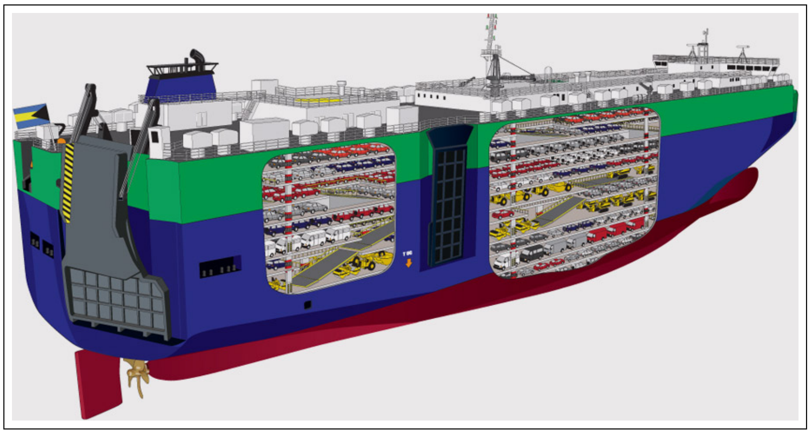

Figure 1.5: Pure Cars and Trucks Carrier (source: *shiptechnology.com*)

(PCTC, Pure Car and Trucks Carriers), see figure 1.5. This type of vessel, mainly known as Ro-Ro (Roll on Roll off) has built in ramps and decks. The finished or semi-finished vehicle can roll, on its own wheels, into the vessels. When inside the vessel, generally, the built up vehicle is parked (and in some case secured with ropes) on one of the decks. In some cases the decks can carry also heavy truck, in those cases the shape it is a bit different because of the height of trucks and other types of heavy vehicles. Today this mode of shipping is the dominant one, in particular for new vehicles.

Containers: the idea of the container were invented by McLean in the 1950s. As shown by Bohlman the use of standardized container reduce the cost of shipping by 35% and the transit time by 84% [7]. This mode of transport is the most used for manufactured good and it is become more and more popular even for commodities (such as coffee). In 2001 the 90% of the transportation of non-bulk goods was operated using standard containers. Cars can also be fitted into containers, see figure 1.6, but they play a minor role in car sipping. This mode, that can be defined as fast and secure, can however be very attractive to premium and/or small volume car manufacturers. An example is Tesla, that moves the vehicles in containers from its US factory to global destinations, another car manufacturer known to use containers for shipping is Lotus.

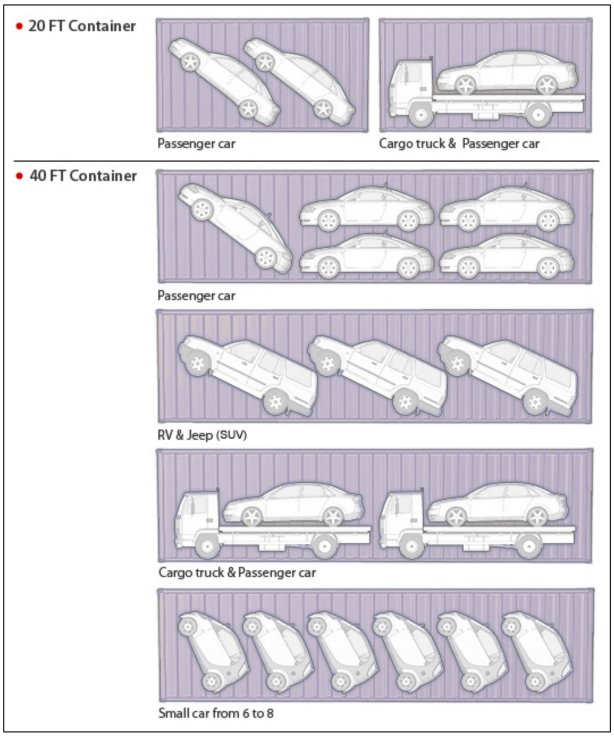

Figure 1.6: Vehicles in Containers (Source: *searates.com*)

1.3 Principles and method for freight pricing

For both type of freight, be them containers or Ro-Ro, the main aspects that are going to form the price are: the type of material transported, which in our case (the automotive industry) is essentially parts stocked into a container or the final product, the car. In both the cases what really matter is the volume transported. The second parameters of course is the distance between the POL (Port of loading) and the POD (Port of discharge). This point could look trivial but is not, in fact there could not exist a straight forward route for any combination of POL and POD. The point of the distance in fact depends on the route the shipping company decided to set up. An examples could be a ship departing from Barcelona bound for the east coast of the USA, see fig 1.7, this route usually happen in the case of ring-type routes. In one case the shipping company could decide to touch for the first time in the south of the united states, in the other case the first touch could be in the northern part of the USA, see fig 1.8, this type of service could exists in the case of a "around the world" route.

The third element are the external services, such as the insurance, the transporta-

Figure 1.7: Route Example

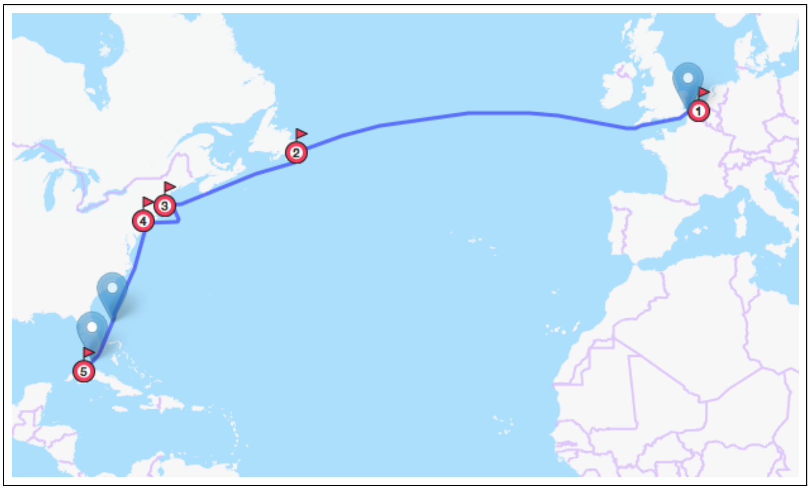

Figure 1.8: Route Example

tion of hazardous material (an example for the automotive industry could be the air bag explosive charge) and so on. Note that a shipping company could offer more than the port to port service and can take car also for the port to door and the door to port transport, of course this services will be charged on top of the port to port tariff [24].

1.3.1 Fuel and bunker adjustment formula (BAF)

The last of the most important ingredient of the tariff is the cost of the fuel used to run the ship during the route. Based on historical data of FCA this cost will count for the 20 to 30 % of the total of the fright rate. But the question is: how will the tariff vary for the variation of the fuel price ? .

FUEL PRICE *dollars* per m^3	**FREIGHT RATE VARIATION**
375	0.00%
425	+3.03%
450	+6.05%
475	+9.08%
500	+12.11%
525	+15.14%
550	+18.16%
575	+21.19%
600	+24.22%

Table 1.1: BAF Table Example

The first introduction of the Bunker Adjustment Formula (BAF) by the FEFC was in 1970s in order to deal with the oil prices shocks. The importance of such a system is that liner operating in the shipping business could not otherwise adjust their prices promptly enough to counteract the effect of bunker price increases. Nowadays BAFs are included and intended by the contracts stipulated between companies and liners.

When dealing with freight contracts between automotive companies and shipping companies, usually, the base price is set for a correspondent base price of the fuel, which can be different from the actual market price of the fuel at the moment of the drafting of the contract. Then the parties agree on the Bunker Adjustment Formula. This is the part of the contract that define the increase in the freight price for an increase in the fuel prices. In the case of long terms contracts the adjustment of the freight, for obvious reasons, is not made in a every-day basis but normally is made on a quarterly base. The most common way the contracts deal with the changes is to the have a table in which, for every "slot" of fuel prices correspond a price for the freight which is computed according to the Bunker Adjustment Formula. Then, at the end of the quarter, the average price of the bunker is observed and the freight price for the next quarter is setted on the one corresponding to the previous quarter average bunker price.

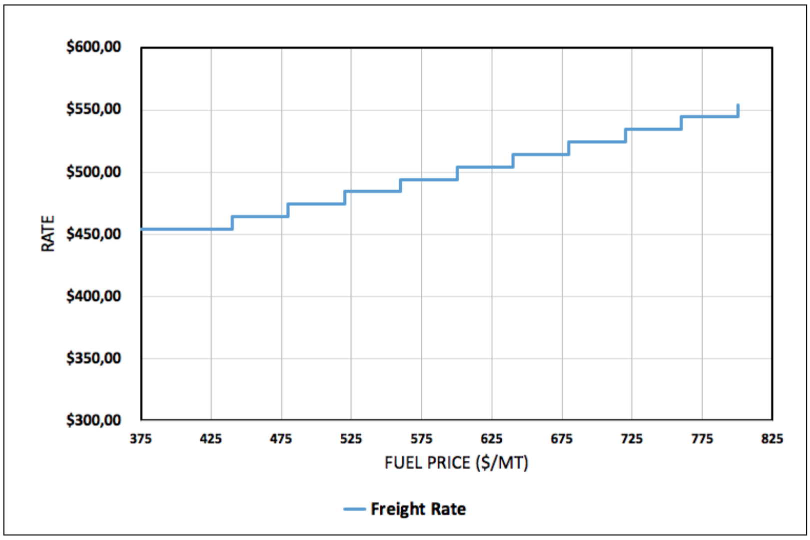

Figure 1.9: BAF Graph Example

1.3.2 Incoterms

Going deeper into the discussion of fees the it could be important to understand who is in charge of what in a logistic contract. To better clarify the role in logistic contracts the International Chamber of Commerce in Paris formulated and codified 13 International Commercial Terms, or Incoterms, the most recent version of which dates from 2000. These terms are periodically revised. While they are not compulsory, Incoterms offer the advantage of providing an international vocabulary of trade that enables the seller and the buyer to communicate on the delivery of the goods [13]. The use of this terms enables the parties in the contract to define:

- the place of delivery of the goods
- the form of delivery
- who is responsible for the main carriage
- how the costs incurred are divided
- the point in which the risk is transferred between the parties of the contract
- the arrangement of custom clearance and liability for customs duties and taxes
- how to load the goods into containers.

Figure 1.10 represent the various Incoterms, every box specify if the responsibility belong to the buyer (B) or to the seller (S):

	EXW	FCA	FAS	FOB	CFR	CIF	CPT	CIP	DAF	DES	DEQ	DDU	DDP
Warehouse Storage	S	S	S	S	S	S	S	S	S	S	S	S	S
Warehouse Labour	S	S	S	S	S	S	S	S	S	S	S	S	S
Export Packing	S	S	S	S	S	S	S	S	S	S	S	S	S
Loading Charges	B	S	S	S	S	S	S	S	S	S	S	S	S
Inland Freight	B	B/S	S	S	S	S	S	S	S	S	S	S	S
Terminal Charges	B	B	S	S	S	S	S	S	S	S	S	S	S
Forwarder's Fees	B	B	B	B	S	S	S	S	S	S	S	S	S
Loading On Vessel	B	B	B	B	S	S	S	S	S	S	S	S	S
Ocean/ Air Freight	B	B	B	B	S	S	S	S	S	S	S	S	S
Charges On Arrival At Destination	B	B	B	B	B	B	S	S	B	B	S	S	S
Duty, Taxes & Customs Clearance	B	B	B	B	B	B	B	B	B	B	B	B	S
Delivery To Destination	B	B	B	B	B	B	B	B	B	B	B	S	S

Figure 1.10: Incoterms [13]

The abbreviation on the upper row are the commercial abbreviation of the combination of responsibility between seller and buyer, in particular there are four type of rule that are used in ocean shipping. Those rules are:

- **FAS:** Free alongside ship, in which costs imputable to warehouse storage, warehouse labour, export packing, loading charges and inland freight are paid by the seller and the other costs buy the buyer
- **FOB:** Free on board, in which the cost division is the same as for the FOB but also the loading on the ship is responsibility of the seller
- **CFR:** Cost and freight in which costs imputable to warehouse storage, warehouse labour, export packing, loading charges, inland freight, forwarder fees, loading on vessel and freight are paid by the seller and the other costs buy the buyer
- **CIF:** Cost, insurance and freight has the same cost division as the CFR but also the insurance is paid by the seller.

1.4 Environmental issues

The 80% of all global trade of goods is done by sea. Nearly 2 millions of marine vessels are registered (in 2016) and this contributes for one third of all the trade-related pollution worldwide. More than 250k death case can be linked to the shipping-related pollution and even more than 6.4 millions of childhood asthma cases per yearn [15]. The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. In fact, this agency has the duty to draft some of the regulation for the maritime transportation in order to create a playing field so that the ship owners cannot simply create profit cutting corners or compromising the environment and/or the safety of workers and stakeholders. Given the numbers shown before, IMO decided to take action and, according to the shipping companies, drafted one of the most stringent anti-pollution regulations ever, which will bring a tremendous shock to the maritime shipping market, the IMO 2020.

1.4.1 IMO 2020

From 1^{st} January 2020, the International Maritime Organization (IMO) Marpol Annex VI regulation on limiting sulphur content of bunker fuel to a maximum of 0.5% will enter into force. As today, the global content of sulphurs in bunker fuel is limited at 3.5%, a level considered easy to comply with for ship owners. The IMO Marpol Annex VI Prevention of Air Pollution from Ships, first adopted in 1997 and came into force in 2005, has established limits on sulphur content in bunker fuel, as well as the creation of ECAs (Emission Controlled Areas) in designated sea areas setting stricter sulphur content limits at just 0.1%. Marpol Annex VI started with a global sulphur cap of 4.5% before it was lowered to 3.5% in 2012. The steep reduction to a global 0.5% sulphur cap by 2020 was decided in October 2016 by the IMO Marine Environment Protection Committee (MEPC).

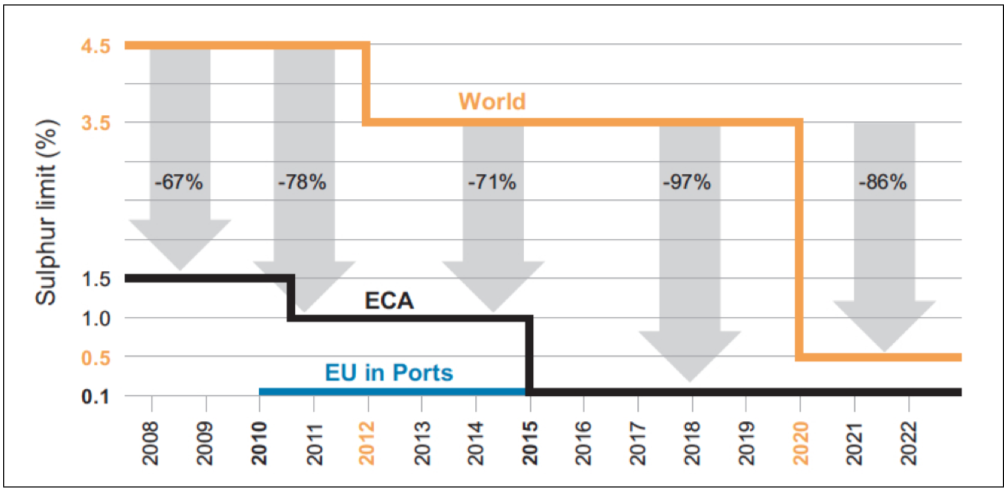

Figure 1.11: Historical Sulphur Emissions Limitations (Source: *dnvgl.com*)

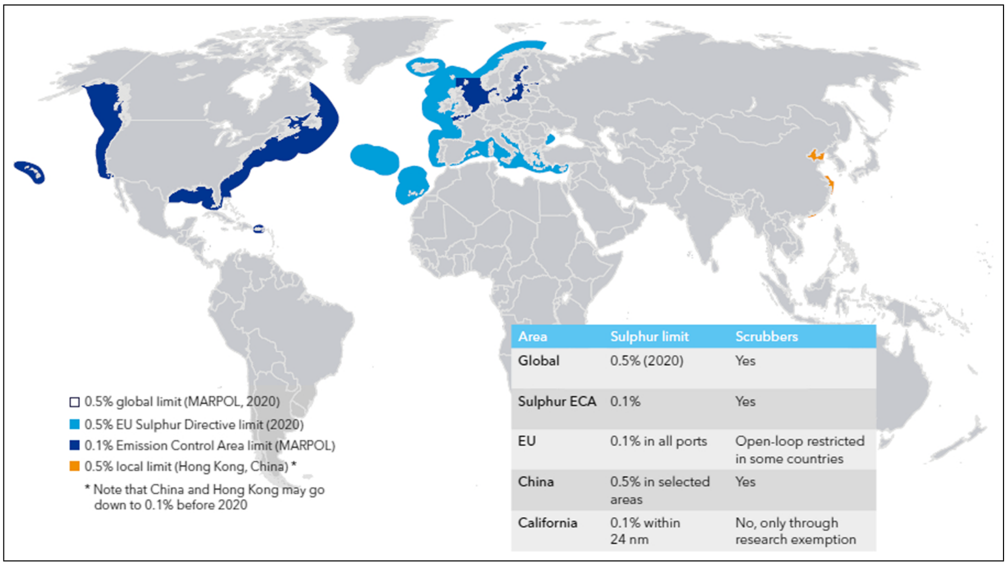

Figure 1.12: ECA (Emission Controlled Area) Maps (Source: *dnvgl.com*)

Technical compliance method

Shipowners have three main path to stay compliant to the new rules. It is quite obvious that those methods require huge investment capabilities by the maritime companies and a possibility that a percentage of them will run out of business exists. In this sub chapter the three main path to follow will be discussed. The first one is to convert the vessels to use the VLSF (Very Low Sulphur Fuel), that is a type of fuel which is compliant with the sulphur regulation. The second method permits the liner to use HSF and this is thanks to the scrubbers. The last possibility is to switch to LNG-propulsion engine.

Very Low Sulphur Fuel: as said before the use of a fuel which its self it is compliant with the sulphur limit is one option. This method is the simplest one and it can be applied to any type of vessel independently by their age. Be noted that, following this path, the legal responsibility for the fuel to meet the standard required is transferred to the fuel supplier. However key considerations are the stability of the market for this type of fuel, which will be available by the 2020 (demand is expected to grow from 0 to 1.4 million bp/d), and so the price is not very known and the time expenditure to fit the vessels with the new fuel and to clean the tanks [4]. Economic incentives are expected to drive increased use of VLSF over time. This method seems to be one with minimal operational difficulty.

Scrubbers: those are equipments that can be fitted to remove sulphur from exhaust gases and enable vessels to burn cheaper high sulphur fuels. This is an option that requires huge investments and it is also the most technically complex. At the moment scrubbers to be retrofitted on vessels, can be divided in three categories: open loop, closed loop and hybrid systems. Open loop is the simplest scrubber system, it uses pumped seawater for the scrubbing process, then it undergoes filtration and eventually gets dispensed, while the sludge remains onboard, to be collected in the respective port facilities. In contrast with the open loop system, closed loop scrubber system discharges merely small quantity of scrubbing liquid. Instead, by chemically treating the liquid in the respective tanks, the fluid is circulated and re-used, fact that attributes to a decrease in the quantity needed and therefore in the size of the mechanism, amid with the energy required [10][5]. Finally, the hybrid system is a combination of the two aforementioned types, which allows the transition between open and closed loop operation, providing the vessel the possibility to reap the benefits of both types of mechanisms. One of the main issue concerning the use of scrubbers is that those equipments are going to be fitted on a vessel which was not designed to fit them, this will of course cause a reducing of the capacity of the tank (if the scrubbers is into the tank) and/or of the cargo capacity.

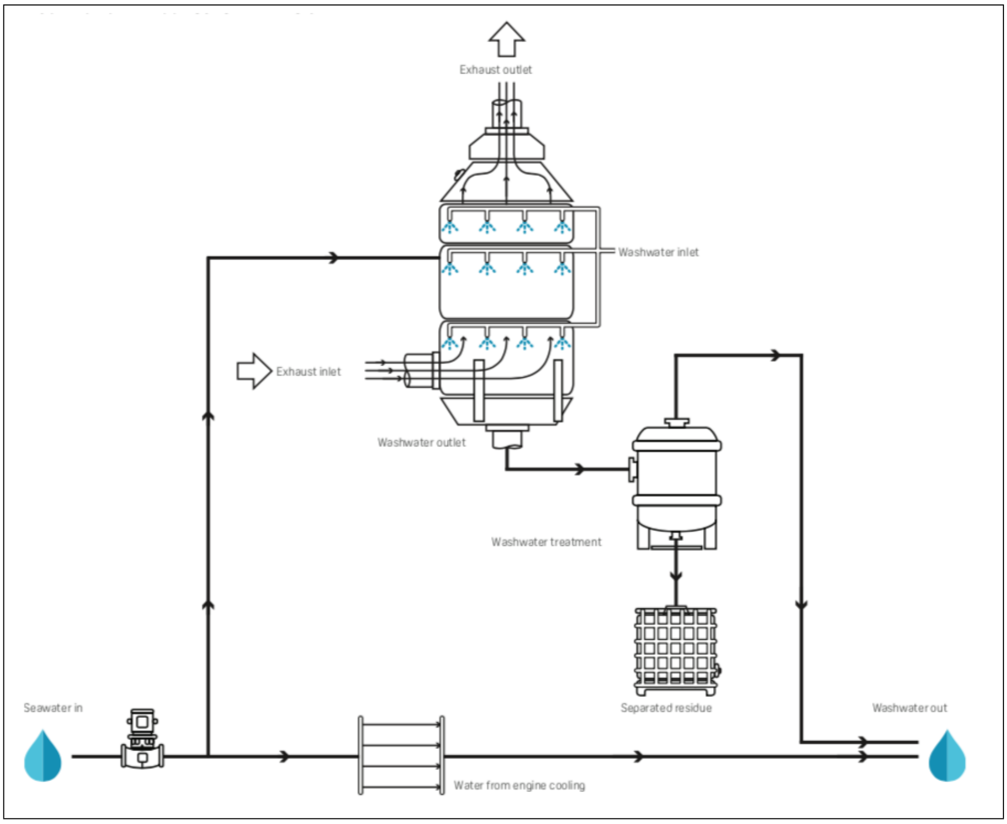

Figure 1.13: Open Loop Scrubber scheme (Source: S& P Global Platts, Exhaust Gas Cleaning Systems Association [25])

LNG propulsion engine: the use of this engines is the best for the matter of compliance with the sulphur regulation since LNG has low NOx and SOx emissions. However due to the expenses of retrofitting the use of this technology is limited to new vessels. A downside for this path is that infrastructure for LNG bunkering will be less established than for other fuel types in 2020.

1.5 Literature review

The impact of the IMO 2020, as said, is an important point for shipping industry and connected. To better understand this point is important to look to the recent literature about it. Many scientist, economists, experts, and organizations have disclosed their thoughts. However those thoughts can come from different point of view. One of the most studied and with the higher expectation is the environmental impact, in fact, as the environmental benefit is the first goal of the IMO 2020 policy this aspect has drawn attention and different studies have been carried on this topic. Then, another point of view from which different studies have been developed is the economic one. In particular, both the academic world and the business world, are questioning how the industry and the shipping market structure will change because of this policy. Moreover another point of view is the operational and technological one. The business world in fact have developed different strategy to comply to the IMO 2020 restrictions, and different studies and publication have been made by both the academic world and the business world to understand which is the best complying strategy in the terms of operational costs. Furthermore, other studies have been focused on even more specific details, for example to study the impact that IMO 2020 will have on the financial health of the companies operating in the United States supply chains.

Several studies have been made to understand and quantify the environmental benefit coming with this new regulation. As an example, Mikhail Sofiev et Al. [17], evaluates public health and climate impacts of the new low-sulphur fuels policy for global shipping. In particular this study applies a known model for climate and pollution studies related to the shipping industry, which is the Ship Traffic Emission Assessment Model (STEAM) developed by the Finnish Meteorological Institute (FMI), in combination with another model for carrying atmospheric simulations which is the, public available for researcher, chemical transport model (SILAM) to estimate country-specific incidence rates for cardiovascular disease, lung cancer and childhood asthma. A first conclusion of this study is that cleaner marine fuels will reduce ship-related premature mortality and morbidity by 34 and 54%, respectively, representing a 2.6% global reduction in PM2.5 resolting in cardiovascular and lung cancer deaths and a 3.6% global reduction in childhood asthma. However, further analysis estimates that despite these reductions, low-sulphur marine fuels will still account for 250k deaths and 6.4 M childhood asthma cases annually, and more stringent standards beyond 2020 may provide additional health benefits. Moreover, lower sulphur fuels also will reduce radiative cooling from ship aerosols by 80%, equating to a 3% increase in current estimates of total anthropogenic forcing. Therefore, stronger international shipping policies may need to achieve climate and health targets by jointly reducing greenhouse gases and air pollution.

A different point of view, however, is brought by Anna Chrysouli [5]. Her work aimed to model and understand the market structure changes that the new fuel policy will cause. Specifically, the study compares the concentration rate of the market before and post the IMO 2020, by utilizing a market concentration measure, the Herfindahl-Hirschman Index (HHI). In a first part of her research, the methodology followed is likely more qualitative. Firstly the study presents an analysis of the IMO 2020 regulation and the challenges posed to the shipping industry, in regards to the alternatives available. Then she proposes a review of factors that can influence markets structure and the investment capacity of the small liner shareholders. Thus, the focal point of the qualitative part, is to determine the elements which will affect the capability of the liner market to adjust within the restrictive time available to be compliant with the IMO 2020. The second part of the study is more quantitative with the aim to analyse the present market structure of the liner shipping industry. As said the measure used for the analysis is the Herfindahl-Hirschman Index (HHI) in combination with a concentration ratio (CR), which uses as input the market shares of the three, four or eight leading companies in the investigated industry and it is important to investigate the overall reaction of the industry.

After investigating the possible alternatives chosen from the liners, in this paper, four scenarios were formed, based on the forecasted increase of Low Sulphur marine Fuel and the price sensitivity of the shippers towards the increased freight rates. The conclusion is that under all cases studied the concentration index will decrease. As mentioned in this particular study, a decrease in the concentration index is translated in a market structure that will become more competitive due to the decrease in the market shares of the fuel compliant liners, as an inflict of the restrictive due to the tight time and cost challenge that IMO 2020 imposes to the industry [5].

Another point of view is brought by James J. Corbett and Edward W. [18]. In this work the researches are focused on the both the environmental and economic shake that IMO 2020 will cause, in the specific, to the United States. This study brought a qualitative analysis of the effects that IMO 2020 will cause to the United States shipping industry. In this study is cited a study carried out by Goldman Sachcs stating the readiness of the United States for the IMO 2020 changes. An interesting finding in their conclusion is that potential fuel shortages should not affect U.S. supply chains and will likely be regional and short-lived. This is in contrast with other different study, especially made by consulting companies that on the other hand are worried for fuel shortages and states that are not that predicable. In particular an encoragiung conclusion is that, as stated in "IMO 2020: Good for the United States", refiners and shippers have been aware of this change for over a decade and have prepared accordingly.

The company IHS Market in collaboration with the website *joc.com* has made an interesting study [19] in which a model for fuel surcharging is developed. In particular their study is guide for shippers to understand the impact that the increase in the fuel price will have on their freight rates. In particular the have reached a increase per every TEU carried. Interesting is the result that bigger shippers benefit from economy of scale and by this competition will be lower than what it is now putting minor shipper in even more difficulty. However their model is not based on time series but is focused in analysing specific operational cost of the shippers. In the specific the study provide an interesting, and quite simple, tool that shipper can use to compute the fuel surcharge deriving from the IMO 2020 for a specific route. Named, *Fuel Surcharge 101*, this tool is about to compute the surcharge by multiply a, namely, *trade factor* by the fuel price. Interesting is that variable composing the trade factor are given but the guide do not provide a specific formula combining the variable because every shipper has its own. Those variables are:

- **Voyage length:** time to complete the entire voyage
- **Ship size:** average capacity of the ship measure in TEU
- **Sea Days:** days of the voyage length spent in the sea
- **Port Days:** days of the voyage length spent in the port
- **ECA days:** days of the voyage length spent in Emission Controlled Areas
- **Ship speed:** average speed used to calculate fuel consumption per day. Be noted that fuel consumption increases at a cubed ratio to speed, therefore an increase of even 3-4 marine knots can double fuel consumption.
- **Fuel consumption:** Tons of IFO 380 fuel used based on average time and ship speed
- **Basic cost embedment:** a standard cost per ton included in the basis ocean freight whereby bunker would only be assessed when prices go above the embedded price

- **Asset utilization:** capacity of the ship assume to be used. It is not a trivial point because the ship, during its voyage, can be loaded and unloaded different time for every port touch

- **Imbalance factor:** percentage of costs that can be attributed to the backhaul

Then, even to compute fuel price, important operational consideration are made:

- **Bunker location:** despite the fact that the cost of the bunker is highly correlated with crude oil price, the location in which the shipper buys its bunker is important because costs vary by port. Carriers will reference the prices of specific ports to monitor fuel prices.

- **Reporting period:** shipper monitors bunker price in different ways. In fact the can monitor it in a weekly or monthly basis, simply computing the average of the price. Moreover shipper can also use brackets or triggers that affect changes when a price in a period rises or falls by a specific amount.

- **Fuel surcharge timing:** a vessel s fuel tanks will need to be fully cleaned and flushed of any HFO, so that none of the high-sulfur remnants are mixed into the MGO. This process needs to start a few months prior to regulation implementation date. Although the IMO and Port States are likely to show some leniency in the first few months, carriers are unlikely to risk reputational damage and will start the switching process early.

Conclusions are that today forecast assumes a short to mid term increase in bunker prices between US$ 180 and US$ 400 per TEU. Due to the significant increase in bunker prices, every company involved in sea freight will be confronted with rising transportation costs. When IMO 2020 comes into effect transportation services may be disrupted as a result of inadequate fuel quality, which may lead to engine failures or insufficient availability of compliant bunker fuels. Those consideration made by this study are totally in contrast with the conclusions made by James J. Corbett and Edward W.

Other and more specific issues are brought by consulting companies, such as KPMG, pointing out emerging issues related to the use of those new low-sulphur fuel. In particular, in the article *"Getting ready for IMO 2020"* [4], is carry out a double analysis for both the supply side, i.e. refiner and fuel supplier, and for the demand side, i.e. shippers. For what concerns the demand side, shipper, an important issue emerged. From their studies and industrial investigations they are questioning that since there is no standard procedure to obtain low-sulphur-fuel-oils, output of the process may not be stable or there could be some incompatibility problems with other fuels. These problems may cause issues inside the engine system of a ship, even result in the engine failure. In addition to the compatibility and stability problems, small ports might not be able to supply fuel oil with low sulphur since the product will be brand-new. All of these issues will continue in the first years of regulation until a standardized product is obtained and delivered to the ports.

As an example to prove the interest, Drewry, which is one of the biggest name in the maritime business consulting, has developed its own *IMO 2020 Cost Impact Calculator*, for obvious reason this instrument is available only for Drewry clients.

However private company are still trying them self to understand what will be the evolution of those rates after the 2020. According to a car manufacturer study, the weight of the fuel on the rate is about from 20 to 30 % of the total of the rate. Furthermore this study foresees a proportional jump in the freight rates in the sense that if the fuel price increase by 100% then the rate will increase by 20% to 30%, or more specifically, by the weight that the fuel price has on the freight rate.

Lastly is important to consider expert opinions on this topic. Several interviews has been made from the above mentioned car manufacturer and the opinion of the experts seems to unanimously agree that the price of the fuel and the freight rates will growth. Furthermore, the increase in the bunker price is expected, in the worst scenario, to double it self. In this case fright rates are expected to growth by the 20-25 %. In particular the interviews were carried out during the negotiation phases for new contracts with shipping companies that have 2020 as the start of the year.

From this review of the academic literature and of the scientific and business articles it is now clearer the impact that this new standard has on the market of shipments by sea and the amount of doubts and uncertainties it raises. Many questions remained without certain answers and only time, which brings the market invariably every day closer to the IMO 2020 entry into force, can give answers.

1.6 Research gap

The study of the freight rates and on how certain parameters, market resistance or factors influences them is commonly made using some time series analysis instruments. Certainly IMO 2020 will have huge impact on these rates. Many studies have been made to forecast what can be the impact of these new IMO mandate, dozen of experts have developed their opinion to predict the impact.

These studies approach the problem from different points of view, as saw in the previous section the problem is dissected from an environmental point of view, from the market point of view, from the financial or operational and technological point of view. However, as will be described in the section 2.3, many problems and analysis of logistical issues are addressed with the use of time series analysis tools.

Despite these analysis that have been made there are no publication that try to apply the instruments of the time series analysis on the IMO 2020 scenario. In particular there are no study that try to model some kind of indicator that reflects the freight rate evolution in relation with an indicator, preferably provided as a time series, that can be logically connected to the fuel price. More in particular, there is no evidence in literature of a study that, besides study the correlation between the factors mentioned above, tries to study the future evolution of such a model.

The aim of this work is to apply basics instruments of time series modelling to the freight rate and fuel case and also to apply the mentioned model to a "IMO 2020" scenario in which the fuel price will increase by the amount foretasted by analysts and by the expert in the logistic sector with the scope of forecasting future freight rates, specifically carring out conditioned forecasts. In particular the comprising instruments such as the Vector Autoregression as a method to build the model and the Minimum Mean Square Errors and the Monte Carlo Simulation as the methods to create the forecasts and the conditioned forecasts [20].

Chapter 2

Forecasting methods analysis

The aim of this work is to test some of the following forecasting method in the new environment setted by the introduction of the IMO 2020. Two of the methods used in the previous taken into consideration will be discussed. Both can be based on the Vector Autoregrassive statistical model. The first is the MMSE method, while the second is the simulation using the Monte-Carlo method.

2.1 Analysis of time series

Freight rates, as already said, are influenced by various factors. These factors can in turn be other prices or other parameters (such as market activity) which, however, can be associated with a value and track over time.This makes them time series. Time series are sequences of ordered values that refer to the evolution of a quantity (be it physical, financial, economic, etc.) over time, each value is associated with an instant in time.

The Vector Autoregressive Model (VAR) for multivariate time series is the easiest model used to study the interdependencies between different variables. A VAR model generalize the univariate Autoregressive Model (AR). Its aim is to describe the evolution of a set of k variables over the same time horizon as a linear function of their past values. Those variables are formalized into a $k - vector$ that will be called y_t. The i-th component of this vector, $y_{i,t}$, can be read as the value of the variable i at time t. The generic value of y_t for a p-order model can be written as:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + .. + A_p y_{t-p} + \varepsilon_t \tag{2.1}$$

where:

- c is a k-vector of constants
- A is a $k \times k$ time invariant matrix
- y_{t-j} is called the j-th lag of y
- ε_t is the k-vector of error

An "evolution" of the auto regressive model is the so called **ARMA** model which stands for Auto Regressive Moving Average. The "AR" part of the model is just the same as what described above. The "MA" part of the model, the Moving Average part, model the error term as a linear combination of previous error terms that occurred contemporaneously. In literature in general the ARMA model is defined as ARMA(p, q) where p is the order of the Auto Regressive part of the model and q is the order of the Moving Average part. Given that the first part, AR, is basically defined as above, thus:

$$y_t = c + \Sigma_{i=1}^{p} A_i y_{t-i} + \varepsilon_t \tag{2.2}$$

and the MA part could be written as:

$$y_t = \mu + \varepsilon_t + \Sigma_{i=1}^{q} B_i \varepsilon_{t-i} \tag{2.3}$$

then the notation of a general ARMA model with p AR terms and q MA terms is:

$$y_t = c + \Sigma_{i=1}^{p} A_i y_{t-i} + \varepsilon_t + \Sigma_{i=1}^{q} B_i \varepsilon_{t-i}. \tag{2.4}$$

The generalization of this model is the **ARIMA** model. As for the ARMA model the "AR" part stands for Auto Regressive then the "MA" part stands for Moving Average. The I instead stands for "integrated". It indicates that the data values have been replaced with the difference between their values and the previous values. The purpose of each of these features is to make the model fit the data as well as possible.

2.2 Forecasting method

Studying, and analysing historical data and possible correlations between different historical time series is one of the first steps when the aim is understand the, in some cases, reciprocal, behaviour of a set of time series. In general, after the development of the model that fit on the set of time series, a possible step further is to forecast. Forecasting, in general terms, means the taking models that fit on historical data and using them to predict future observations. Be noted that herein the term forecast refers to to predict future values based on previously observed values. Based on previously observed values, in some way, means that the past of the values influence the future of the values. The most commonly used models for forecasting and specifically the most used for forecast time series related to some logistic topics, as freight rates, are: the Minimum Mean Square Error Forecast and the Monte Carlo Simulation. At the end conditional forecasting is the generation of forecasts conditioned on different policy scenarios. These scenario-based conditional forecasts allow one to answer the question: if something happens to some variables in the system in the future, how will it affect forecasts of other variables in the future?[20]

2.2.1 Minimum Mean Square Errors Forecast

To define this method useful is referring to the definition given by Zhou and Chen [9]. The mean square error is a common measure of estimator quality, of the fitted values of a dependent variable. The minimum mean square errors forecasting method is an estimation the minimize this mean square error.

The mean squared error (MSE) is defined as:

$$MSE = \int_{\mathbb{X}} p(\mathbf{x} \mid z)(\hat{\mathbf{x}} - \mathbf{x})^T(\hat{\mathbf{x}} - \mathbf{x})\, d\mathbf{x} \tag{2.5}$$

in which $p(\mathbf{x} \mid z)$ is the *priori* distribution of $\mathbf{x}$. Therefore the minimum MSE is obtained as follow:

$$MMSE = min_{\hat{\mathbf{x}}} \int_{\mathbb{X}} p(\mathbf{x} \mid z)(\hat{\mathbf{x}} - \mathbf{x})^T(\hat{\mathbf{x}} - \mathbf{x})\, d\mathbf{x} \tag{2.6}$$

by taking its derivative and making it to be zero:

$$\frac{d \int_{\mathbb{X}} p(\mathbf{x} \mid z)(\hat{\mathbf{x}} - \mathbf{x})^T(\hat{\mathbf{x}} - \mathbf{x})\, d\mathbf{x}}{dx} = 0 \tag{2.7}$$

and so the optimal estimation is:

$$\hat{\mathbf{x}}^{\star}_{MMSE} = \int_{\mathbb{X}} p(\mathbf{x} \mid z)\mathbf{x}\, d\mathbf{x}. \tag{2.8}$$

2.2.2 Monte-Carlo Simulation

The Monte Carlo simulation is a simulation-based forecast and it permits to study the behaviour of a system in a controlled environment. After the construction of a model that, with n equation describes the link among the variables the objective is to carry out "virtual" experiments on the mathematical model assuming that the results of these experiments constitute a sufficiently accurate "reproduction" of the behaviour that the system would have. The elements for the Monte Carlo Simulation are:

- Parameters: inputs specified by the decision-maker / analyst, and therefore controllable (i.e. the price of the bunker).
- Exogenous input variables: input variables that depend on events that are not under the control of the decision maker, whose progress is however describable in probabilistic terms.
- Output variables: they represent the results of the simulation; in the specific case of interest here (i.e. the freight rates).
- Model: mathematical equations (functions of parameters and input variables) that describe the relationships between the components of the system / problem and define the link of the outputs with the parameters and input variables.

Practically, the Monte Carlo method is based on the fact that a direct analytical solution of the problem, which allows to directly express the link of the output to be obtained with the input data, can be too burdensome or perhaps impossible. The problem is then solved numerically, producing a sufficiently high number N of possible combinations of the values that the input variables can assume and calculating the relative output based on the equations of the model.

To build each of the N combinations is generated (ie extracted) randomly a value for each input variable, according to the specified probability distribution and respecting the correlations between variables. Repeating on the computer N times this procedure (with N large enough to allow statistically reliable results) N will be obtained independent values of the output variables, which therefore represent a sample of the possible values assumed by the output, a sample that can be analyzed with statistical techniques to estimate them the descriptive parameters, reproducing the histograms of the frequencies, and numerically obtaining the trends of the output distribution functions.

2.3 Prior studies & other forecast models

There are many attempts in literature made to analyse, model and predict time series. In particular in this section the focus will be on those attempts that as object have time series with a logistic meaning. In particular those that have shipping rates as objects.

In 1990 a study by Dingra, Mujumdar and Gajjar [11] was done with the aim of modelling and predicting shipping rates by truck for the Journal of Advance Transportation. In this study, the a first standardization of the logistics variables was made. The standardization consists in taking the differences of the time series and in arrange those differences into a new time series on which fit the model. Then, in this article the Auto Regressive model has been chosen. In particular the model used is the Auto Regressive Moving Average. Then, for the forecasts uses the MMSE method. Its conclusions indicate that this type of analysis can be successful for the time series of tariffs.

In 2010 Goulas [12] developed a study with the intention of predicting shipping rates and the price of derivative instruments connected to them. As can be seen from his conclusions, there is a high success rate in the prevision for the pure rates, but as regards the price of derivative instruments (IMAREX future) the same cannot be said. In particular its said that a result is an evidence of strong predictable pattern for the Baltic index. The study provides a first application of the Vector Autoregressive model on the Baltic Freight Index and then, to analyse its predictability, divide the totality of the sample in two subsample that are both known and using the preceding sample predict, using Monte Carlo technique, the following sample. Then further study have been made to asses the right dimensionality of the first sample for the best forecast, this part however is not developed herein.

In 2016 was developed the ARIMARCH model that combine the ARIMA and ARCH technique by Ziaul Haque Minimum et al. [6]. The ARIMA model was defined is section 2.1. Instead ARCH models consider the variance of an observation σ_t^2, at a given t, as a function of the previous error terms. Thus, ARCH model can be formulated as follows:

$$\sigma_t^2 = \alpha + \Sigma_{i=1}^{m} \alpha_i \epsilon_{t-i}^2. \tag{2.9}$$

In their case ARCH is not fitted to the original time series or differenced time series, but has the purpose to model the noise of only the selected ARIMA models through ARCH to develop the ARIMARCH model. This means the ARCH model is modelling the variance of error terms of the ARIMA model as a function of previous error terms of those error terms [6].

Different prior studies have been made to find a link between the fright rate and oil price. One of them has been made by UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT [1] in 2010, with the aim to assesses the effect of oil prices on maritime freight rates for containerized goods and two particular commodities, iron ore and crude oil. However, the statistical studies made in this work are about the supply and demand equilibrium and about the elasticity of the right price. Thus, this study is focused more on the econometric factors. However even in this case the authors used time series analysis such as the auto model applied to logistics variables to reach its results.

Cue and inspiration has been taken from those study. Despite their deeper statistical coverage, my study tries to capture the essential instrument to perform a basic analysis.

Chapter 3

Development and application of the proposed previsional model

The aim of this work is to study the relationships between the price of some freight and other factors, with a particular clue on the price of the bunker. Since those variables evolve as time series, the model selected to approach this study is the Vector Auto Regressive Model (VAR).

3.1 Variables influencing the freight prices

As mentioned in section 2.2, shipping rates are determined by many factors that sometimes, like for additional services, have a contractual nature and therefore difficult to control. However, the purpose of this work is to understand how these tariffs will be affected by the IMO 2020. To do this, therefore, it is necessary to find data that reflects the tariffs and at the same time are in a "format" comparable with, for example, the historical fuel price data.

3.2 Data collection

This section describes the collection process of the data necessary for the analysis. The three time-series considered are: Brent Oil, Harpex index and Baltic Dry index.

Brent-Oil: A suitable time series for bunker prices is the Brent-Oil index, in fact its correlation with bunker prices is 0.98 [1]. This type of index can be downloaded from different websites, in this case opted for `investing.com`.

Harpex: this index tracks worldwide international container shipping rates for eight classes of container ships. The index is tracked by ship brokers Harper Petersen & Co and was compiled in 2004, though records exist as far back as 1986. The index is available as time series at the website `http://www.harperpetersen.com`. The time series provides with the index also the rates for 9 types of container vessels (TEUs: 700, 1100, 1700, 2500, 2700, 3500 4250, 6500, 8500)

Baltic Dry Index: this index measures the demand for shipping capacity versus the supply of carriers. The demand for shipping varies with the amount of cargo that is being traded or moved in various markets. In some way this index can seen as an indicator of the shipping activity.

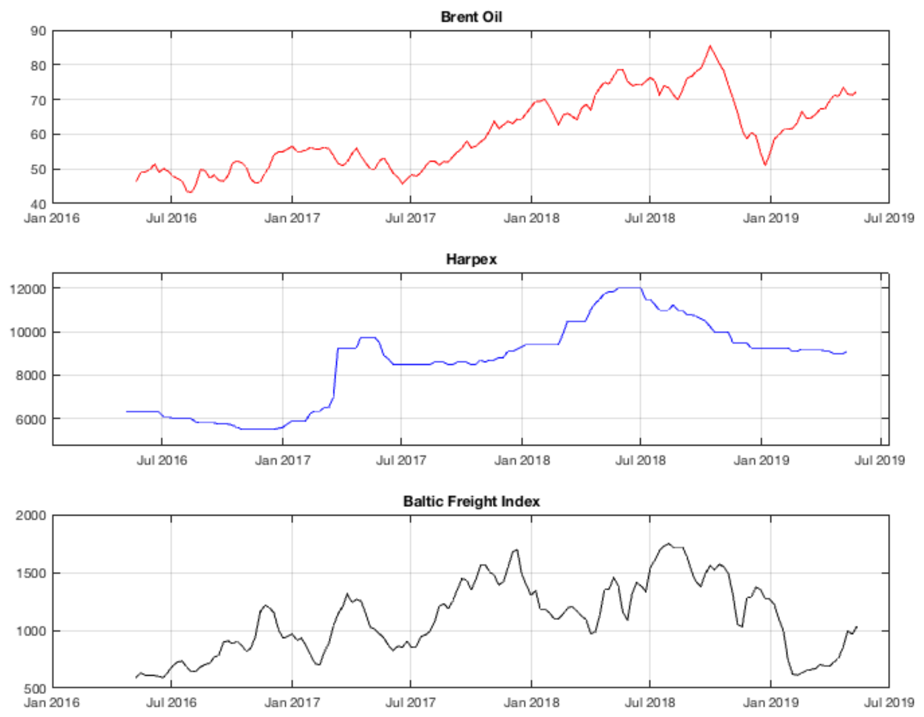

Figure 3.1: Time series Variables

3.3 Choice of the model

Vector autoregressions (VARs) have become the workhorse model for macroeconomic forecasting. The initial use in economics was to a large degree motived by Sims in 1980 [16] critique of the "incredible restrictions" used by the large macro-econometric models developed in the 1970s and much effort was put into tools for policy analysis based on VAR models.

A VAR model generalize the univariate Autoregressive Model (AR). Its aim is to describe the evolution of a set of k variables over the same time horizon as a linear function of their past values. Those variables are formalized into a $k - vector$ that will be called y_t. The i-th component of this vector, $y_{i,t}$, can be read as the value of the variable i at time t. The generic value of y_t for a p-order model can be written as:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + .. + A_p y_{t-p} + \varepsilon_t \tag{3.1}$$

where:

- c is a k-vector of constants
- A is a $k \times k$ time invariant matrix
- y_{t-j} is called the j-th lag of y
- ε_t is the k-vector of error.

The Vector Autoregressive Model is one of the most successful, flexible, and easy to use models for the analysis of multivariate time series and it is also used for structural inference and policy analysis [20].

In particular for the conditioned forecasting part of the model the two method chosen are the MMSE and the Monte Carlo Simulation-based forecast.

3.4 Model development

In this section the application of the model is discussed. The software suitable to implement the model can be Matlab, R, Minitab, STATA, S-PLUS or RATs and others. The software used in this specific work is Matlab since its toolbox packages provides all the instrument to develop model and its full-feature programming language is easier to write and understand for those not used to the more statistics oriented programs.

The descriptive statistics of the time series examined are shown in table 3.1. Table 3.2 instead shows the correlation values between the 3 time series. Is immediately clear the high correlation between the series that describes the price of fuel and the Harpex index.

Statistic	**Baltic**	**Harpex**	**Brent Oil**
Average	1099.31	8622.75	60.32
Max	1747.80	12000	85.44
Min	590.40	5500	43.12
Median	1099.20	9100	58.35
Standard Deviation	319.03	1931.42	10.52
Kurtosis	1.99	2.02	1.94
Skewness	0.167	-0.219	0.356

Table 3.1: Descriptive Statistics

Statistic	**Baltic**	**Harpex**	**Brent Oil**
Baltic	1		
Harpex	0.604	1	
Brent Oil	0.554	0.788	1

Table 3.2: Correlation matrix

First of all the data came with different time frequency. In order to implement the model in Matlab the data had to be synchronized between them in a way such that the different data series has the same number of rows for each column.

The synchronization is made using the Matlab function *synchronize*, the function creates three new time series objects by synchronizing the three time series using a common time vector and a specified method. The method used in this case was the *mean* method with a *weekly* interval. Thus, the result of this operation is a set of three new time series having an equal number of rows, each row corresponding to the same week. The value corresponding to a week is the mean of the different values that the index has take during the week.

Then, to stabilize the time series, it comes to take the difference between time steps. To the variables showing an exponential trend the difference of the logarithm has been taken, instead for the linear trend variables the first difference is enough. This operation is made using the Matlab function *diff*, in general the argument of this function is a vector, if the vector has length m, then $Y = diff(X)$ returns a vector of length $m - 1$. The elements of Y are the differences between adjacent elements of the vector object of the function:

$$Y_{t=0} = 0 \tag{3.2}$$

$$Y_{t=k} = v_{k+1} - v_k. \tag{3.3}$$

Then, thanks to the Matlab function *array2timetable*, the arrays, or vectors, containing the differences have been converted into time table. Figure 3.5 shows a plot of the resulting time series.

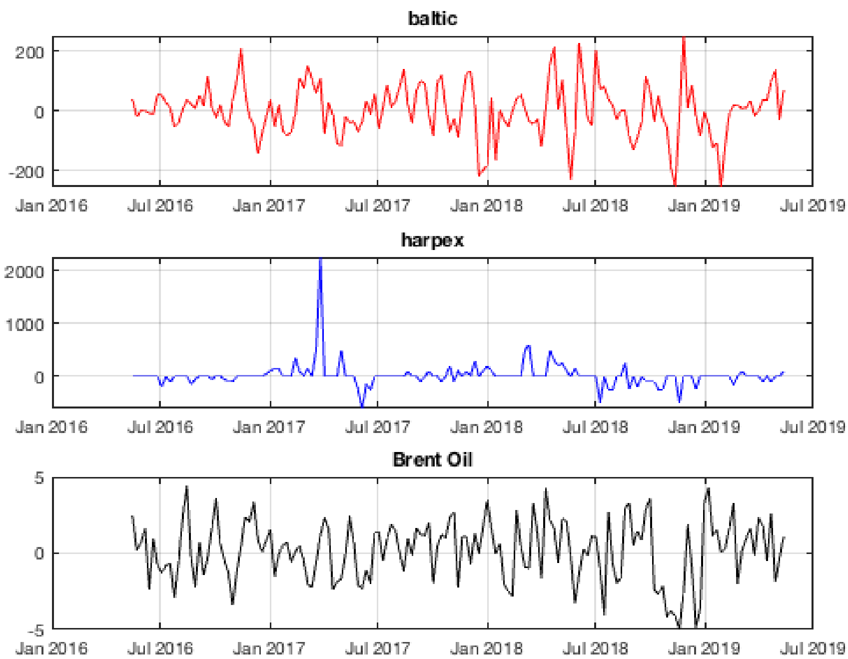

Figure 3.2: Stabilized Time Series

Following the stabilization of the variables there is the creation of the model. Be noted that the model is created on the results of the $diff$ function, i.e. on the difference between the original time series. To create the model, which is the Auto Regressive model, the Matlab function *varm* was used. The *varm* function returns a *varm* object specifying the functional form and storing the parameter values of a p-order, stationary, multivariate vector auto regression model *(VAR(p))* model. The key components of a *varm* object include the number of time series and the order of the multivariate autoregressive polynomial *(p)* because they completely specify the model structure. As mentioned before the time series on which the model is applied are the differences time series. Once defined the parameters of the model, the next step was to estimate the model. To estimate the model the Matlab function *estimate* that to returns a fully specified $VAR(p)$ model. This model stores the estimated parameter values resulting from fitting the $VAR(p)$ model Mdl to the observed multivariate response series using maximum likelihood. Those parameter are shown in Appendix B.

Following the creation of the Vector Autoregressive Model it comes to a forecasting analysis. The idea was to set one parameter, the oil price, to a certain level that reflects the increase in price due to the IMO 2020 regulations. For a broader comparison, both forecasting methods were applied, both MMSE and Monte-Carlo. For an initial test an unconditional forecast was produced. As already mentioned the methods used in this work are the MMSE and the Monte Carlo simulation. For each MMSE method two different forecasts have been made. The first forecast, namely unconditioned forecast, is just the prediction of future observation without superimposing any value. This procedure has been made for both forecasting methods. The second forecast, namely conditioned forecast, is made imposing future value for a time series (e.g. the future oil price). Also this procedure has been made for both methods. Thus, to summarize the result of this operation will be 2 type of forecast, the one using the MMSE and the one using the Monte Carlo simulation, for 2 different scenario, i.e. the conditioned and the unconditioned.

To forecast the future observation accordingly to the MMSE method the Matlab function $forecast$ was used. The input parameters for the $forecast$ function are: a Model, the number of periods for the future observations and a presample. Thus, the function returns a path of minimum mean squared error (MMSE) forecasts over the length numperiods forecast horizon using the fully specified VAR(p) model Mdl. The forecasted responses represent the continuation of the presample data. The model used, of course, is the one crated, fitted to the data and estimate as described above. The number of periods *numperiods* of future observation is setted as 30. Then the pre sample data are, obviously, all the past observations. The $forecast$ function also offers the possibility to use additional options for the function. An additional option used in this work is the YF option to perform future multivariate response series for conditional forecasting, specified as the comma-separated pair consisting of YF and a numeric matrix. The $forecast$ function treats the numeric matrix after YF as deterministic future responses that are known in advance, for example, set by policy or estimated effects of some policy (e.g. IMO 2020).

To forecast future observation accordingly to the Monte Carlo method the Matlab function *simulate* was used that returns a random numobs-period path of multivariate response series (Y) from simulating the fully specified VAR(p) model Mdl, where *numobs* is the number of future period for which simulate and forecast. The input parameters are: a Model and the number of future observation *numobs*. Thus, the function returns a Monte Carlo simulation of vector autoregression (VAR) model. As above the number of future observation is set as 30. The, using the option 'Y0' of the *simulate* function initial values for the model are provided, specified as the comma-separated pair consisting of 'Y0' and a numeric matrix. Then, the number of sample paths to generate is specified as the comma-separated pair consisting of 'NumPaths' and a positive integer. In this case the number of paths is 1000. The last additional option of the *simulate* function is the 'YF' option. As for the MMSE method, the *simulate* function treats the numeric matrix after YF as deterministic future responses that are known in advance. Appendix A shows the whole Matlab code, for a better understanding. A flow diagram of the three principal function used is provided in Figure 3.3. In particular the *time series* cited in figure are the input data (harpex, Baltic and brent oil) then the *model parameters* are the parameters of the autoregressive model generated by the *varm()* function of Matlab, in particular they are shown in Appendix B. *Outputs* means the forecast results. The *Conditioning* arrows stands for the input given to the *simulate* or *forecast* function, this input representing the variation in the fuel price.

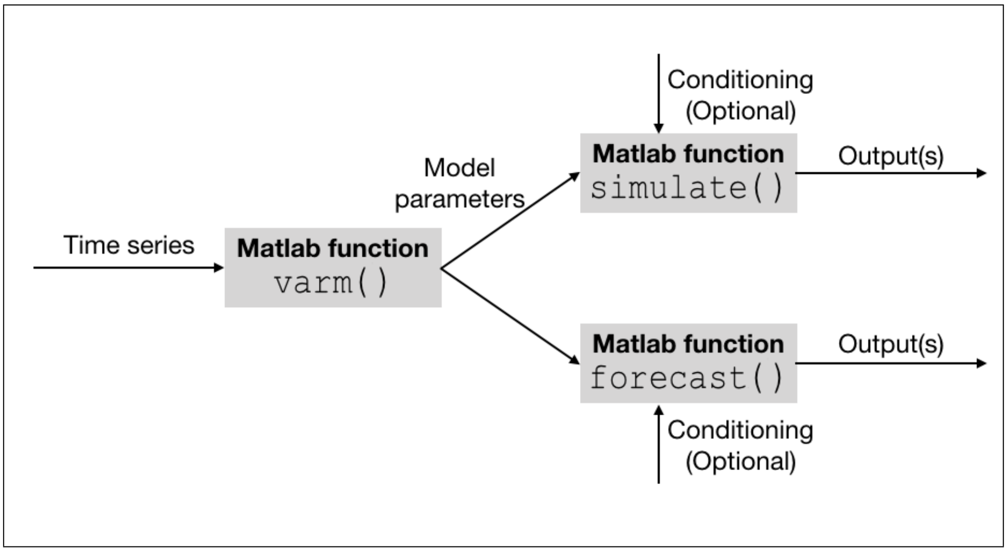

Figure 3.3: Flow diagram

3.5 Model validation

Once the model was developed, a validation was made to ascertain its adequacy. In particular, the validation consist in a forecast test performed using the Matlab *forecast* function. Recalling what has been described in section 3.4, the forecast function requires a so-called presample, and on the basis of it, the function develops the forecasts. In particular, this test uses 75% of the data lines of the original time series as the presample for the Matlab function and generates a forecast for the remaining 25% of the original time series, which are known. The result of this forecast is then compared with the actual values of the known data of the original time series. In figure 3.4 can be noted that the values of the test forecast follow the trend of the values actually observed and in addition the values actually observed fall within the range of 95% of the forecast. This interval is calculated on the basis of the statistical distribution of the model parameters, see Appendix B. In fact, because of the fact that the forecast function of Matlab use the parameter of the generated model, which have their standard errors, another output of the forecast function is an error covariance associated with the autoregressive component of the input model and on the basis of it the 95% interval can be calculated. The dashed lines instead represent the approximate 95% forecast intervals. The orange line represents the forecast test which has the first 75% of the data lines as presample. The blue line instead represents the data actually observed. The plot shows the predicted values on the shaded region, which represents the 25%. The white region instead is the first 75% of the time series on the basis of which the prediction is made. The summary of the model and its parameters are reported in Appendix B.

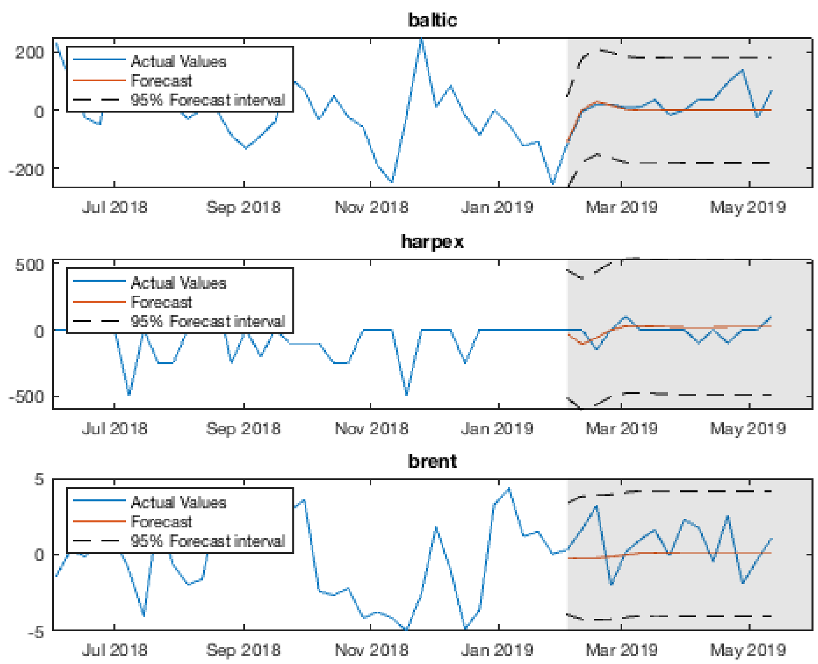

Figure 3.4: Model Fitting the Data

3.6 Results analysis

In this section the results of the forecasts will be showed. To summarize the model output are three simulation. The first one in a MMSE method unconditioned simulation. The second one is a MMSE method conditioned simulation and the third one is a Monte Carlo conditioned simulation.

The first analysis is to understand the basic effect of the increase in oil price. In the totality of the conditioned simulations carried the evidence is that the Harpex index, which is, as above, an indicator of the freight price, will increase as an effect of this conditioning.

The outputs are not showing any relevant differences between the simulation made thanks to the MMSE method compared with the Monte Carlo simulation.

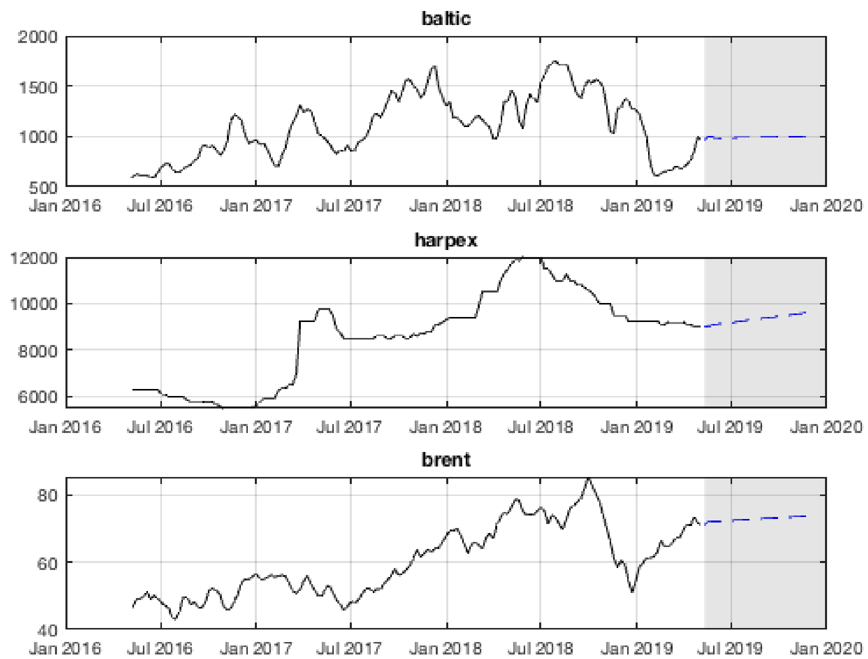

Figure 3.5: Unconditioned forecast

Figure 3.6 shows the output of the forecasts made accordingly with the MMSE method conditioning only the oil price.

For what concerns the unconditioned simulation the output shows a growth trend for the Harpex index for the mid term. This graph is not particularly interesting but

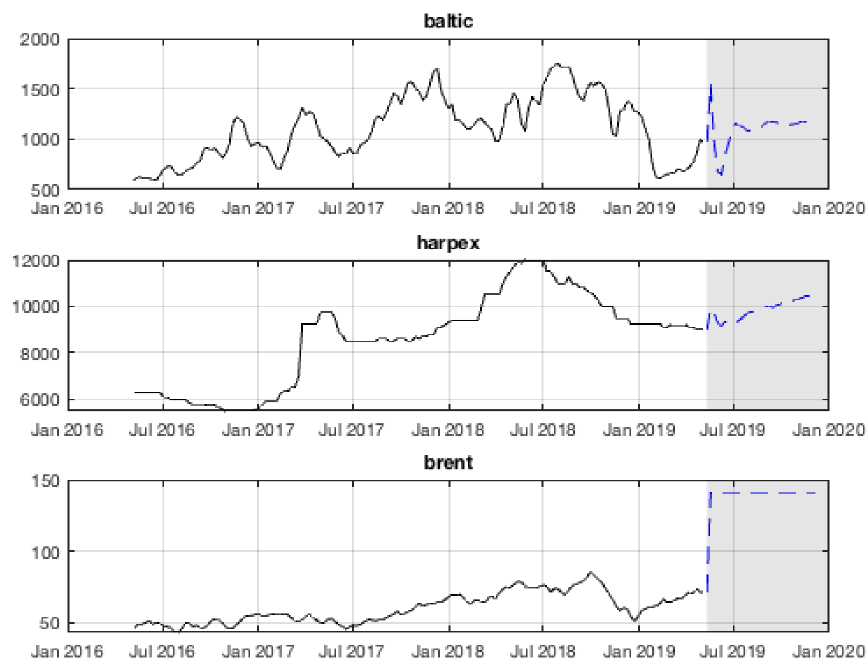

Figure 3.6: Forecast accordingly with the MMSE, conditioning only oil price

can be taken as a validation graph.

Figure 3.7 shows the output of the forecasts made accordingly with the MMSE method conditioning both the oil price and the Baltic Index, in particular in this simulation the Baltic index is supposed to remain constant even after the increase in oil price.

Interesting is comparing those two plots. It is evident that keeping Baltic index free the forecasts meets in a better way the expectations. In fact in the forecast made accordingly with the MMSE method conditioning only the oil price is visible a consistent increase in the Harpex index, event in a mid term. Instead in the forecast made accordingly with the MMSE method conditioning both the oil price and the Baltic Index. A conjecture can be made, since the Baltic index represent the shipping activity and since the forecasts made keeping it free to change seems to better fit expectations, it can be understood that the IMO 2020 not only will cause some changes in freight price but even shipping activity could be influenced by the policy. Talking numbers both the forecast shows a short term peak them in the mid term, 30 weeks, the forecast first Figure 3.6 shows a 20% increase in the Harpex index, instead

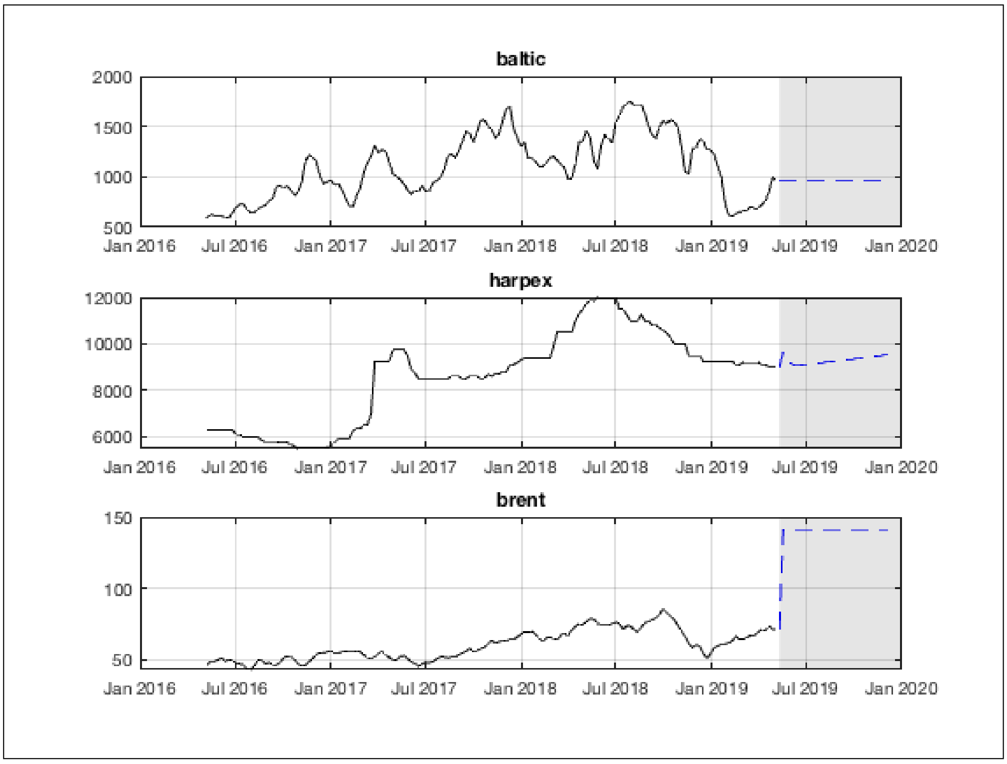

Figure 3.7: Forecast accordingly with the MMSE, both oil price and Baltic index

the second figure shows a 6% only increase in the Harpex index.

As shown in Figure 3.8, which is the plotted output of the conditioned Monte Carlo simulation, the Harpex will grow by the 15% for a 100% variation in oil prices. This result is not completely expected, in particular is the expected increase in the Harpex is greater the the effective increase obtained by the developed model. In particular in this graph is plotted only the Harpex index time series with different Monte Carlo path and the blue dotted-marked line is the average between the 1000 paths of the Monte Carlo simulation.

Overall the model seems to output results which are slightly lower that expectation. This difference with the expectation can be imputed to the fact that the Harpex index, which is, as mentioned above, the variable reflecting the freight rates, is its self a composition of different freight rates. This, of course

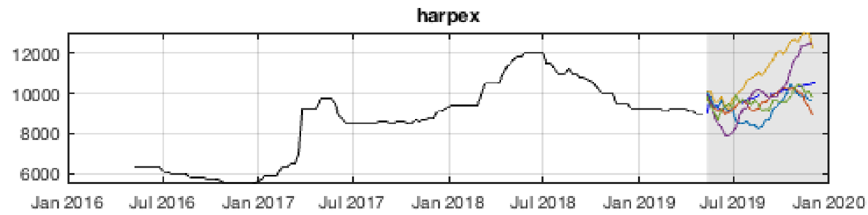

Figure 3.8: Conditioned Monte Carlo Simulation

3.7 Results summary

In this section a brief summary of the obtained results is provided. Be noted that: MMSE forecast stands for the forecasts made using the minimum mean square error method, Monte Carlo stands foe the forecasts made using simulation-based method, unconditioned means that no variables have been super imposed and conditioned means that some variables have been super imposed in the forecast and those variables are stated between brackets. Be noted again that when conditioning the Brent oil the super imposed value are the double of the last observed value in the time series, so as to simulate a doubling of the oil price, instead, when conditioning the baltic value, the super imposed value are the same as the last observed value.

Forecast Method	**Forecasts**	**Delta with expectations**
MMSE, Unconditioned	5%	20%
MMSE, Conditioned (Brent oil and baltic)	6%	19%
MMSE, Conditioned (Brent oil)	20%	5%
Monte Carlo, Conditioned (Brent oil)	15%	10%

Table 3.3: Results summary

The first column of the table indicates which to refer to. The second column shows the value of the percentage increase in the shipping price according to the corresponding forecast. The third column indicates how much is the difference between the percentage value of the expected increase and the value obtained with the forecast. From what has been obtained, the forecast obtained with the MMSE method is the one that comes closest to the expected percentage increase in prices. In particular, IMO 2020, which brings with it an increase in naval bunker prices, implies a quantitative increase in shipping prices of at least 20%.

Chapter 4

Conclusions

The aim of this study is to propose a different point of view in the forecasting freight rates in the sight of the upcoming IMO 2020. In particular in the literature are present several works using time series analysis to study correlation among different logistics variable, freight prices and oil prices included. For what concerns the IMO 2020, different work papers are available from both the academic world and the business world. A plurality of studies emerges with very divers approaches to the problem of understanding what effects of such a new regulation could be. Different conclusion were reached in some cases even opposite. The only common point between all this work is that IMO 2020 will be a disruptive event for the shipping market. Furthermore, among the different works in literature on the IMO 2020 there is no evidence of one of them proposing a conditioned simulation for time series that tries to model future variation of freight prices based on the future expected value of the oil prices.

4.1 Benefit of this study

This study, in its simplicity, has applied the most multivariate time series analysis instruments also used in literature to study logistics variable to the IMO 2020 scenario. The results of this work are that the freight prices will growth but less than expected by experts opinion. In particular, the most fitting with the expectation forecasts result of this study is the one outputted by the forecast made with the MMSE method and with only one variable (the Brent oil, obviously) conditioned to reflect the increase in oil price coming with the policy. As seen in chapter 3.6 the mentioned forecast is 5% under the expectation. This study gives the opportunity to the business world to develop time series analysis models to understand better the variables impact to their commodity prices. Instead, for the academic side this study provides a quantitative analysis of the change in freight rates due to the IMO 2020.

4.2 Limitations of this study

One of the biggest limitations of this study is that it is not about a single freight. In fact, by definition, Harpex index is a composed index computed with different freight rates corresponding to different routes. This can be misleading since the impact of oil surcharges will be different among different routes since different routes uses different amount of fuel. Another factor that this study is not taking into account is the readiness of the industry with respect to this policy, in fact the model developed assumes that the only change will be the price of the fuel but it does not take into account that it is not just a matter of an higher price but the policy involves different other aspects such as, for example, providing the ships with the equipments to run with this new fuel, or even providing shipping companies with trained experts able to run and to set up the ships in the optimal way. Another aspect is that, implicitly, this study assumes that the fuel consumption will remain constant and will not vary using new types of fuel. Furthermore, other issues can be brought from the fuel supply side, in fact producing in large scale low sulphur fuel is not trivial and a large increase in demand can produce some problem that may affect quality of the fuel or its supply chain.

4.3 Further studies

This work con bring with it different clues for further studies. The first one can be to perform a similar analysis but considering only a single routes, in this way the limitation due to the fact that this study consider the Harpex index, which is an aggregation of freight rates, disappears. As said discussing the limitations, this study lacks in evaluation the operational impact on the shipping industry derived from the IMO 2020. A possible study could try to take into account also the investment on new technology that shipping companies have to make in order to be compliant with the new policy and on the basis of that calculate a the impact on the freight rates. Furthermore, a nice evolution can be to wait for Jan 2020 and to observe the real increase in bunker price and, on the basis of the real observed increase, it can be very interesting to repeat a like-herein-before analysis, meaning a a VAR(p) model and a MMSE-based forecast, and also to keep observed freight rates evolution. In this way a real observation versus model forecast comparison can be traced. Doing this an improved calibration of the model can be provided. Moreover, on the basis of this study, some model tracking the influences of variables on commodity prices, con be provided to help industry to better predict the impact of possible future policy.

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Appendix A

Matlab code

```
load('tesi_BAASE.mat')
TTbaltic = table2timetable(baltic);
TTharpex = table2timetable(harpex);
TTbrent = table2timetable(brent);
TTharpex = removevars(TTharpex, {'VarName2','TEU700','TEU1100
    ','TEU1700','TEU2700','TEU3500','TEU4250','TEU6500','
    TEU8500'});
TTbaltic = removevars(TTbaltic, {'Open','High','Low','Vol','
    Change'});
TTData = synchronize(TTharpex,TTbrent,TTbaltic,'weekly','mean
    ');
TTData=TTData(~any(ismissing(TTData),2),:);
TTData.Properties.VariableNames{3} = 'baltic';
TTData.Properties.VariableNames{2} = 'brent';
TTData.Properties.VariableNames{1} = 'harpex';
figure
subplot(3,1,1)
```

```
plot(TTData.Date,TTData.baltic,'r');
title('Baltic')
grid on
subplot(3,1,2);
plot(TTData.Date,TTData.harpex,'b');
title('Harpex')
grid on
subplot(3,1,3);
plot(TTData.Date,TTData.brent,'k')
title('Brent Oil')
grid on
difbaltic = diff(TTData.baltic);
difharpex = diff(TTData.harpex);
difbrent = diff(TTData.brent);
DataDiff = array2timetable([difbaltic difharpex difbrent],...
    'RowTimes',TTData.Date(2:end),'VariableNames',{'baltic' 'harpex' 'brent'});
figure
subplot(3,1,1)
plot(DataDiff.Time,DataDiff.baltic,'r');
title('baltic')
grid on
subplot(3,1,2);
plot(DataDiff.Time,DataDiff.harpex,'b');
title('harpex')
grid on
subplot(3,1,3);
plot(DataDiff.Time,DataDiff.brent,'k'),
title('Brent Oil')
grid on
idx = all(~ismissing(DataDiff),2);
DataDiff = DataDiff(idx,:);
numseries = 3;
```

```
dnan = diag(nan(numseries,1));
seriesnames = {'baltic','harpex','brent'};
VAR2diag = varm('AR',{dnan dnan},'SeriesNames',seriesnames);
VAR2full = varm(numseries,2);
VAR2full.SeriesNames = seriesnames;
idxPre = 1:4;
T = ceil(.9*size(DataDiff,1));
idxEst = 5:T;
idxF = (T+1):size(DataDiff,1);
fh = numel(idxF);
[EstMdl2,EstSE2,logL2,E2] = estimate(VAR2full,DataDiff{idxEst,:},...
    'Y0',DataDiff{idxPre,:});
[FY2,FYCov2] = forecast(EstMdl2,fh,DataDiff{idxEst,:});
extractMSE = @(x)diag(x)';
MSE = cellfun(extractMSE,FYCov2,'UniformOutput',false);
SE = sqrt(cell2mat(MSE));
YFI = zeros(fh,EstMdl4.NumSeries,2);
YFI(:,:,1) = FY2 - 2*SE;
YFI(:,:,2) = FY2 + 2*SE;
figure;
for j = 1:EstMdl2.NumSeries
    subplot(3,1,j);
    h1 = plot(DataDiff.Time((end-49):end),DataDiff{(end-49):end,j});
    hold on;
    h2 = plot(DataDiff.Time(idxF),FY2(:,j));
    h3 = plot(DataDiff.Time(idxF),YFI(:,j,1),'k--');
    plot(DataDiff.Time(idxF),YFI(:,j,2),'k--');
    title(EstMdl2.SeriesNames{j});
    h = gca;
    fill([DataDiff.Time(idxF(1)) h.XLim([2 2]) DataDiff.Time(idxF(1))],...
```

```
            h.YLim([1 1 2 2]),'k','FaceAlpha',0.1,'EdgeColor','none');
        legend([h1 h2 h3],'True','Forecast','95% Forecast interval',...
            'Location','northwest')
        hold off;
end
[YPred,YCov] = forecast(EstMdl2,30,DataDiff{idxF,:});
YFirst = TTData(idx,{'baltic' 'harpex' 'brent'});
EndPt = YFirst{end,:};
YPred = [EndPt; YPred];
YPred(:,1:3) = cumsum(YPred(:,1:3));
fdates = dateshift(YFirst.Date(end),'end','week',0:30);
figure
for j = 1:EstMdl2.NumSeries
        subplot(3,1,j)
        plot(fdates,YPred(:,j),'--b')
        hold on
        plot(YFirst.Date,YFirst{:,j},'k')
        grid on
        title(EstMdl2.SeriesNames{j})
        h = gca;
        fill([fdates(1) h.XLim([2 2]) fdates(1)],h.YLim([1 1 2 2]),'k',...
            'FaceAlpha',0.1,'EdgeColor','none');
        hold off
end
Oil = [70 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
Baltic = [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
NF = [Baltic' nan(30,1) Oil'];
[YPred,YCov] = forecast(EstMdl2,30,DataDiff{idxF,:},'YF',NF);
```

```
YFirst = TTData(idx,{'baltic' 'harpex' 'brent'});
EndPt = YFirst{end,:};
YPred = [EndPt; YPred];
YPred(:,1:3) = cumsum(YPred(:,1:3));
fdates = dateshift(YFirst.Date(end),'end','week',0:30);
figure
for j = 1:EstMdl2.NumSeries
    subplot(3,1,j)
    plot(fdates,YPred(:,j),'--b')
    hold on
    plot(YFirst.Date,YFirst{:,j},'k')
    grid on
    title(EstMdl2.SeriesNames{j})
    h = gca;
    fill([fdates(1) h.XLim([2 2]) fdates(1)],h.YLim([1 1 2 2]),'k',...
        'FaceAlpha',0.1,'EdgeColor','none');
    hold off
end
numpaths = 1000
Oil = [70 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
Baltic = [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
NF = [nan(30,1) nan(30,1) Oil']; %sbagliata
N = simulate(EstMdl4,30,'Y0',DataDiff.Variables,'NumPaths',numpaths,'YF',NF);
MCForecast = mean(N,3)
C = cumsum(N(:,2,:))+9100
YFirst = TTData(idx,{'baltic' 'harpex' 'brent'});
EndPt = YFirst{end,:};
YPred2 = [EndPt; MCForecast];
YPred2(:,1:3) = cumsum(YPred2(:,1:3));
```

```
fdates = dateshift(YFirst.Date(end),'end','week',0:30);
for j = 1:EstMdl2.NumSeries
    subplot(3,1,j)
    plot(fdates,YPred2(:,j),'--b')
    hold on
    plot(YFirst.Date,YFirst{:,j},'k')
    grid on
    title(EstMdl2.SeriesNames{j})
    h = gca;
    fill([fdates(1) h.XLim([2 2]) fdates(1)],h.YLim([1 1 2 2]),'k',...
        'FaceAlpha',0.1,'EdgeColor','none');
    hold off
end
for j = 2:2
    subplot(3,1,j)
    plot(fdates,YPred2(:,j),'--b')
    hold on
    plot(YFirst.Date,YFirst{:,j},'k')
    for k = 1:5
    plot(fdates(1:30),C(:,:,k))
    hold on
    end
    grid on
    title(EstMdl2.SeriesNames{j})
    h = gca;
    fill([fdates(1) h.XLim([2 2]) fdates(1)],h.YLim([1 1 2 2]),'k',...
        'FaceAlpha',0.1,'EdgeColor','none');
    hold off
end
```

Appendix B

Model Summary

```
summarize(Model)

  AR-Stationary 3-Dimensional VAR(2) Model

    Effective Sample Size: 136
    Number of Estimated Parameters: 21
    LogLikelihood: -1998.05
    AIC: 4038.09
    BIC: 4099.26

                       Value      StandardError    TStatistic      PValue
                     ----------   -------------    ----------    ----------

    Constant(1)        1.0902        6.8788          0.15848        0.87408
```

```
    Constant(2)          15.266          20.796         0.73408      0.4629
    Constant(3)        0.014851         0.15765        0.094204     0.92495
    AR{1}(1,1)          0.51238        0.087504          5.8555  4.7556e-09
    AR{1}(2,1)        -0.076944         0.26455        -0.29085     0.77116
    AR{1}(3,1)       0.00013747       0.0020054        0.068549     0.94535
    AR{1}(1,2)        -0.039444        0.028255          -1.396     0.16273
    AR{1}(2,2)           0.2309        0.085424           2.703   0.0068709
    AR{1}(3,2)        0.0016192      0.00064755          2.5005      0.0124
    AR{1}(1,3)          -6.9715          3.7497         -1.8592    0.062995
    AR{1}(2,3)          0.36221          11.336        0.031952     0.97451
    AR{1}(3,3)          0.38649        0.085934          4.4975  6.8742e-06
    AR{2}(1,1)         -0.20627        0.086357         -2.3886    0.016912
    AR{2}(2,1)           0.4861         0.26108          1.8619     0.06262
    AR{2}(3,1)       0.00011421       0.0019791        0.057708     0.95398
    AR{2}(1,2)         0.032224        0.029232          1.1024      0.2703
    AR{2}(2,2)         0.027201        0.088375         0.30779     0.75824
    AR{2}(3,2)       0.00014408      0.00066992         0.21507
```

```
                 0.82971
   AR{2}(1,3)           -1.2358            3.6914          -0.33478
                 0.73779
   AR{2}(2,3)           -9.2477             11.16          -0.82864
                 0.40731
   AR{2}(3,3)          -0.16996          0.084599           -2.0089
                0.044543



  Innovations Covariance Matrix:
  1.0e+04 *

    0.6347    0.2927    0.0025
    0.2927    5.8013    0.0041
    0.0025    0.0041    0.0003


  Innovations Correlation Matrix:
    1.0000    0.1525    0.1734
    0.1525    1.0000    0.0937
    0.1734    0.0937    1.0000
```