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Comparative feasibility analysis of the Sales and Purchase market of new-building and second-hand crude carriers

by

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Finally, I dedicate the thesis to my parents.

Abstract

The newbuilding and second-hand markets of crude carriers are the most significant markets in shipping. Their activities are affected by various factors and shipowners have to decide whether to buy newbuilding or second-hand vessels. These decisions are based on the examination of the current market's situation and are usually subject to alterations. Modelling the factors, that affect the newbuilding and second-hand prices will help us conclude to the best option, according to the results. This thesis focuses on the research of the factors that affect the newbuilding and second-hand prices for VLCC-ULCC, Suezmax and Aframax tankers.

Our study begins with the introduction to the topic and a brief analysis of the shipping industry follows. An academic literature review of relevant studies is demonstrated, which help us define the appropriate variables for our models. On the remainder, we choose the variables according to the available data in time series and construct the models for newbuilding and second-hand prices. Our models are being tested for stationarity and cointegration with the Augmented Dickey Fuller and the Johansen Cointegration tests respectively. All variables are stationary to their first differences and cointegration equations exist. Least squares regression method is being applied, and the statistically significant variables of every vessel type on both markets are being demonstrated. We test for the best ARMA model, and ARCH tests are applied in order to define whether or not there is ARCH effect in our models. If they depict ARCH effect, we estimate the ARCH, GARCH and E-GARCH models and conclude that newbuilding prices for VLCC-ULCC and Suezmax tankers, as well as second-hand prices for VLCC-ULCC crude carriers are vulnerable to external shocks and previous asymmetric effects. A comparison based on their lowest AIC is done and the conclusion is that E-GARCH is the most suitable model in all three cases. For these categories we estimate the VAR model, and the significant variables of previous periods that affect the dependent variables of every model are being defined. For the rest categories that do not illustrate ARCH effect, VEC model is estimated. Short run and long run causality arises from our variables to newbuilding prices for Aframax tankers and second-hand prices for Suezmax and Aframax crude carriers. However, according to the diagnostic tests, the VEC model for second-hand prices of Suezmax tankers is not valid.

This analysis can be used from shipowners and investors as a good tool in order to decide whether they want to invest in newbuilding or second-hand crude carriers. In addition, buyers of second-hand ships can forecast the second-hand prices of the crude tankers and detect the appropriate time to buy the vessels.

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List of Abbreviations

UNCTAD	United Nations Conference on Trade and Development
RO-RO	Roll On-Roll Off
DWT	Dead Weight Tonnage
VLCC	Very Large Crude Carriers
ULCC	Ultra Large Crude Carriers
S & P	Sale & Purchase
ARMA	Autoregressive Moving Average
ARCH	Autoregressive Conditional Heteroscedasticity
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
E-GARCH	Exponential-Generalized Autoregressive Conditional Heterosced.
VAR	Vector Autoregressive
MDO	Marine Diesel Oil
HFO	Heavy Fuel Oil
IFO	Intermediate Fuel Oil
IMO	International Maritime Organization
OPA	Oil Pollution Act
US	United States
LIBOR	London Interbank Offered Rate
GDP	Gross Domestic Product
OECD	Organization for Economic Cooperation and Development
ADF	Augmented Dickey Fuller
VAR	Vector Autoregressive
AIC	Akaike Information Criterion
SIC	Schwarz Information Criterion
JC	Johansen Cointegration
VEC	Vector Error Correction
ARIMA	Autoregressive Integrated Moving Average
HQ	Hannan-Quinn

Chapter 1 Introduction

1.1 Introduction

Seen as one of the most important drivers of globalization, the shipping industry is a fascinating business which grew remarkably in the last six decades. According to UNCTAD (United Nations Conference on Trade and Development), maritime transportation carries approximately the 90% of the global trade, since it is considered to be the cheapest way of transportation. The total number of commercial ships increased by 6,000 since 2011, and it is continuously increasing, as we can observe in figure 1. In the past, all ships were constructed as general cargo ships but nowadays ships have been specialized with respect to the cargo which they carried. Thus, the global fleet constitutes from liquid and dry bulk vessels, containers, reefers, chemical tankers, Roll On-Roll Off (RO-RO), project vessels, conventional general cargo vessels, ferries and other more specialized categories.

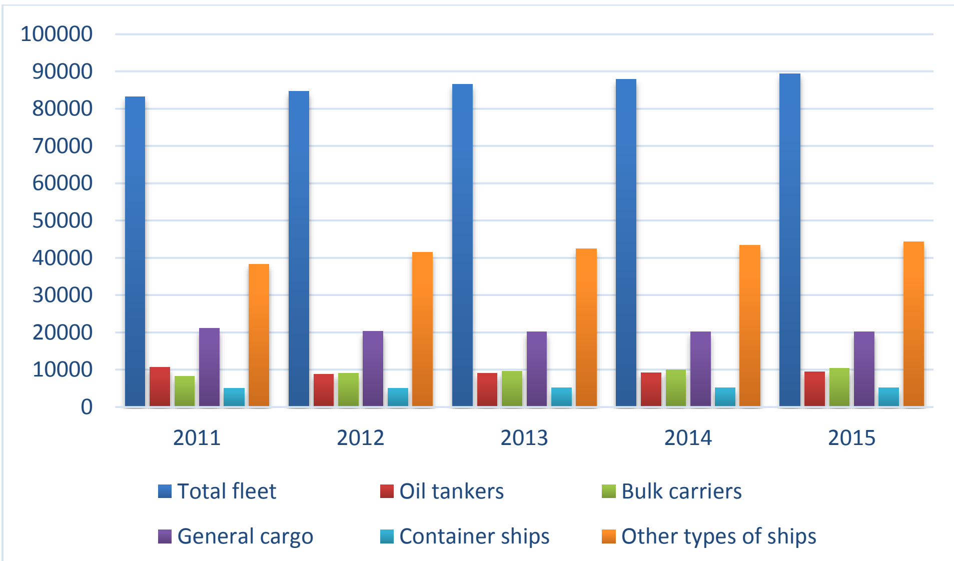


Figure 1: Number of ships by category, from 2011 to 2015
Source: Compiled by author via UNCTAD

Crude and product tankers are the two basic types of oil tankers, designed for the bulk transport of oil. The crude oil market (unrefined crude oil) in which we will mainly focus, started its activities in 1859, when crude oil was first produced at Titusville, Pennsylvania (Stopford, 2009). Thereafter, for several years the oil was shipped in barrels to refineries until 1886, when Glückauf, a 2,307 tons purpose-built tanker was built, using the outer skin as the containment vessel and instigating many ship-owners to adopt this revolutionary design (Wijnolst et al., 2009). Supply and demand for oil has been increased over the years, and nowadays, crude tanker designs have been upgraded, to reach the mammoth capacity of more than 550,000 Dead Weight Tonnage (DWT) per Ultra Large Crude Carrier (ULCC).

Shipowners in order to respond to the fluctuations of supply and demand, usually want to increase their vessel capacity, thus they invest in vessels. Nevertheless, they face daily the dilemma of either investing in new-building or second-hand crude tankers (Merikas, Merika and Koutroubousis, 2008).

In the case where shipowners decide to buy a second-hand vessel, they refer to the Sales and Purchase (S & P) market, while if they decide to buy a new vessel they refer to the New-building market.

The S & P and the new-building market of crude tankers are by far the most upcoming markets in shipping. According to recent studies, there is an increasing trend in the number of new-building and second-hand crude tankers, which are being sold every year, and thus the same trend occurs at the transactions of this market. However, the decisions for either new-building or second-hand vessels do not come at random.

1.2 Research Objectives

Given the uncertainty that outlines the shipping investments, this study will examine their feasibility, based on different factors that affect the Sale and Purchase of new-building or second-hand crude tankers. The scope of this research is to prove how the Sales and Purchase market of new-building and second-hand crude tankers is affected by different factors, thus we will find which factors affect more and which less each market.

Shipowners are continuously looking for investment opportunities. If these opportunities are defined in time, they can lead to significant benefits to the investors. As a result, the main research question that this study aims to answer is posed as the following:

“Which factors affect the S & P of new-building and second-hand crude tanker vessels?”

The main idea behind this question is to understand and analyze the functions of the Sales and Purchase market of new-building and second-hand crude tankers. There are many significant variables, but not all of them have an impact in the market. To sufficiently answer the main research question a number of sub-questions must be answered:

1. *“How can we produce accurate estimations through an econometric model for the Sale & Purchase of new-building and second-hand crude tankers?”*

2. *“Which econometric model is more appropriate in our research”*

1.3 Research Design and Methodology

In order to answer the questions which mentioned above, both quantitative and qualitative methods will be applied. For the first sub-question, we will have to specify from the literature the different variables that may affect the Sales and Purchase market of new-building and second-hand crude tankers. Some of them will be freight rates, prices of new-building and second-hand crude tankers, technology, level of the economy and the orderbook of the each vessel type but inclusion also depends on data availability. Clarkson will be our main database and then we will check the variables for stationarity by applying the Augmented Dickey Fuller test. The models will be estimated, and Johansen Cointegration test will be conducted.

In order to answer the second sub-question, a number of models will be evaluated and assessed. Firstly, we will estimate the models with the least squares method and apply diagnostic tests. Then, we will further estimate ARMA (Autoregressive Moving Average), ARCH (Autoregressive Conditional Heteroscedasticity), GARCH (Generalized Autoregressive Conditional Heteroscedasticity), E-GARCH (Exponential Generalized Autoregressive Conditional Heteroscedasticity), VAR (Vector Autoregressive) and VEC (Vector Error Correction) models, and we will decide which model is the most appropriate to our research.

1.4 Thesis Structure

The thesis consists of six chapters and is structured as follow. The introduction demonstrates the general outlay, and rationalizes the selection of our topic.

In the second chapter, we aim to introduce the reader to the background of the shipping industry. The four shipping markets are analyzed and the shipping cycle is described. Additionally, the types and the management of risk in shipping is illustrated, and a brief presentation of the costs of a vessel is demonstrated. This chapter ends with the description of the crude tanker vessels types.

Chapter 3 includes a concise literature review of previous related studies. The academic literature contains previous researches regarding the tanker sector, as well as studies analyzing the functions of the newbuilding and second-hand markets.

The fourth chapter of the thesis details the methodology which will be applied. In addition, the data used together with the problems experienced from the data collection are described. Moreover, the variables are identified, and the models for the newbuilding and the second-hand markets are estimated. The tests for stationarity and cointegration are conducted to each model. Finally, the data is depicted in graphs both in level and first differences, and the descriptive statistics of all models are illustrated.

In the fifth chapter, the data analysis and the results are interpreted. The models for newbuilding and second-hand markets for every tanker vessel type are assessed followed by a number of diagnostic tests. Furthermore, we estimate the ARMA, ARCH, GARCH, E-GARCH, VAR and VEC models.

In chapter 7 we summarize the results of all the applied models per crude carrier type and per market. Moreover, we compare the models and based on the AIC we choose the most appropriate.

Chapter 8 concludes by summarizing the results of our research. In addition, recommendations for further researches are suggested.

On the remainder, the bibliography of all sources used is demonstrated, and the thesis ends with the appendices.

Chapter 2 Market Structure in the Shipping Industry

2.1 Introduction

The main responsibility of the maritime industry is to transport cargo from departure point A to its destination point B. This transportation constitutes only a part of the global supply chain, which has as ultimate objective to link supply and demand. The maritime transportation can be divided in three categories, based on the origin/destination patterns of cargo flows.

- *Deep sea shipping*: It includes ocean transportation to another continent.
- *Short sea shipping:* It is the transportation over shorter destinations. Smaller vessels are required and it is usually faster than deep sea shipping.
- *Inland transportation:* It covers the transportation over rivers, canals and rarely lakes (Case of Lake Victoria).

As reported by UNCTAD in 2013, the shipping industry was responsible for the transportation of approximately 9.5 billion tons of cargo all over the world. Figure 2 presents the percentage traded per type of cargo in 2013. At this point it should be stressed out, that the shipping market consists of a group of people, such as shipowners, shipbrokers, shipbuilders and bankers (Stopford, 2009).

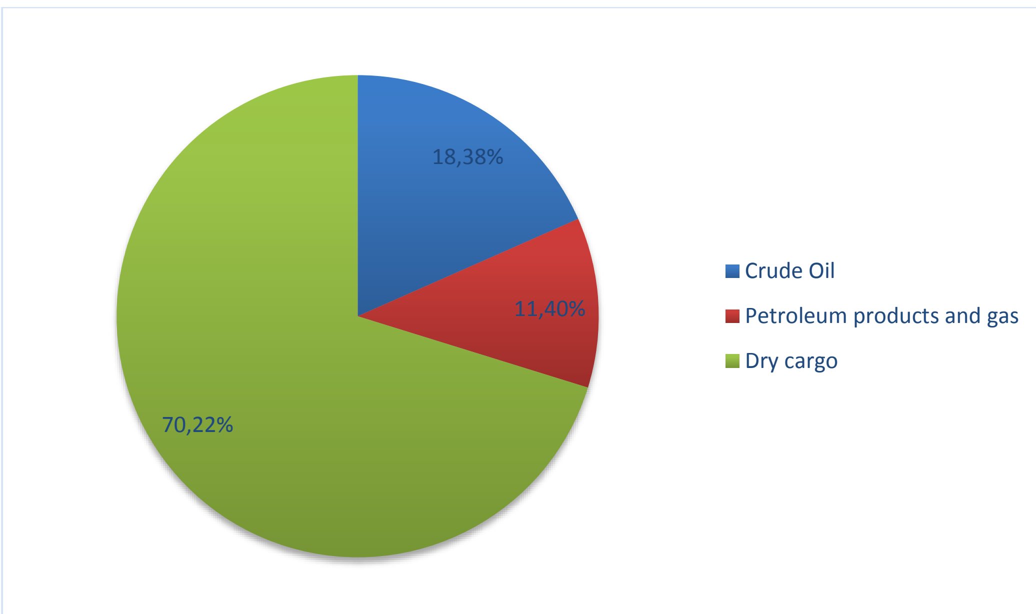


Figure 2: World seaborne trade by cargo type, 2013
Source: Compiled by author via UNCTAD

This chapter introduces us to the shipping industry. Firstly there will be a short description of the four shipping markets and continuous with the significance of the shipping cycle. The types of risk and the ways that a shipping industry deals with these are presented, following there an extensive explanation to the occurring costs of a vessel. This chapter ends with the presentation of the crude oil tankers, which will be used in this research and a short summary.

2.2 The Shipping Markets

Shipping companies, in order to survive and satisfy the changing requirements of their customers, need to continuously upgrade their services. Thus, according to Stopford (2009) they compete to the following factors:

- **Price**: Charter rates is a significant factor, but the price is determined together with costs. However, usually customers prefer a higher price, for the provision of better quality of transportation.

- **Speed**: Time in transit means inventory costs for shippers, who seek faster deliveries of their cargoes. Speed is also important for two more reasons. Firstly, seasonal products are preferable in a specific time of the year. Secondly, some products such as vegetables, fruits and meat are perishable, thus shorter delivery time would be beneficial for both shippers and buyers.

- **Reliability**: Delays are not pleasant for anyone, hence shippers are looking for reliable carriers with just on time deliveries.

- **Safety**: Charterers pay higher prices in order to ensure that the cargo will be transferred safely, and no loss or destruction will occur during the voyage.

Today, the shipping industry includes four different but closely linked markets. The freight market is responsible for the sea transport services while scrapping of old ships tales place in the demolition market. New ships are ordered and traded in the newbuilding market, whereas second-hand ships are traded in the Sales and Purchase market (Lun, Hilmola and Goulielmos, 2013). A short explanation of these markets is performed below.

2.2.1 The Freight Market

The freight market is responsible for freight revenues, which are the primary source of cash for shipping companies. Shipping firms make the decision to invest in trade volume, only when they foresee that future freight rates will rise. Nevertheless, if the investors choose to invest in capacity, the delivery of the new vessels may take some years to be fulfilled.

This market can be separated in two categories. The first category is the freight contract category, in which shippers agree to pay a fixed price per ton of cargo transported and leave the shipowner responsible for the transportation. The second category is the time charter, in which the vessel is hired per day, but the shipper takes over the management of the transportation (Stopford, 2009). If any of these two cases occurs, the vessel is said to be “fixed”. The parties engaged in this market are the shipowners, the charterers and the shipbrokers. The shipowner provides the vessel available for cargo transportation. The charterer has the cargo which needs to be transported. Finally, shipbrokers from both sides link the available ships with the available cargo, fit the day of transportation, check the amount to be paid and the expectations and needs of both charterers and shipowners. Rarely these activities can be executed without brokers, but usually more than one is needed to connect all the information. As a result, shipbrokers are gathered in shipping centers such as London, Singapore, New York and Piraeus (Stopford, 2009).

There are four types of contracts (Stopford, 2009):

i. **Voyage Charter**. In this case the charterer agrees to a fixed rate per metric ton of shipped cargo. The shipowner retains the nautical and commercial control of the ship, while the charterer is entitled to use the ship for a standard voyage from port of departure A to port of destination B.

ii. **Contract of Affreightment**. Popular for the dry bulk cargoes. This long term contract provides higher responsibility and efficiency to servicing the charterer. Considering that is liable for a series of voyages, the definite volume and exact time of transportation is not available in advance.

iii. **Time charter**. It is a contract for a fixed duration of time, and the price is usually on a daily rate. Shipowners retain the nautical control and charterers obtain the commercial control/risk over the ship. Furthermore, the owners are still responsible for fixed costs such as crew wages, insurance premiums, cost of ship maintenance and repair, while charterers pay only the variable costs such as bunker fuel and port costs.
Subcontracting is taking place for different reasons. First of all the shipper may need to have the commercial control of a ship but without acting as a shipowner. Moreover, time charter may be cheaper rather than buying new vessels, in the case where the subcontractor has a large fleet (economies of scale). Finally, the charterer by subcontracting the vessel, may act as a speculator when he expects a change in the market.

iv. **Bareboat charter**. This is a special kind of time charter and can be characterized as an investment for the shipowner. The time period is usually 10 to 20 years, during which the shipowner receives a fixed hire rate. Charterers obtain nautical and commercial control/risk over the ship, and pay all fixed and variable costs arising in ship operations. They also appoint and give instructions to the master, officers and crew. Usually in this case the shipowner is a financial institution and no maritime skills are required.

2.2.2 The Newbuilding Market

This market is positively connected with the freight market. Shipowners order new ships that may take 1 to 3 years to be delivered. These orders take place for various reasons. To begin with, shipowners may foresee increase in freight rates and thus they want to increase their capacity. Moreover, they order new vessels because they want to replace the old ships of their fleet with new ones. Another reason is that no suitable vessels of certain specifications and characteristics are available in the second-hand market (Stopford, 2009).

The negotiations with the shipyard may be complicated and usually brokers deal with these matters. If the investor has already a relationship with the shipyard, he may contact direct to speed up the negotiations, which are divided in 4 parts:

- Adjustment of price.
- Specification of the vessel.
- Terms and conditions of the agreement.
- The financing provided by the investor.

2.2.3 The Sale and Purchase Market

Newbuilding ships may require from 1 up to 3 years to be built as discussed earlier, however in the Sale and Purchase (S & P) market an investor can deploy a second-hand ship in much shorter time. If the freight rates have been skyrocketed, a shipowner considers the Sale and Purchase market as a good option to faster increase his shipping capacity and by extension his revenue (Goulielmos, 2009). This market also gives the ability to shipowners to exit the shipping industry, as they can sell their vessels and decrease their exit costs, or to reorganize their fleet in order to respond to the fluctuations of supply and demand (Strandenes, 2002). Additionally, another reason for shipowners to sell their vessels is that they may have a certain age replacing policy, or because they need cash to meet their daily commitments. Consequently, high freight rates increase the price of used vessels and low freight rates decrease the second-hand vessels' price respectively (Lun and Quaddus, 2009). Shipbrokers are instructed to find provisional buyers, and often several shipbroking offices offer the same vessels. The sale procedure of a ship in the S & P market has 5 phases which are:

1. Placing the ship in the S & P market.
2. Negotiations for price and conditions adjustment.
3. Memorandum of agreement.
4. Inspections by the buyer.
5. Finalizing the deal.

Selling vessels at the bottom of a shipping cycle will be a disaster for the seller, but will be beneficial for the buyer. Ship prices in this market can be influenced by freight rates, age of the vessel, inflation and future expectations (Stopford, 2009).

2.2.4 The Demolition Market

This recycling market deals with the scrapping of the old or obsolete vessels. The global shipping capacity can be determined by the activities of this market together with the newbuilding market (Strandenes, 2002). As stated by Knapp et al. (2008) an increase in scrap price leads to more vessels being scrapped. Moreover, high steel price, which results in high scrap price, in relation with negative future expectations and weak S & P market for selling the used vessels, will lead the shipowners to the recycling market. Specialized broker desks are available in almost every broking office. The most famous scrapyards are in the Far East countries such as India, Turkey and Pakistan.

2.3 The Shipping Cycle

Commercial shipping can be characterized as the epitome of the market economy. For this reason commercial shipping presents cycles (similar with the economic cycles) either with an upward trend (development) or with a downward trend (recession). Even if the shipping industry is closely related with the global economy, the shipping cycle is not necessarily correlated with the cyclicality of the global economy and the international trade. Upward cycles are marked with increase in freight rates and ship prices, while downward cycles are characterized by the opposite. Shipping cyclicality obey the law of supply and demand. Available cargoes are looking for available vessels in order to be transported (Scarci, 2007). Figure 3 below displays the different stages during a shipping cycle.

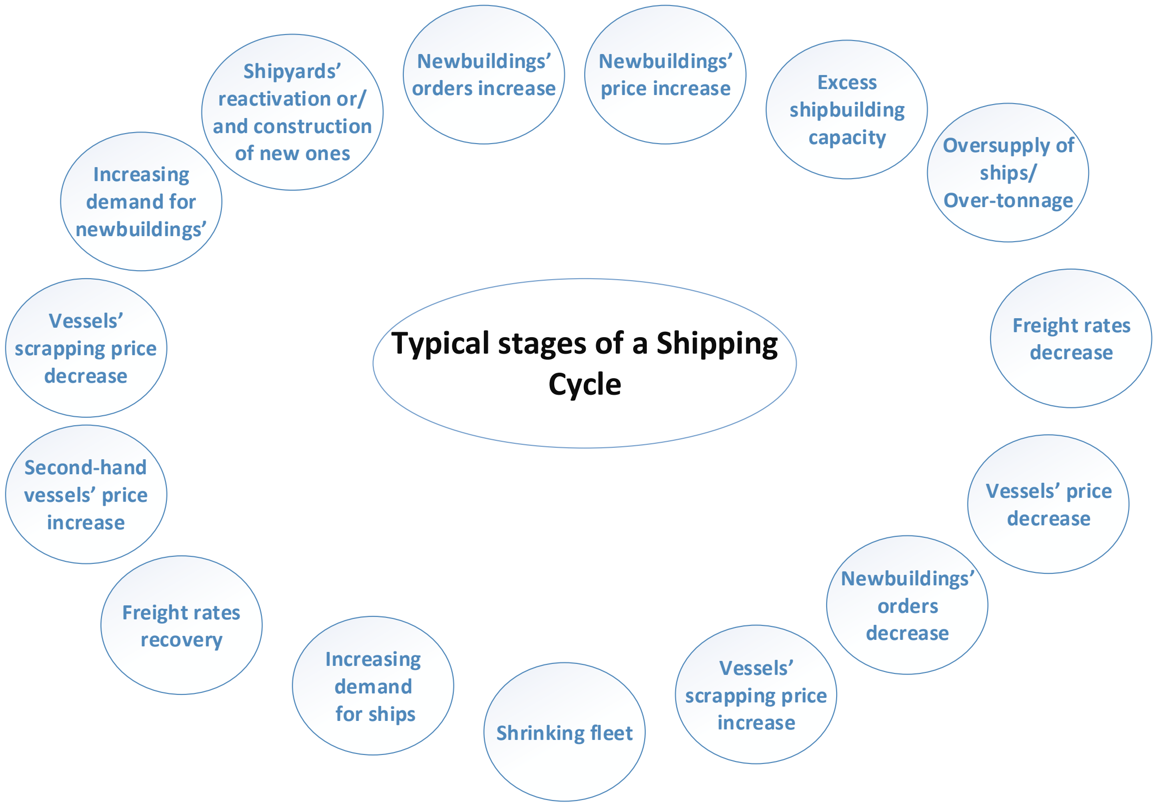


Figure 3: Typical stages of a Shipping Cycle
Source: Compiled by author from various sources

In other words shipping cycles are a reflection of supply and demand, and can be affected by different factors. If supply exceeds demand we have recession, and if supply is lower than demand we have a booming market. In case the shipping cycle is in growth, the shipping market looks very attractive, thus overconfidence is spread, which results shipowners to compete among themselves and invest in newbuildings in order to increase their capacity and therefore their revenue. These investments will create oversupply and decrease the freight rates (market declines). On the other hand, many shipowners invest in capacity during recession when vessel prices are very low, and this will benefit them during the rise of the shipping cycle. They can either sell their vessels in better price or take advantage of the increased freight rates and make profit.

As stated by Stopford (2009) three types of cycles exist:

- *Long term cycles or secular trends:* These cycles are affected by technological developments. They have a time horizon from 20 to 50 years. Such cycles occurred by the replacement of steam by diesel, from the containerization and other technical improvements.
- *Short-term cycles:* They are also known as business cycle, and they represent the most common category of shipping cycles. The time horizon of these cycles is approximately 8 years.
- *Seasonal cycles:* They are characterized by fluctuations within a year. For example the dry bulk sector is weak during the summer months, because there is a decrease in grain cargoes.

Shipping cycles are closely related to shipping risk, which is the determinant of liability for financial loss occurring from the inequality of supply and demand in shipping. The shipping cycles will never be the same, it is hard to be predicted and can be divided in 4 phases which are the following (Stopford, 2009) and are depicted in figure 4.

Phase 1: Trough. This phase is characterized by oversupply of shipping capacity. Shipyards are empty and freight rates drop below the operating costs, thus shipping companies find it hard to survive. Consequently, the price of old vessels becomes equal to their scrap price and shipowners are forced to scrap their ships or to sell them in distressed prices in order to recover.

Phase 2: Recovery. As total fleet capacity decreases, supply levels approach the levels of demand, and freight rates increase above operating costs. Confidence spreads in the market, and prices of second-hand vessels begin to increase as a result of liquidity.

Phase 3: Peak. Supply and demand are balanced in equilibrium. Freight rates increase three to ten times more than operating costs, and vessels are operating in full speed. The time horizon for this phase can vary from some weeks to some years, and relies upon the balance of supply and demand. Overconfidence predominates the market and because of high liquidity levels and revenues, second-hand vessel prices are skyrocketed, even above their relevant newbuilding cost. Second-hand vessels' transactions become without inspections, and newbuildings' orders are highly increased, resulting in delivery times that can exceed 4 years.

Phase 4: Collapse. The last phase of a shipping cycle. By the time newbuildings are delivered, supply exceeds demand and freight rates fall vertically. Vessels decrease their speed, and less appealing ships wait for cargo. Vessel transactions still occur, but at lower levels. Confusion pervades the market, and shipowners are unwilling to accept that the peak is over, and that they have to sell their vessels at discounted prices.

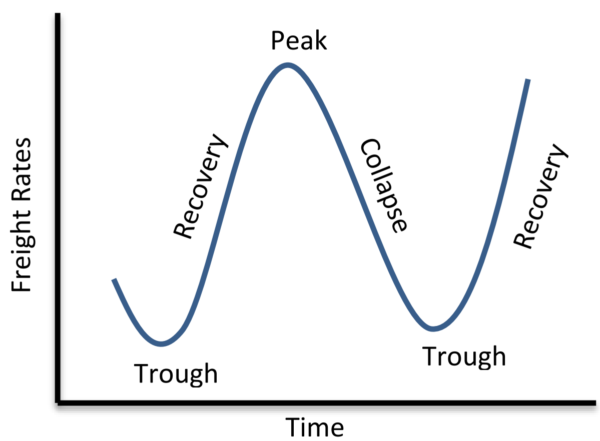


Figure 4: Phases of a Shipping Cycle
Source: Compiled by author

2.4 Types of Risk in Shipping

As reported by Stopford (2009), shipping industry's entrepreneurs are well known for taking risks. Irrational speculating activities, such as over-ordering of vessels, are mistakes repeated by every generation. However, shipping investors' risk choices differ from financial organizations', thus they appraise investments in another way. We discussed previously the cyclical fluctuations of the shipping industry. The risk based on fluctuations' magnitude and repetitiveness, affects the shipping firms' daily decisions (Cullinane, 1995).

The risks associated with shipping can be divided into three main categories (Harrington and Niehaus, 2004):

i. **Price Risk**. It expresses the uncertainty over the size of cash flows, because of changes in prices. It can be subdivided in the following categories:

   - *Freight-rate risk*. It is the risk that occurs from the volatility of the revenues of the shipping companies, due to changes to freight rates. This risk is considered to be the most significant in the shipping industry, since it determines the profitability of the company.
   - *Operating-cost risk.* On the other side, cost volatility is also an important factor that affects the profitability. Bunker costs account for more than 50% of the total voyage costs, thus fluctuations in bunker fuel prices have serious effects in shipping companies. The latter have to take preventative measures in order to decrease their exposure to these fluctuations.
   - *Interest-rate risk.* Derives from the exposure to interest rate fluctuations. Shipping is capital intensive, and vessels' transactions are financed up to 70% with loans. Changes in interest rates, may generate liquidity problems for the shipping companies.
   - *Currency risk.* The most commonly used currency in shipping is the US dollar. Nevertheless, several currencies are used globally. Changes in exchange rates may cause important losses during the conversion of freight income, or in situations where loans are taken in another currency but then are paid off in US dollars.
   - *Asset-price risk.* It arises from changes in the price of the assets of a shipping firm. The most important assets of a shipping firm are the vessels, thus fluctuations in their prices can affect both the balance sheet and the creditworthiness of the shipping company. Banks, shipowners and charterers observe these fluctuations of vessels' price, and use their observations in their lending and investment arrangements.

ii. **Credit Risk**. It is generally known as counterparty risk or debtor risk. It reflects the uncertainty whether debtor will fulfill their financial obligations towards the shipping company in total and without delay. This risk is created because in shipping many deals, trades and other transactions, are performed directly between the engaged parties and are based on their ability to adhere the agreement, which is not the case every time.

iii. **Pure risk**. It is also known as physical risk, and it is linked to physical damages, accidents, human errors, risk of collision, liability from oil spillage and other similar types of accidents that can negatively affect the value of the company's assets.

The risk-management process, which is used for all the types of risk presented above, has the following process as described Harrington and Niehaus (2004):

1. *Risk identification.* In this phase the loss vulnerability is identified, but first a complete understanding of the company and the factors that affect it, is required.
2. *Risk evaluation.* The exposure of the shipping firm to the risk type, needs to be quantified by checking the losses over a specific period of time. This phase helps managers to perform a cost-benefit analysis regarding the loss control.
3. *Risk management.* In this step the selection of the most suited tools in order to manage the risks is performed. Different types of risk may need different instruments.
4. *Risk monitoring.* The last phase of the risk-management process includes the monitoring of the performance and fitness of the third phase, on a continuous base. Because market dynamics fluctuate on an ongoing basis, the vulnerability of the shipping company may fluctuate in the same way. As a result, the shipping firm must be aware of these changes in order to manage the risks.

2.5 Costs and Expenses of a Vessel

A vessel must be consecutively properly equipped, capable and legitimate, in order to be able to transfer cargo without problems. It is required to meet all the global shipping regulations and this generates costs for the shipping company. In his book, Stopford (2009) divides the costs in five main categories, depicted in figure 5:

i. **Operating Costs.** Those are the daily expenses needed in order to run a vessel, without fuel, which is considered to be voyage cost. They constitute 14% of the total costs and can be divided as below:

- *Crew costs:* Are the costs generated by the crewing of the ship. The level of these costs varies depending on the number of the crew and the employment policies of the shipping company. Moreover, crew costs constitute more than 50% of the operating costs, and usually shipowners choose flags of convenience which have less restrictions in the employment regulations. Manning costs are also subdivided in direct and indirect costs.

  Direct costs include:
  - Wages and salary costs
  - Pensions
  - Training and union fees
  - Onboard victualing and repatriation costs
  - Social insurance
  - Travel and leave expenses

  Similarly, *indirect costs* include:
  - Crew agency expenses
  - Crew selection process
  - Bank fees
  - Crew costs at ports

- Social contribution
- Working allowances
- Accident prevention insurances
- Medical expenses

- *Stores and consumables:* Can be divided in general stores and engine room stores, such as the expensive lubricating oil.
- *Repairs and maintenance:* In case of damage, the vessel needs to be repaired, but also preventive maintenance takes place. The latter can be broken down in the following three subcategories:

  - *Routine maintenance*. It includes the maintenance of the main engine and the ancillary equipment, as well as the cleaning and the painting of the hull.
  - *Breakdowns*. Accidental failure of the equipment will arise extra costs.
  - *Spares*. Engine's and ancillary equipment's replacement parts.

- *Insurance:* All vessels have to be insured against all types of risk. More than 66% of these costs are occurring from the insurance of the hull and machinery.
- *General costs:* They include the flag's registration fees.

ii. **Periodic Maintenance**. This category's costs vary, depending on the age and the current condition of the vessel, but they are approximately 4% of the total costs. These costs include special surveys for checking the seaworthiness of the ship (every 4 years) and dry-docking (every 2 years).

iii. **Voyage Costs.** These costs represent the 40% of the total costs and can be divided in three categories:

- *Fuel/Bunker costs:* They account for almost 50% of the voyage costs, and are they are mainly influenced by the design and type of the main engine. The bunker price depends also on the type of fuel, which can be MDO (Marine Diesel Oil), HFO (Heavy Fuel Oil) and IFO (Intermediate Fuel Oil).
- *Port costs:* They vary depending on the port, but they mainly consist of port dues and service expenses, for example the captain's room at ports.
- *Canal dues:* Most canals such as Panama and Suez have dues that depend on the type of the vessel.

iv. **Cargo Handling Costs.** They are basically costs incurred from the stevedoring activities of the cargo, and an allowance for the cost of claims that may appear.

v. **Capital Costs.** They stand for the 42% of the total costs. These costs do not affect the operations of the vessel, and they compose the commitment to pay the shipyard, as well as the obligations to repay bank loans or equity investors periodically, who put the capital to purchase the vessel.

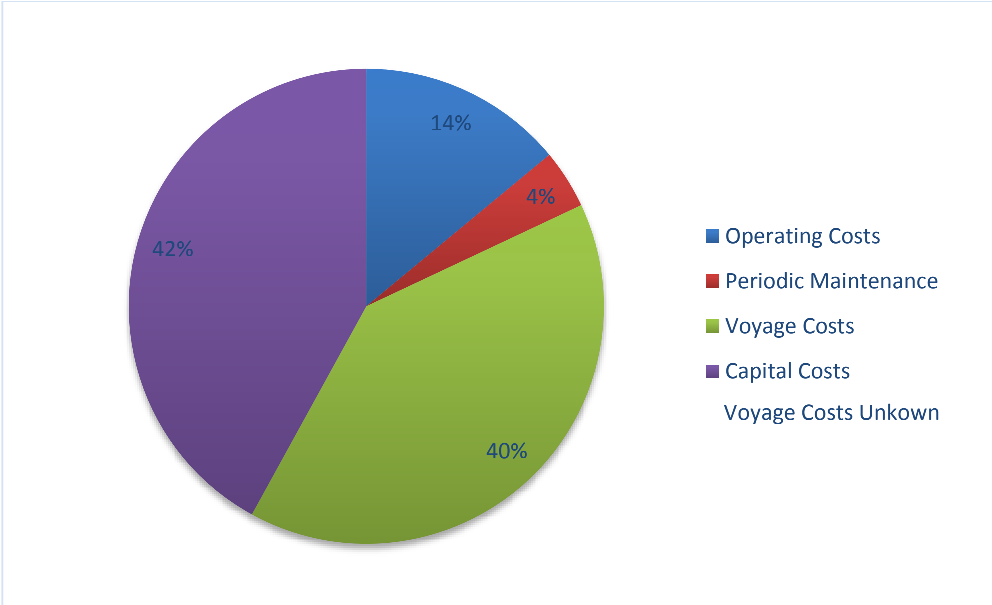


Figure 5: Costs of a vessel by category, excluding Voyage Costs
Source: Compiled by author via Stopford (2009)

2.6 Crude Oil Tanker Vessel Types

In the tanker market, clean attributes to product tankers, which carry diesel fuel, jet fuel and gasoline, while dirty refers to crude oil tankers transferring crude oil and black products. There are two shipbuilding designs for tankers, the single hull and the double hull. In 1993, the International Maritime Organization (IMO) regulation, that forced the double hull requirement in tankers, became effective, after proposed by the Oil Pollution Act of 1990 (OPA-90). Since then, oil accidents have been decreased dramatically and more than 90% of the existing tanker fleet consists of double hull tankers (Kim, 2002). Tankers have an economic life cycle of almost 30 years, thus in some years single hull tankers will not exist.

There are several types of tanker vessels but our research will be based only in crude oil tankers. According to Statista in January 1st 2014, there were globally 6,816 crude oil tankers that transported more than 1.8 billion metric tons of oil. They can be divided in five categories with a varied range from 60,000 Dead Weight Tonnage (DWT) to over 500,000 DWT. The categories are Panamax, Aframax, Suezmax, Very Large Crude Carriers (VLCC) and Ultra Large Crude Carriers (ULCC). Every category carries out its activities in different markets and has its own characteristics presented in table 1.

Panamax

Panamax vessels are ships that can pass through Panama Canal. They have displacement between 60,000 and 80,000 DWT and they are frequently used in short distances.

Aframax

The next category is the Aframax tankers with displacement from 80,000 to 120,000 DWT. They transfer cargo in medium and short distances and can be found in all regions. Because of their size, they operate in low crude oil production areas, or where restriction of draft and size occur.

Suezmax

Suezmax crude tankers are named after the Suez Canal and have a displacement from 120,000 to 200,000 DWT. Their size provides them with flexibility and access to the majority of the ports. Their main trading area is in the Atlantic Basin, transporting crude oil from the North Sea, West Africa and the former Soviet Union.

VLCC

VLCC's size is ranging from 200,000 to 320,000 DWT. They carry cargoes in long distances, usually from the Arabian Gulf to Western Europe, or via the Cape of Good Hope to the United States (US) and Asia.

ULCC

ULCC's displacement can exceed 500,000 DWT or more than four million barrels, and they are the largest operating vessels regarding crude oil transportation. They are generally known as supertankers and only specialized ports with the available depth can accommodate them. Their trading areas are Asia, North America and Europe from the Persian Gulf.

Table 1: Characteristics per Crude Oil Tanker category

Type	Size in DWT	Average Length Overall (LOA) in meters	Average Draft in meters	Average Beam in meters
Panamax	60,000 - 80,000	230	13.7	32.2
Aframax	80,000 - 120,000	250	14.8	44
Suezmax	120,000 - 200,000	274	17	47
VLCC	200,000 - 320,000	323	21	60
ULCC	320,000 - 500,000+	380	24.5	68

Source: Compiled by author from various sources

2.7 Summary

Taking everything into consideration, each of the four shipping markets is liable for different activities. The Newbuilding market is responsible for the orders of new vessels, while in the S & P market shipowners can sell their vessels and exit the market or increase their cash liquidity. Freight rates are negotiated in the Freight market, and the demolition of mainly old vessel takes place in the Demolition market. The cyclicality in shipping is a significant determinant and shipping companies must have in mind the different phases in order to consider their activities and increase their revenues. Furthermore, there are many types of risk and different categories of costs occurred in a vessel. Shipowners, must conduct an in depth analysis in order to manage the different types of risk, and estimate the complex expenses of a vessel. Finally, the five types of crude carriers are described in the last sub-chapter.

Chapter 3 Literature Review

3.1 Introduction

This chapter contains a brief description of previous studies and researches that can be linked to and help with our research. It mainly includes journal articles since 1985 and focuses in newbuilding and second-hand markets' affairs.

3.2 Literature Review

The newbuilding market was already been researched very early. From 1931, Tingerben analyzed his theory about this market. According to his theory, the newbuilding market is directly connected with the freight rate market. Moreover, he argues that another factor that affects the newbuilding prices is the time lag between the order and the delivery of the vessels.

Reliance on expectation is made because of the time lag between the order of a vessel and its delivery, which takes several years (Koopmans, 1939). Koopmans suggested that many times freight rates are determined directly from the oil refineries, because of the latter's monopsony. As a result, the production of oil is a critical determinant of freight rates. Hawdon (1978) also studied the newbuilding market. He concluded that steel prices are a significant indicator of the newbuilding vessels' prices.

Beenstock (1985) proved that shipyard competition, excess shipbuilding capacity and subsidies are the newbuildings' price drivers. Four years later, based on this design process, Beenstock and Vergottis (1989) used annual data from 1950 till 1986, and created an aggregate econometric model for the tanker and the dry bulk sector by assuming that investors have "rational expectations". They characterize the newbuilding market as a forward market for the reason that new existing vessels will have different prices from vessels of the same type that are just ordered in shipyards, because of their late delivery. Their model for newbuildings' prices is an occasion of asset pricing. They make the assumption that there is a perfect substitution between newbuilding and used ships, but this is not valid in reality because of the following reasons:

- Trading conditions, costs and risks differ as a consequence of timing.
- Their availability is in different time horizons.
- Newbuilding vessels can be traded for more years that second-hand vessels.
- Newbuilding vessels may be technologically improved.

In another research, Beenstock and Vergottis (1993) supported that newbuilding prices are determined by the orderbook and from the activities of the second-hand market. Many researchers disagree with this view, however shipping history verifies that these two markets fluctuate in the same direction.

For Jin (1993) shipbuilding capacity is defined as the quantity of labour and capital in the industry, while increasing shipbuilding capacity will lead to increasing supply. Nevertheless, the measurement of shipbuilding costs in world scale is not possible, since labour cost, shipbuilding materials and energy prices differ from country to country and among suppliers. In addition, he specified that technological improvements can negatively affect vessels' prices.

Glen in 1997 analyzes the efficiency of second-hand prices in dry and liquid cargo vessels, without resulting in a clear answer. This research is reviewing the study of Hale and Vanags (1992) by using the Johanssen approach and resulting in vigorous indications of cointegration in both market categories. One year later, Glen and Martin (1998) by applying a consistent GARCH model, verified the results of Kavussanos in 1996 (even if they used different model and data) that investments in bigger tanker vessels entail more risk, and that spot market is much more risky than a charter contract.

In his book/research "Quantitative analysis of shipping markets", Veenstra (1999) researches the second-hand vessel market, from the replacement perspective but he also investigates the speculating activities and the possible benefits that may occur from the S & P from future increase in the vessels' price. His research includes monthly data from tankers and dry bulk vessels, dividing them in two categories; five years old vessels depicting the replacement purpose and ten years old vessels representing the speculating activities. Time charter rates, newbuildings' prices and scrap prices are variables included in the models, which in their sum proved to be non-stationary. Moreover, the variables from all models in both categories, had a three cointegration equations relationship, in a set of four variables. In addition, he connects the above variables with the voyage charter rates, the orderbook, the trade flows and the second-hand vessel prices and produces a Vector Autoregressive (VAR) model that defines the relationship between second-hand vessel prices, voyage and time charter rates.

In their study, Alizadeh and Nomikos (2003) test the price-volume and volume-volatility relationship for used dry bulk vessels. They use different econometric models (regression analysis, Granger causality, E-GARCH model) and result that there is a considerable positive connection between price change and activities in the S & P market of dry bulk vessels. Moreover, they find out that negative forecast errors have bigger influence in dry bulk vessels' prices except for the Handysize category, and that price volatility and trading volume have negative relationship. A similar study which used the same methodology, and also included the tanker sector, was conducted in 2007 by Syriopoulos and Roumpis (2006). Regarding the dry bulk sector, they resulted in the same conclusion as the previous study, however in the tanker market the influence of volume on volatility was restricted.

Dikos and Marcus (2003) used as statistics for the second-hand vessels prices, the newbuildings' prices and the charter rates. They developed a model for the second-hand vessel price estimation, taking into account their Real option value. By introducing two descriptive variables, they collected equilibrium prices in a respective framework and contributed a fundamental insight that determines the second-hand vessel prices. They argued that since the S & P market of second-hand vessels does not rely in supply and demand patterns, should not exist in reality. Nevertheless, they pass by it stressing that it is the main driver of maritime economics and investments in shipping.

One year later Dikos (2004) performs an econometric research to find out if newbuildings' prices are inelastic to demand for new ships. This result is explained by the lack of volatility of the time charter rates in comparison with the lack of volatility in newbuilding vessels' prices. Furthermore, he investigates the competition of the newbuilding market, and concludes that there is a competitive equilibrium in the supply of newbuilding vessels.

Vessel prices were also researched by Haralambides et al. (2004). After upgrading their previous study which was only for second-hand vessels, they conducted a similar study to our research based on economic theory by establishing an econometric model to observe the behavior of the second-hand and newbuilding vessels' prices. They found that the price of second-hand vessels is mostly affected by the freight rates, but also from the newbuildings' prices. The capital is only important for the bulk carriers, while the orderbook has a negative relationship with the price of used ships in the tanker sector. Regarding the newbuilding vessels, they conclude that the main determinant affecting their price is the shipbuilding cost. In addition they found that freight rates affect only some categories and exchange rates create variations in cost rather than impacting in prices. In this case, orderbook stands as a mark for shipyard capacity, mainly in the tanker sector, signifying that shipyards are expanding basically for large vessels such as tankers. In the end, they mention that speculative activities and asset pricing can be characterized till a degree, as drivers of certain types of newbuilding vessels' prices.

Lun and Quaddus (2009) among others also investigated the dry bulk vessels' prices. They firstly characterize the newbuilding and second-hand markets as factor markets and the freight market as product market and then argue that the prices of both newbuilding and second-hand vessels do not affect the size of the fleet, but freight rates do. Newbuilding vessels' prices are slightly positively correlated with freight rates. Second-hand dry bulk vessels' prices are affected by both freight rates and newbuildings' prices. Finally, they perform a regression analysis for the prediction of the fleet, which is positively correlated with the trade by sea, indicating that if seaborne trade is increased, the shipowner has to modify his fleet size.

Knapp et al. (2008) made an unprecedented econometric research in 2008, and investigated how the demolition market reacts and affects the S & P market of vessels according to different variables through time. In their model they used data from the previous twenty nine years, including variables such as newbuildings' prices, revenue, second-hand and steel prices. They designated that an increase in revenue will decrease the probability of vessels being scrapped, while when scrap prices increase will result to bigger probabilities of ships being scrapped. This study, can be useful to our research, since it investigates the factors that affect the shipowners' decisions to either scrap or sale their vessels in the S & P market. Nevertheless, scrap prices are not treated to be a significant variable in our research that can affect S & P of second-hand vessels, since we will only use prices of five year old vessels, which will outlast for more than twenty years.

In their study, Alizadeh and Nomikos (2006) investigate the trading strategy in the tanker market. More specifically, they introduce a new technique for scheduling the investment and divestment decision by applying the relationship between price and revenue variables in all the tanker categories, and also arranging tactics to determine the right time to act in the S & P market of tankers. They generate a strategy by implementing the cointegration approach between vessels' prices and time charter rates, and moreover they adopt bootstrap technique for ascertainty reasons of their model. Finally, they conclude that there is possibility to schedule the investments in the tanker market because future vessels' prices can be identified up to a level, from the connection of price with earnings. This can be applied better in big tankers such as VLCC, as a result of the larger volatility for bigger vessels, giving the advantage to asset investors to schedule their activities and assisting them in their selection in the case which they integrate technical trading with crucial analysis.

Kavussanos (1997) conducts a research where he examines the monthly ship prices of Handysize, Panamax and Capesize bulk vessels, by applying the ARCH model and by adopting macroeconomic variables linked to shipping. His results indicate that after shortcoming and shocks, the volatility is high in the shipping industry. Panamax vessels are presented more stable in comparison with the other two categories in terms of volatility. Furthermore, Capesize vessels display the highest levels of volatility and Handysize the lowest. According to Kavussanos and Alizadeh (2002) the conditions that prevail in the oil market and the freight rates affect the sale and purchase of crude tankers. If the oil price increases, the freight rates of crude tankers are expected to increase. Kavussanos makes a similar research to this of 1997 in 2003 focusing in the tanker market. He concludes that time charter markets are less risky from spot markets, and bigger tanker vessels are much more volatile in terms of risk that smaller vessels. He suggests that by using smaller vessels, in markets where the big tanker operate that risk can be restricted.

A research with a different methodology was carried out by Merikas et al. (2008), where they model the investment decision of the entrepreneur to choose between newbuilding and second-hand tanker vessels. Their purpose is to introduce the ratio of second-hand over newbuilding prices, which should be the main determinant for the investment decision, and check its fluctuations. They use time series analysis and create an equations with variables such as time charter rates, volatility of the freight rates, crude oil prices and the level of LIBOR (London Interbank Offered Rate). In addition, they adopt relevant data from 1995 to 2006 in four tanker vessel categories (VLCC, Suezmax, Aframax and Handysize). In their conclusion, among the usefulness of the price ratio described previously, they argue that future expectations from the engaged parties together with the level of shipping cycle, demonstrate the movement of the price ratio and consequently affect the investment decision.

To conclude, the literature review contains studies and researches that focus in many aspects of the shipping market. More specifically, newbuildings price' drivers are presented, as well as the examination of the factors that affect both newbuilding and second-hand vessels' prices. Spot and time charter markets are compared, and result that the first is more risky. The same applies for the bigger tanker vessels such as VLCCs. A short reference on how scrap prices can affect the S & P market of second-hand vessels is also included. Moreover, newbuildings' prices are inelastic to demand for new ships, and speculating activities of vessels' transactions are always in effect. Finally, the variables that are discussed and have an impact in newbuilding and second-hand vessels' prices are the i) time charter rates; ii) Newbuildings' prices; iii) Second-hand vessels' prices; iv) Scrap prices; v) Orderbook; vi) Exchange rates; vii) Interest rates; viii) bunker fuel prices; ix) steel prices. We can see that there are many studies, but they mainly focus in dry bulk vessels and less in tanker vessels. Moreover, even if Haralambides et al. (2004) conducted a similar research, the data acquired is more than 10 years old. In addition, given that global recession is prevailing for many years, the shipping industry and by extension the investment decision of the shipowners have been affected substantially, thus our results will be different.

Chapter 4 Research Methodology and Data

4.1 Introduction

The methodology applied and the necessary data collected to perform our analysis and come to the conclusions of this research will be extensively described in this chapter. All our estimations will be conducted with the statistical packages EViews 9.0 and IBM SPSS Statistics. The chapter starts with the identification of the variables. An analysis of the data collection follows, together with the problems occurred from this procedure. Thirdly, the multiple regression models are specified and the descriptive statistics of the data are depicted. Furthermore, stationarity tests are conducted for both the newbuilding and second-hand markets for each vessel category. The Johansen Cointegration test is also applied. The chapter ends with the illustration of the data in graphs.

4.2 Variable Identification

The supply and demand of newbuilding and second-hand crude tanker vessels can be expressed by a set of variables. Specifically, supply and demand of newbuilding vessels is affected by time charter rates and spot rates as well as the orderbook as percentage of the fleet. Moreover, steel prices and production are significant for the newbuilding prices' specification, while second-hand vessel prices are also an important variable. In addition, crude oil prices and the global oil production have an impact in newbuilding and second-hand crude tankers' demand, since it is the only cargo that they can carry. GDP (Gross Domestic Product) and inflation are important determinants of the world's economic level and thus will be included together with LIBOR.

On the other hand, second-hand vessels' supply and demand are influenced by another group of variables. To begin with, newbuilding tankers' prices and freight rates are of great significance in the determination of the second-hand crude tankers' prices, and thus they affect the supply and demand patterns of these vessels. Furthermore, oil price and production are equally important as described above, while LIBOR has an impact on capital costs. GDP and inflation will be also included.

4.3 Data Collection

In order to be able to conduct our research, it is necessary to gather or convert large quantities of relevant data. The data used in this research, is mainly collected by the database Shipping Intelligence Network provided by Clarkson. Furthermore OECD (Organization for Economic Cooperation and Development) and UNCTAD are used in few cases. A comprehensive analysis of the different data used and of the problems occurred to carry out this research can be found below.

The sample time of our research will be constituted from 185 monthly observations particularly from January 2000 until May 2015. This time horizon includes the economic and financial crisis that begun in 2008, thus it is a representative sample regarding the progress of the newbuilding and second-hand markets and the length of the maritime crisis.

More specifically, we use the average time charter rates of 1 year for each crude tanker vessel category expressed in dollars per day. The second-hand vessels' prices are collected per category only for the 5 years old vessels. The newbuilding vessels' prices are referring to the average price per category that the shipowners have to pay in delivery of the vessel. Spot rates are expressing the average rates used worldwide divided in the vessels' categories. Moreover, we computed the orderbook as percentage of the fleet. For each category and for each time period we divided the number of crude vessels' orders with the total of their fleet.

Apart from the maritime variables, we also use economic variables. The oil prices are in dollars per barrel, while the oil production is defined in barrels per day for each monthly observation. Steel prices and steel production are also collected from Clarkson. The steel production is in tons while the steel prices of japan steel ship plates are expressed in dollars per ton. In addition, LIBOR is depicted as percentage per time period. Finally, inflation and GDP are collected from OECD, and only for the OECD countries. Inflation is expressed as percentage change of the same period of the previous year, while GDP is expressed as percentage change of the previous period.

4.3.1 Problems experienced with Data

Data collection is a difficult and time consuming procedure, thus usually problems arise. To begin with, one problem that we experienced while collecting the data, was that we could not find the desirable data for the Panamax crude tankers but only for the Panamax product tankers. As a result, we will not include this crude tanker vessel category in our research. Moreover, Clarkson has the same data for both the ULCC and VLCC vessels, and it considers these two categories as one. The fact that we found the GDP and the inflation only for the OECD countries can be also considered as a problem. Finally, we could not find the GDP in monthly observations but only in quarterly prices. We applied the same value for each month of every quarter. Taking everything into consideration, we conclude that the categories of crude tankers, which will be researched are the Aframax, the Suezmax and the VLCC-ULCC.

4.4 Model Specification

Different models will be specified for the newbuilding and second-hand markets of crude tanker vessels and the descriptive statistics of the data on levels will be presented. The Augmented Dickey Fuller test will be conducted to each model and each tanker category, in order to check the variables' stationarity.

4.4.1 The Newbuilding Model

Briefly from the literature review, Tingerben (1931) was the first who mentioned that the newbuilding market is affected by the freight market (time charter rates and spot rates). Koopmans (1939) mentioned the oil production as a significant factor, while Hawdon (1978) resulted that steel prices are an indicator of newbuilding vessels' prices. Few years later were Beenstock and Vergottis (1993) who argued that the orderbook and the activities of the second-hand market have also an impact in the newbuilding's prices. Jin (1993) indicated the technological improvements as a determinant of the price, while Dikos (2004), Lun and Quaddus (2009) and Kavussanos (2002; 2003) pointed out the significance of the freight rates for newbuildings' prices. Haralambides et al. (2005) based their research on the theory of supply and demand, indicating that newbuilding vessels' prices are established by second-hand prices and time charter rates.

In this research, the dependent variable that will be used for the assessment of the newbuilding market's model, will be the prices of the newbuilding crude tankers. The independent variables will be the spot and time charter rates of 1 year; the second-hand prices (regularly mentioned in the literature review), the GDP and the inflation of the OECD countries that depicts the global economy, the steel prices; the steel production; the LIBOR; the earnings; the oil prices and the oil production. The economic indicators GDP, LIBOR and inflation are important determinants of the economic level of each period. High inflation and LIBOR, may result in increased vessel prices. On the other hand, GDP may justify the amount of products seeking transfer thus may result in increased vessel prices due to higher demand for transfer. We could also use a dummy variable that will have the value 1 if there was technological improvement in the shipbuilding production, and 0 if there was not any significant technological change that could affect the newbuilding crude tanker price, in the reporting period, but this did not happened in our selected period from January 2000 to May 2015.

The descriptive statistics are important to help us describe and summarize the data. Tables with the descriptive statistics of the data on levels, of all models are compiled by author from EViews and are presented in Appendix 1. From the descriptive table we can point out the mean, the median, the minimum and the maximum values, which are considerable indications. Moreover, the standard deviation signifies how much the data deviates from the mean. Skewness and kurtosis are equally significant. The first reveals the asymmetry of each variable from the mean and can be positive, negative or undefined. On the other hand, kurtosis describes the distribution of data around the mean.

4.4.1.1 VLCC-ULCC

Time series most of the times are characterized by tendency that makes them integrated (nonstationary), because of the continuous increase or decrease of the variable's values. If the variables are nonstationary, then the estimators with the least squares method are inconsistent and thus the statistical tests will not be valid. In this case, the statistical results may be satisfactory, but this will be meaningless and the results will be false. Consequently, in order to check whether a unit root is present or not in our variables, we will conduct the Augmented Dickey Fuller (ADF) test, as defined by Dickey and Fuller (1979; 1981), with EViews 9.0. In the null hypothesis (H_0) there is no stationarity, while in the alternative hypothesis (H_1) stationarity exists. We have different data for each vessel category and for each model, thus we will carry out separate stationarity tests for every case. We set the significance level at 5%.

After conducting the Augmented Dickey Fuller test to find whether a unit root is present or not in our autoregressive model, it was found that at 5% significance level only spot rates, earnings, steel production and inflation were stationary. The stationarity test agrees with the maritime theory of previous studies that in extended samples the spot rates are stationary. Consequently, we convert all variables to their first differences in order to achieve stationarity. After the conversion, we can see that all variables are stationary with probability less than 5%, thus we can assess the model with the least squares method and perform the appropriate diagnostic tests.

Table 2: Model 1 ADF Test

	Levels		1st Difference	
Series	Probability	Stationarity	Probability	Stationarity
D(NEWBUILD_PRICES)	0.787	No	0.0034	Yes
D(SECOND_PRICES)	0.7907	No	0.0000	Yes
D(TIMECHARTER1)	0.1835	No	0.0000	Yes
D(SPOT)	0.0005	Yes	0.0000	Yes
D(ORDERBOOK)	0.8964	No	0.0000	Yes
D(EARNINGS)	0.0005	Yes	0.0000	Yes
D(STEEL_PROD)	0.0482	Yes	0.0107	Yes
D(STEEL_PRICE)	0.4875	No	0.0000	Yes
D(OIL_PROD)	0.0533	No	0.0000	Yes
D(OIL_PRICE)	0.2421	No	0.0000	Yes
D(LIBOR)	0.7069	No	0.0000	Yes
D(INFLATION)	0.0405	Yes	0.0000	Yes
D(GDP)	0.0685	No	0.0000	Yes

Source: Compiled by author from EViews

4.4.1.2 Suezmax

The same results occur for the Suezmax crude tankers. We convert the variables in their first differences in order to become stationary.

Table 3: Model 2 ADF Test

	Levels		1st Difference	
Series	Probability	Stationarity	Probability	Stationarity
D(NEWBUILD_PRICES)	0.6315	No	0.0026	Yes
D(SECOND_PRICES)	0.8512	No	0.0000	Yes
D(TIMECHARTER1)	0.2429	No	0.0000	Yes
D(SPOT)	0.0012	Yes	0.0000	Yes
D(ORDERBOOK)	0.7276	No	0.0000	Yes
D(EARNINGS)	0.0005	Yes	0.0000	Yes
D(STEEL_PROD)	0.0482	Yes	0.0107	Yes
D(STEEL_PRICE)	0.4875	No	0.0000	Yes
D(OIL_PROD)	0.0533	No	0.0000	Yes
D(OIL_PRICE)	0.2421	No	0.0000	Yes
D(LIBOR)	0.7069	No	0.0000	Yes
D(INFLATION)	0.0405	Yes	0.0000	Yes
D(GDP)	0.0685	No	0.0000	Yes

Source: Compiled by author from EViews

4.4.1.3 Aframax

Similarly, first differences were applied in the data of Aframax crude tankers to achieve stationarity.

Table 4: Model 3 ADF Test

	Levels		1st Difference	
Series	Probability	Stationarity	Probability	Stationarity
D(NEWBUILD_PRICES)	0.7168	No	0.0001	Yes
D(SECOND_PRICES)	0.8346	No	0.0000	Yes
D(TIMECHARTER1)	0.6248	No	0.0000	Yes
D(SPOT)	0.0009	Yes	0.0000	Yes
D(ORDERBOOK)	0.3823	No	0.0075	Yes
D(EARNINGS)	0.0005	Yes	0.0000	Yes
D(STEEL_PROD)	0.0482	Yes	0.0107	Yes
D(STEEL_PRICE)	0.4875	No	0.0000	Yes
D(OIL_PROD)	0.0533	No	0.0000	Yes
D(OIL_PRICE)	0.2421	No	0.0000	Yes
D(LIBOR)	0.7069	No	0.0000	Yes
D(INFLATION)	0.0405	Yes	0.0000	Yes
D(GDP)	0.0685	No	0.0000	Yes

Source: Compiled by author from EViews

In all three categories (VLCC-ULCC, Suezmax, Aframax) stationarity is obtained by converting the variables in their first differences. As a result, the newbuilding market model which will be estimated with the least squares method will be:

Dnewbuild_prices=a1Dsecond_prices+a2Dtimecharter1+a3Dspot+a4Dorderbook+
a5Dearnings+a6Dsteel_prod+a7Dsteel_price+a8Doil_prod+
a9Doil_price+a10Dlibor+a11Dinflation+ a12Dgdp

…where:

Dnewbuild_prices= the returns of the newbuilding vessels' prices in dollars
Dsecond_prices= the returns of the second-hand vessels' prices in dollars
Dtimecharter1= the returns of the average spot rates in dollars
Dspot= the returns of the average time charter rates of 1 year in dollars
Dorderbook= the returns of the orderbook as percentage of the fleet
Dearnings= the returns of the average earnings in dollars per day
Dsteel_prod= the returns of the world steel production in tons
Dsteel_price= the returns of the Japan steel ship plate in dollars per ton
Doil_prod= the returns of the global oil production in barrels per day
Doil_price= the returns of the crude oil prices in dollars per barrel
Dlibor= the returns of the LIBOR interest rates
Dinflation= the returns of the inflation as % change of the same period of previous year
Dgdp= the returns of the GDP as percentage change of the previous period

4.4.2 The Second-hand model

The second-hand market is analyzed in Chapter 2. Together with the newbuilding market constitute the most significant markets of the shipping industry. In the Sale and Purchase market the only participants are the shipowners. At first sight, this market seems easy to be analyzed, however this is not valid since it contains factors that are difficult to be measured, such as the shipowners' future expectations about the return on investments. Their decisions are connected with the current phase of the shipping cycle. For example, if they foresee a long time horizon of the collapse phase then they maybe postpone the purchases of second-hand vessels. For this reason, literature review presents previous studies that researched the variables that affect this market.

In brief, Beenstock (1985) argues that second-hand prices are affected by the global wealth, the fleet of each vessel category, the annual earnings, as well as the interest rates. He also stressed out that the second-hand market is inseparable with the newbuilding market, which was also supported by Strandenes (1986). Veenstra in 1999 designates that the second-hand prices are affected by the time charter rates and also the newbuilding prices. He also specifies that all variables are stationary at first differences. Time charter rates were mentioned by everyone as a determinant that has a crucial impact in the purchases of the vessels, especially in the tankers. Time chartering gives the possibility to the shipowner to compute his earnings and thus his investments.

The model for the second-hand market will contain as a dependent variable the second-hand crude vessels' prices and as independent variables the newbuilding's prices; the spot and time charter rates of 1 year; the LIBOR; the earnings; the GDP and the inflation; the oil production and the oil prices. We could also include scrap prices as an independent variable but since the second-hand vessels of our research are only 5 years old, they still have an economic life of more than 20 years.
We need to conduct the Augmented Dickey Fuller test, to check the stationarity of our variables and the existence or not of a unit root.

4.4.2.1 VLCC-ULCC

In the VLCC-ULCC category, we result that only spot rates, earnings and inflation are stationary in the tests of unit root in their levels. We then test for unit root in their first differences where it is ascertained that all variables are stationary.

Table 5: Model 4 ADF Test

	Levels		**1st Difference**	
Series	Probability	Stationarity	Probability	Stationarity
D(SECOND_PRICES)	0.7907	No	0.0000	Yes
D(NEWBUILD_PRICES)	0.787	No	0.0034	Yes
D(TIMECHARTER1)	0.1835	No	0.0000	Yes
D(SPOT)	0.0005	Yes	0.0000	Yes
D(ORDERBOOK)	0.8964	No	0.0000	Yes
D(EARNINGS)	0.0005	Yes	0.0000	Yes
D(OIL_PROD)	0.0533	No	0.0000	Yes
D(OIL_PRICE)	0.2421	No	0.0000	Yes
D(LIBOR)	0.7069	No	0.0000	Yes
D(INFLATION)	0.0405	Yes	0.0000	Yes
D(GDP)	0.0685	No	0.0000	Yes

Source: Compiled by author from EViews

4.4.2.2 Suezmax

After, the conduction of the ADF test in the Suezmax tankers, we found that all variables are stationary in their first differences.

Table 6: Model 5 ADF Test

	Levels		**1st Difference**	
Series	Probability	Stationarity	Probability	Stationarity
D(SECOND_PRICES)	0.8512	No	0.0000	Yes
D(NEWBUILD_PRICES)	0.6315	No	0.0026	Yes
D(TIMECHARTER1)	0.2429	No	0.0000	Yes
D(SPOT)	0.0012	Yes	0.0000	Yes
D(ORDERBOOK)	0.7276	No	0.0000	Yes
D(EARNINGS)	0.0005	Yes	0.0000	Yes
D(OIL_PROD)	0.0533	No	0.0000	Yes
D(OIL_PRICE)	0.2421	No	0.0000	Yes
D(LIBOR)	0.7069	No	0.0000	Yes
D(INFLATION)	0.0405	Yes	0.0000	Yes
D(GDP)	0.0685	No	0.0000	Yes

Source: Compiled by author from EViews

4.4.2.3 Aframax

In this category the results were similar with the previous two tests. Stationarity achieved after converting the variables in their first differences, something that can be also verified from the theory of Veenstra (1999) "It is unlikely that any of the maritime time series contains two unit roots (i.e. is I (2))".

Table 7: Model 6 ADF Test

	Levels		**1st Difference**	
Series	Probability	Stationarity	Probability	Stationarity
D(SECOND_PRICES)	0.8346	No	0.0000	Yes
D(NEWBUILD_PRICES)	0.7168	No	0.0001	Yes
D(TIMECHARTER1)	0.6248	No	0.0000	Yes
D(SPOT)	0.0009	Yes	0.0000	Yes
D(ORDERBOOK)	0.3823	No	0.0075	Yes
D(EARNINGS)	0.0005	Yes	0.0000	Yes
D(OIL_PROD)	0.0533	No	0.0000	Yes
D(OIL_PRICE)	0.2421	No	0.0000	Yes
D(LIBOR)	0.7069	No	0.0000	Yes
D(INFLATION)	0.0405	Yes	0.0000	Yes
D(GDP)	0.0685	No	0.0000	Yes

Source: Compiled by author from EViews

The final model for the evaluation will be:

Dsecond_prices=b1Dnewbuild_prices+b2Dtimecharter1+b3Dspot+b4Dorderbook+ b5Dearnings+b6Doil_prod+b7Doil_price+b8Dlibor+b9Dinflation+b10Dgdp

…where:

Dsecond_prices= the returns of the second-hand vessels' prices in dollars
Dnewbuild_prices= the returns of the newbuilding vessels' prices in dollars
Dtimecharter1= the returns of the average spot rates in dollars
Dspot= the returns of the average time charter rates of 1 year in dollars
Dorderbook= the returns of the orderbook as percentage of the fleet
Dearnings= the returns of the average earnings in dollars per day
Doil_prod= the returns of the global oil production in barrels per day
Doil_price= the returns of the crude oil prices in dollars per barrel
Dlibor= the returns of the LIBOR interest rates
Dinflation= the returns of the inflation as % change of the same period of previous year
Dgdp= the returns of the GDP as percentage change of the previous period

4.5 Testing for Cointegration

Cointegration of a group of non-stationary time series is indicated if there is a stationary linear combination of them. This linear combination which is characterized as cointegrating equation demonstrates that there is a long run equilibrium relationship in our time series. We will apply the Johansen Cointegration (JC) test (Johansen, 1991) using EViews 9.0, which will allow us to check if such relationships exist between our variables, and thus enables us to use them together in our models.
One of the weaknesses of the Johansen's Cointegration test is that the results are very sensitive to the lags chosen to run the model. As a result, the lag selection process is very important in order to run effectively the JC test.

First of all, we need to estimate the lags which we should include in the test. By estimating an unrestricted Vector Autoregressive (VAR) model with all our variables, we will proceed with the VAR lag order selection criteria. We will focus in AIC (Akaike Information Criterion) and SIC (Schwarz Information Criterion). We will choose the minimum value of AIC and SIC and note their respective lag numbers. If their minimum is in the same lags, then we select that lag. Otherwise, we can choose one among the two. In this case SIC signifies 1 lag and AIC signifies 8 lags. We will prefer SIC indication because the 1 lag seems more feasible. The results for each model, for both lag estimation and JC test are presented in Appendix 2.

4.5.1 The Newbuilding Market Models

The results signify that for the newbuilding market the cointegrating equations vary depending on the ship type. For the VLCC-ULCC vessels there are 4 equations, while for the Suezmax category 3 relations. Finally, the JC test reveals 6 cointegrating relations for the Aframax vessels. These results allow us to estimate them. For every tanker category the null hypothesis (no cointegration) is rejected at 5% significance level. This means that our variables have cointegration and can be further estimated.

4.5.2 The Second-hand Market Models

In the second-hand market, the results also differ for every vessel category. Specifically, the VLCC-ULCC and the Suezmax categories indicate 3 cointegrating equations at 5% significance level. However, the cointegration test for the Aframax crude carriers displays 6 cointegrating equations at the same significance level. The results point out that cointegration exists between our variables since the null hypothesis is rejected.

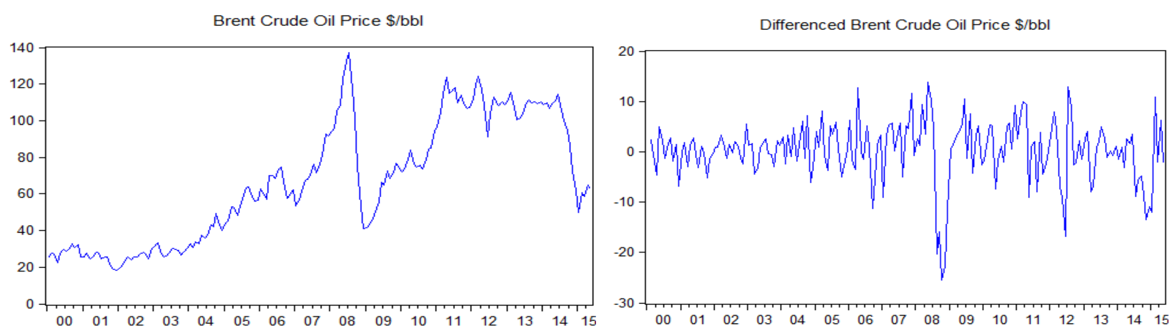
4.6 Data Presentation

In this subchapter, the data observations will be graphically depicted in their normal levels and in their first differences which is the subject of study of this research. Firstly, we will present the graphs of the economic indicators and commodity prices and then the variables' graphs per vessel type. All graphs are compiled by author from EViews 9.0.

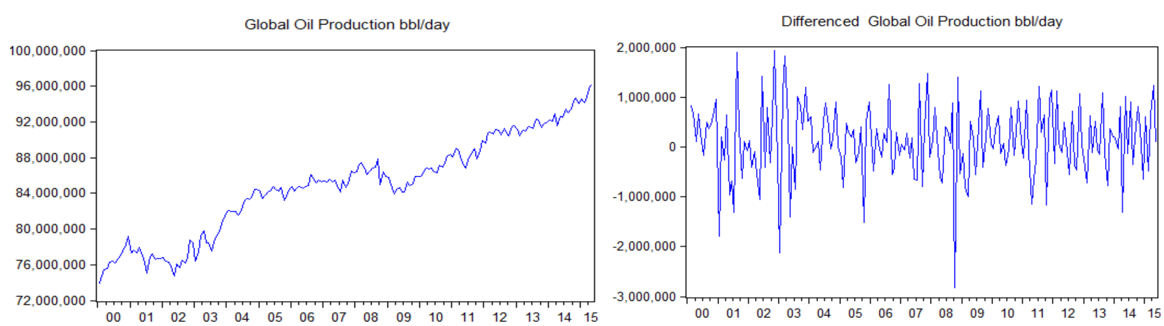
4.6.1 Economic Indicators and Commodity Prices

Some variables have the same values in all 6 models, thus their values do not change when we convert them to their first differences. These variables are the oil prices; the oil production; the steel prices; the steel production; the inflation; the GDP and the LIBOR. Their graphs are presented below in their levels and their first differences.

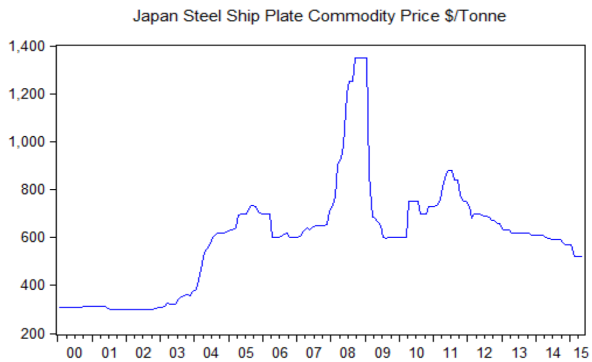
4.6.1.1 Oil prices

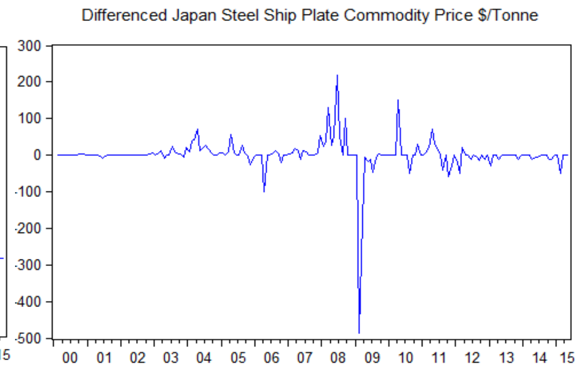


4.6.1.2 Oil production

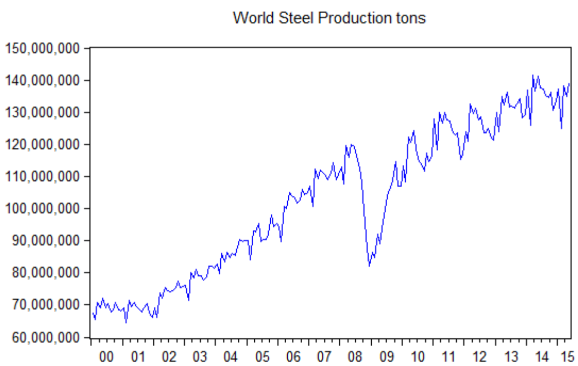


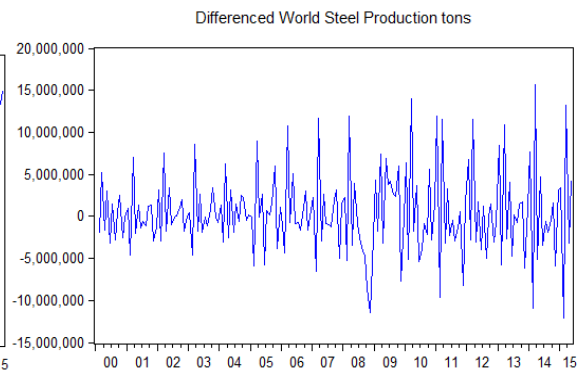
4.6.1.3 Steel prices



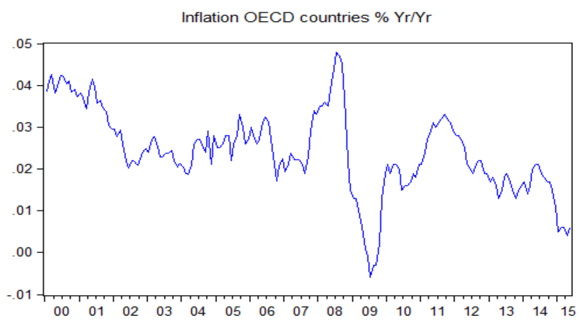


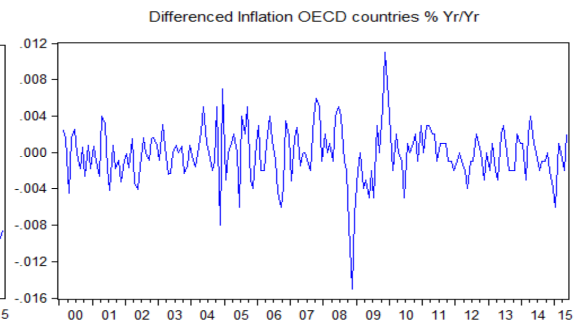
4.6.1.4 Steel production



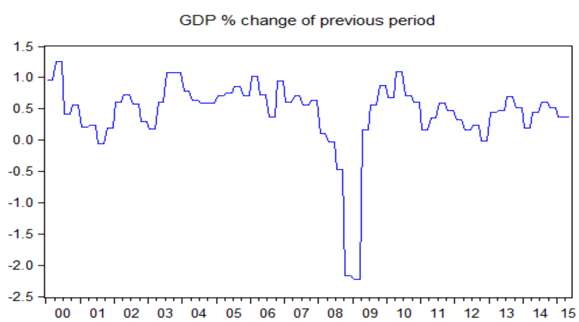


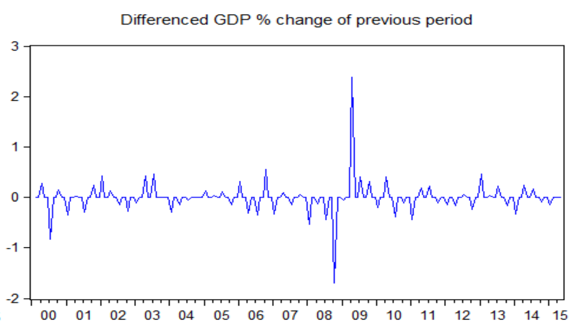
4.6.1.5 Inflation



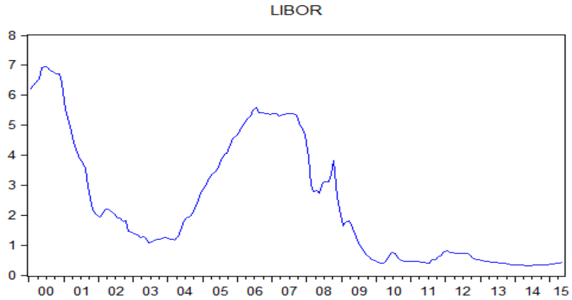


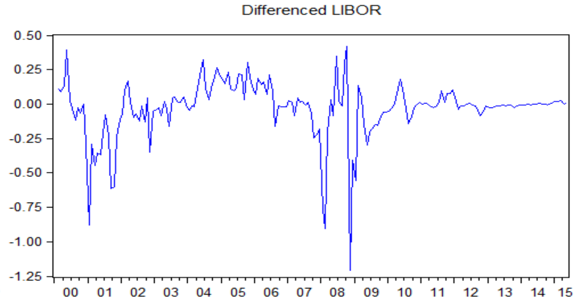
4.6.1.6 GDP





4.6.1.7 LIBOR

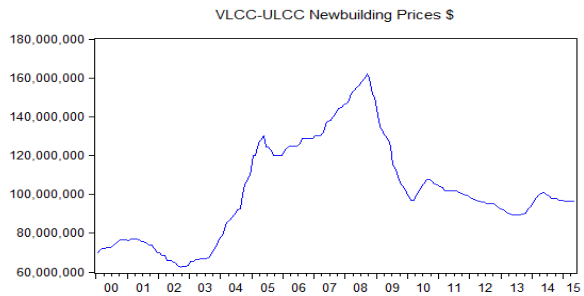


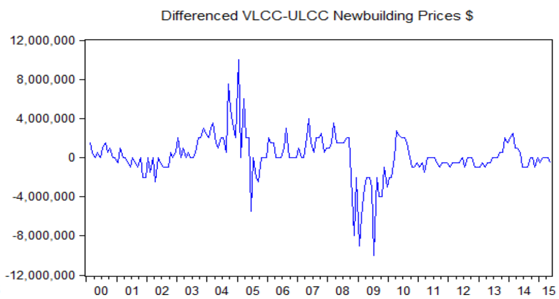


<u>*4.6.2 VLCC-ULCC*</u>

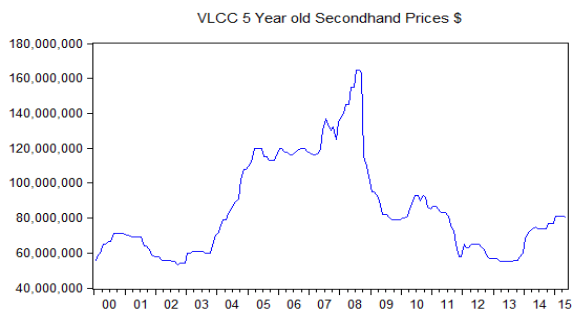
The variables' graphs that will be presented will be the newbuildings' prices; the second-hand prices; the time charter rates of 1 year; the spot rates; the orderbook as percentage of the fleet and the earnings.

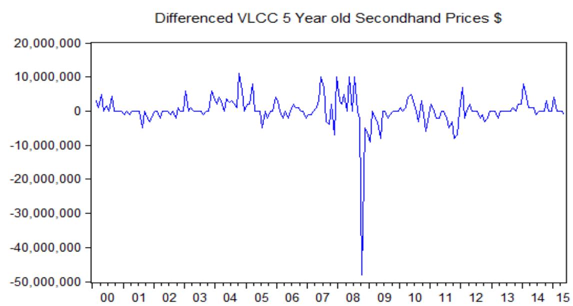
4.6.2.1 Newbuildings' prices



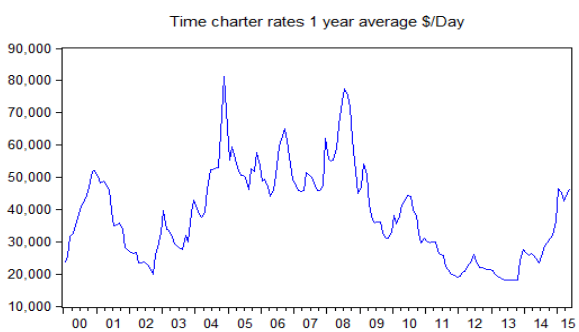


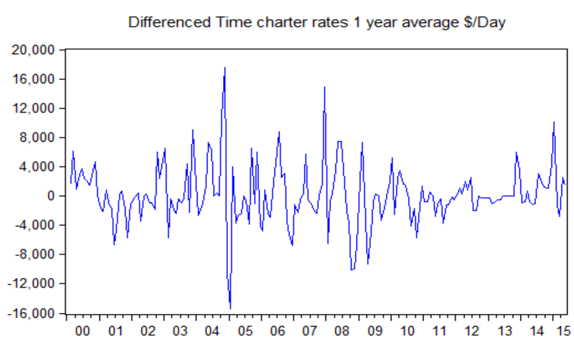
4.6.2.2 Second-hand prices



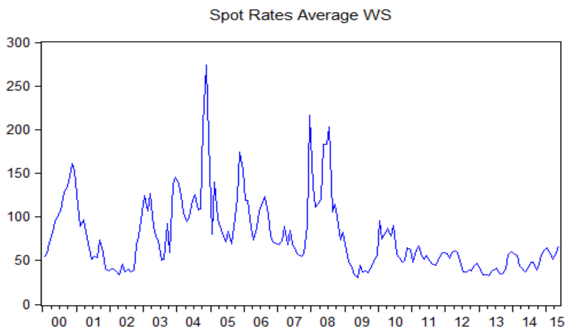


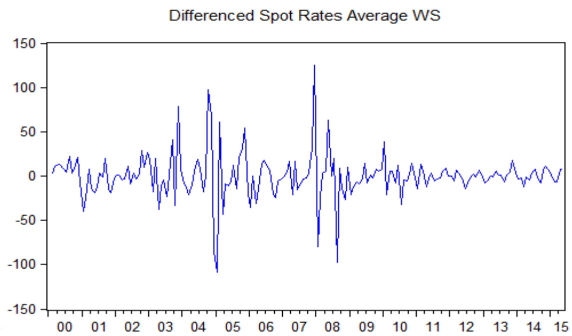
4.6.2.3 Time charter rates of 1 year



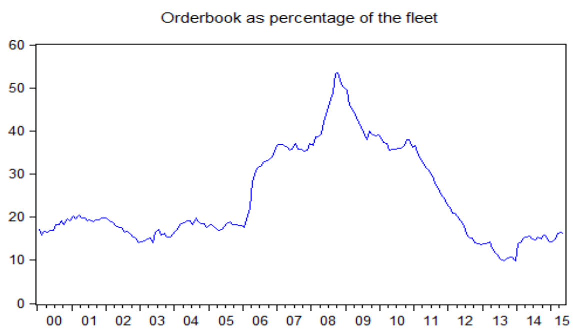


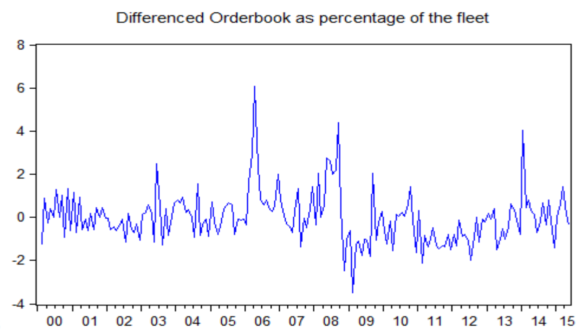
4.6.2.4 Spot rates



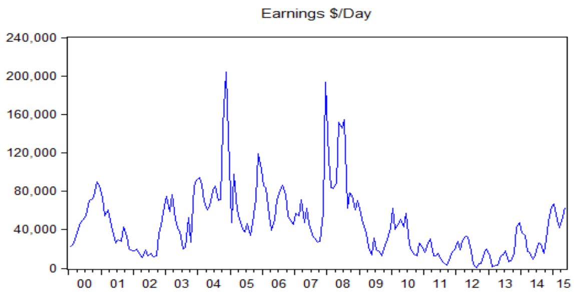


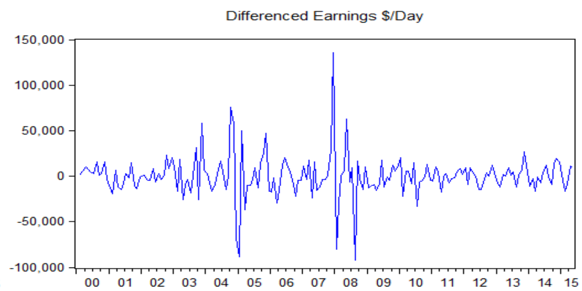
4.6.2.5 Orderbook





4.6.2.6 Earnings





The graphs for the Suezmax and Aframax categories will be presented in Appendix 3 and 4 respectively.

In conclusion, most of the variables' graphs present a significant downward spike approximately in the middle of 2008. This period points out the beginning of the fiscal and economic crisis that affects the world until today. The world trade and consequently the maritime transport were critically affected resulting in tremendous losses for the shipping companies. This spike, steadily smoothed through the years and this is the reason for which we did not include a dummy variable in our model. Such monstrous economic disasters are usual every few years and that is why we include them in our research.

Chapter 5 Data Analysis and Results

5.1 Introduction

In this chapter an extensive analysis of the data in their first differences is demonstrated. The results from various tests are presented and discussed. Each of the following subchapters includes the separate analysis of every model. We begin with the model assessment and diagnostic tests follow. We test the heteroscedasticity, the autocorrelation, the normality, the multicollinearity and the stability. This chapter also contains other model techniques such as ARMA, ARCH, GARCH, E-GARCH, VAR and VEC (Vector Error Correction). The statistical packages EViews 9.0 and IBM SPSS Statistics are used for the analysis.

5.2 Model 1 Newbuilding Market VLCC-ULCC category

The newbuilding market model of the VLCC-ULCC category is analyzed below.

5.2.1 Model 1 Assessment

We run the model with either earnings or spot rates and resulted that with spot rates our model has better results. Moreover multicollinearity existed between these two variables, thus we decided to drop the variable earnings that has the highest p-value. Our model is estimated with the least squares method, and the results are depicted:

Dependent Variable: NEWBUILD_PRICES
Method: Least Squares
Date: 07/25/15 Time: 13:29
Sample (adjusted): 2000M02 2015M05
Included observations: 184 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SECOND_PRICES	0.187039	0.035894	5.210802	0.0000
TIMECHARTER1	-30.21106	51.50858	-0.586525	0.5583
SPOT	-11283.32	7568.381	-1.490850	0.1378
ORDERBOOK	111685.6	122906.0	0.908708	0.3648
STEEL_PROD	-0.021419	0.028807	-0.743549	0.4582
STEEL_PRICE	12678.91	2908.000	4.360012	0.0000
OIL_PROD	0.086873	0.193435	0.449105	0.6539
OIL_PRICE	-10049.63	27341.88	-0.367554	0.7137
LIBOR	3452586.	679062.6	5.084341	0.0000
INFLATION	42038503	53083547	0.791931	0.4295
GDP	-1301118.	558099.0	-2.331338	0.0209
C	219488.7	138183.5	1.588386	0.1140

R-squared	0.368647	Mean dependent var	141304.3
Adjusted R-squared	0.328270	S.D. dependent var	2208962.
S.E. of regression	1810447.	Akaike info criterion	31.71904
Sum squared resid	5.64E+14	Schwarz criterion	31.92871
Log likelihood	-2906.152	Hannan-Quinn criter.	31.80402
F-statistic	9.130063	Durbin-Watson stat	1.491718
Prob(F-statistic)	0.000000		

The coefficients specify the relationship of the independent variables with the dependent. For example if time charter rates of 1 year increase by 1 unit, the newbuilding prices which is our dependent variable will decrease by 30.21 $, assuming that the other independent variables in this model are held constant. The negative sign in the coefficients point out, that an increase in the independent variable will decrease the dependent by the value of the coefficient. From the R^2 and the adjusted R^2 which are 0.36 and 0.32 respectively it is implied that our model has an average fitting. Moreover, the high value of the F-statistic and the low p-value which is less than 5% signify that the model is statistically significant. The F-test, checks if there is at least one independent

variable that interprets the dependent one, and obviously when the model is statistically significant at least one variable exists.
Finally, from the p-values of the independent variables we can observe that the significant variables that affect the dependent variable at 5% significance level are the second-hand prices, the steel prices, the LIBOR and the GDP. This can be explained from their p-value which is less than 0.05. Nevertheless, we need to run multicollinearity test, in order to check if there are any independent variables that are highly correlated and affect the results of the regression.

<u>*5.2.2 Diagnostic Tests*</u>

5.2.2.1 Multicollinearity Test

If only few variables are significant while others are not, there are suspicions for multicollinearity in our model. Multicollinearity exists in all multiple regression models and it is rare to find two totally uncorrelated variables. Multicollinearity is a high correlation between two independent variables. It makes a significant variable insignificant, by increasing its standard error. If the standard error goes up, t-value goes down and hence comes with high p-value. As a result, that particular variable becomes insignificant but in reality it is not.

In order to detect multicollinearity, we run correlation analysis only for the independent variables. If it is more than 95% we have problem of multicollinearity and we need to drop one of the two variables. We drop the variable with the higher p-value from the regression.

	SECOND_PRI	TIMECHARTE	SPOT	ORDERBOOK	STEEL_PROD	STEEL_PRICE	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
SECOND_PRI	1.000000	0.397078	0.184222	0.142450	0.176389	0.109579	0.172590	0.326127	0.017366	0.203083	0.275389
TIMECHARTE	0.397078	1.000000	0.692062	0.032854	0.076014	0.018816	0.114385	0.090617	0.209783	0.113113	-0.072720
SPOT	0.184222	0.692062	1.000000	0.005801	0.024292	0.066738	0.085674	0.118484	0.161977	0.057469	-0.020009
ORDERBOOK	0.142450	0.032854	0.005801	1.000000	0.082259	0.263336	-0.026345	0.007802	0.105996	0.105095	-0.189328
STEEL_PROD	0.176389	0.076014	0.024292	0.082259	1.000000	0.026368	-0.014982	0.123970	0.045103	0.124490	0.004823
STEEL_PRICE	0.109579	0.018816	0.066738	0.263336	0.026368	1.000000	0.110367	0.049831	-0.007072	0.124730	0.005896
OIL_PROD	0.172590	0.114385	0.085674	-0.026345	-0.014982	0.110367	1.000000	0.040263	-0.064293	0.091681	0.189423
OIL_PRICE	0.326127	0.090617	0.118484	0.007802	0.123970	0.049831	0.040263	1.000000	0.066195	0.507805	0.184344
LIBOR	0.017366	0.209783	0.161977	0.105996	0.045103	-0.007072	-0.064293	0.066195	1.000000	0.159686	-0.054721
INFLATION	0.203083	0.113113	0.057469	0.105095	0.124490	0.124730	0.091681	0.507805	0.159686	1.000000	0.016149
GDP	0.275389	-0.072720	-0.020009	-0.189328	0.004823	0.005896	0.189423	0.184344	-0.054721	0.016149	1.000000

We can detect that there is no multicollinearity problem in our model.

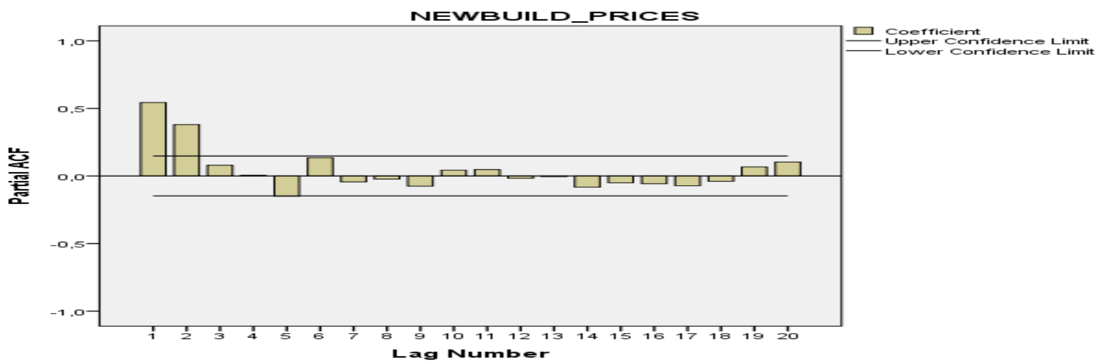
5.2.2.2 Heteroscedasticity Test

We test the heteroscedasticity of our model by applying Levene's Test.

		Levene's Test for Equality of Variances	
		F	Sig.
Model 4	Equal variances assumed	0,073	,788
	Equal variances not assumed		

We conducted Levene's Test, and the results indicate that we cannot reject the null hypothesis at 5% significance level, since Sig=0.788. As a result, the error terms are homoscedastic.

5.2.2.3 Autocorrelation Test



The horizontal lines signify the upper limit and the lower limit. We can witness that there are only few extreme observations that exceed these limits but the majority does not. According to the partial autocorrelation function, our model is uncorrelated and the time series is stationary.

5.2.2.4 Normality Test

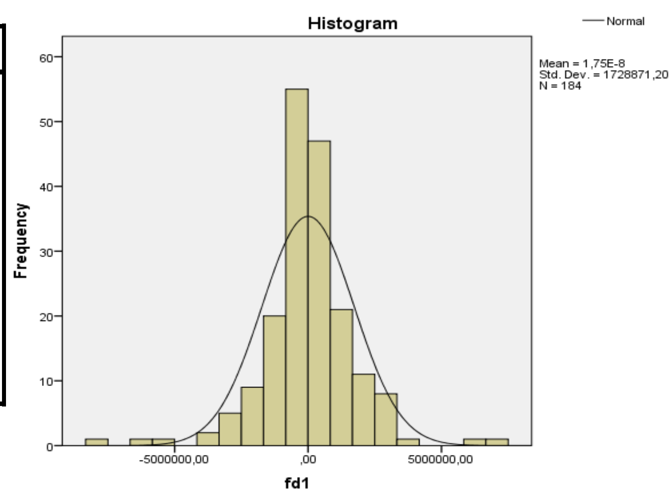
In order to check the normality, we will apply the Kolmogorov-Smirnov Test.

One-Sample Kolmogorov-Smirnov Test

		Model 1
N		184
Normal Parameters[a,b]	Mean	,0000
	Std. Deviation	1728871,19986
Most Extreme Differences	Absolute	,119
	Positive	,098
	Negative	-,119
Kolmogorov-Smirnov Z		1,611
Asymp. Sig. (2-tailed)		,011

a. Test distribution is Normal.

b. Calculated from data.



The results indicate the p-value=0.011. This means that we reject the H0 and the residuals are not normal. However, if we remove the extreme values 56, 60 and 114 and repeat the test, the results reveal that the normality test is valid and the residuals are normal. This is presented in the table below, where p-value=0.085 and is larger than the 5% significance level. We will continue our analysis without these three extreme values.

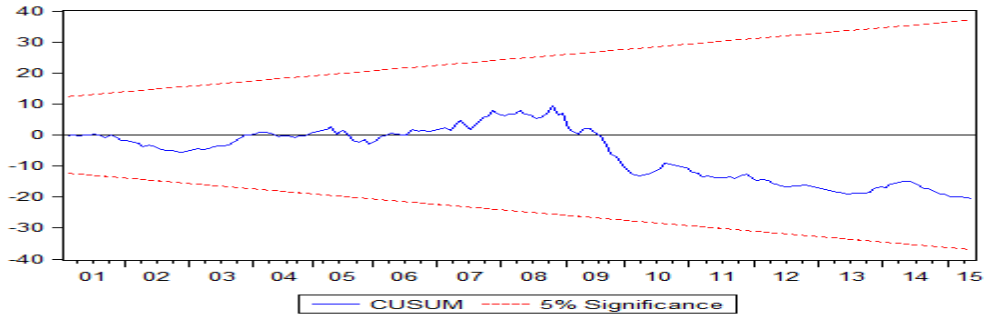
One-Sample Kolmogorov-Smirnov Test

		Model 1
N		181
Normal Parameters[a,b]	Mean	-31055,7343
	Std. Deviation	1469850,65048
Most Extreme Differences	Absolute	,093
	Positive	,064
	Negative	-,093
Kolmogorov-Smirnov Z		1,257
Asymp. Sig. (2-tailed)		,085

a. Test distribution is Normal.
b. Calculated from data.

5.2.2.5 CUSUM Test

There are many ways to check if the variables remain stable throughout the considered period. In this thesis, CUSUM graph will be presented which uses the cumulative sums.



The variables fluctuate within the upper and lower limit at 5% significance level, thus they remain stable during this period.

5.2.3 ARMA Model

The ARMA models are time series that have both autoregressive (p) and moving average terms (q). In general, they are known as ARMA (p, q) and must be stationary in order to be estimated. Thus, we will use our data converted in their first differences. The ARMA models that belong to the ARIMA (Autoregressive Integrated Moving Average) family of models, try to interpret different economic results based on the previous values of the dependent variable (Washington et al., 2010), which in this case is the newbuilding prices of VLCC-ULCC tanker vessels.

We will estimate the best ARMA model as a predecessor of the ARCH family models. ARCH test will be conducted in the best ARMA model and this will allow us to conclude if we will estimate ARCH models or not. For the selection of the best ARMA model it is indicated to use either the Akaike Information Criterion (AIC) or the Schwarz Information Criterion (SIC). The most appropriate number of autoregressive and moving average terms is based in the minimum value of these criteria. In this thesis, our selection will be based on the AIC, because it gives better results. The combinations of the terms can be countless, thus we will limit our research till the number 8. This includes 64 possible combinations of autoregressive (p) and moving average terms (q). The examination revealed that the model with the lowest AIC value is the ARMA (1, 2). The regression is depicted below.

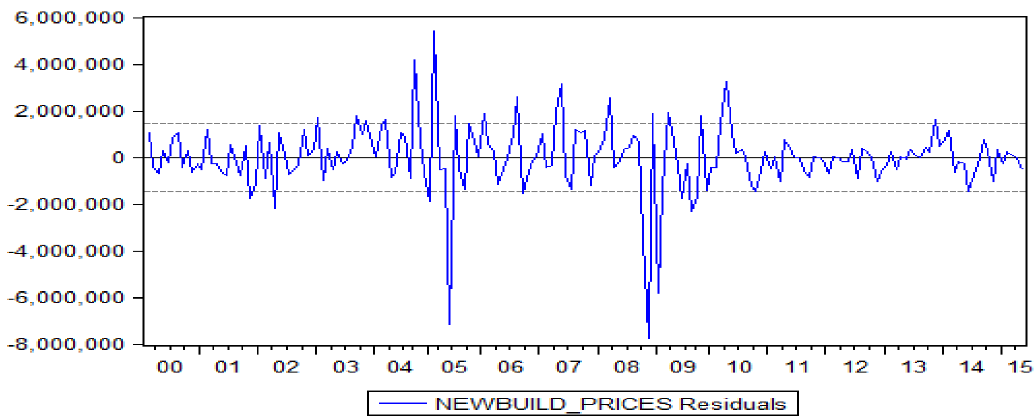
Dependent Variable: NEWBUILD_PRICES
Method: ARMA Maximum Likelihood (OPG - BHHH)
Included observations: 181
Convergence achieved after 38 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	114059.2	443256.8	0.257321	0.7972
AR(1)	0.772415	0.078825	9.799112	0.0000
MA(1)	-0.350043	0.086015	-4.069569	0.0001
MA(2)	0.131820	0.061616	2.139375	0.0338
SIGMASQ	2.06E+12	1.06E+11	19.48618	0.0000

R-squared	0.416805	Mean dependent var	102209.9
Adjusted R-squared	0.403551	S.D. dependent var	1883384.
S.E. of regression	1454540.	Akaike info criterion	31.24893
Sum squared resid	3.72E+14	Schwarz criterion	31.33728
Log likelihood	-2823.028	Hannan-Quinn criter.	31.28475
F-statistic	31.44646	Durbin-Watson stat	1.991444
Prob(F-statistic)	0.000000		

It is observed that the model is statistically significant since its p-value is less than the 5% significance level, and 41.68 % of the variation of newbuilding prices of VLCC-ULCC tankers, is explained by the model. Apart from C all the independent variables are statistically significant at 5 % significance level.

We have also to check if the model fits well since other combinations may fit better. For that reason we will apply diagnostic tests in the residuals. The residuals are characterized by non-normality, however this is not a problem because our model contains many observations. Furthermore, the correlogram of the residuals signifies that there is no autocorrelation and our model is stationary, at 5 % significance level. All the tests are presented in appendix 5. The residuals' graph is illustrated below:



5.2.4 ARCH Model

In the ARCH family models, the variance of the disruptive term is not a function of the explanatory variables, but changes over time. This change is related to how volatile the disruptive term in the recent past was. As a result, a peculiar heteroscedasticity exists, in the sense that the variance of the disrupting terms depends on the volatility of previous values (Xekalaki and Degiannakis, 2010).

In order to examine if the above happens in our model, we need to check if there is ARCH effect. We apply the test in the best ARMA model, which was found in the previous sub-chapter. However, firstly we need to find the appropriate lags for our model. The lag selection is based on the value of the Akaike Information Criterion and the best result is 2 lags. Then we run the ARCH test for heteroscedasticity. The null hypothesis signifies that there is no ARCH effect, while in the alternative there is ARCH effect. Thus, we can estimate the ARCH family models only if we reject the null hypothesis of the ARCH test. The ARCH effect can be detected from another method as well, but the result is not so obvious. We can check the graph of the residuals in our best ARMA model, which was founded in the previous sub-chapter. If periods of high volatility are followed by periods of high volatility and periods of low volatility are followed by periods of low volatility for big periods of time, then we have all the justification to run the ARCH family models. These methods suggest that the residuals or error terms are conditionally heteroscedastic and they can be represented by the ARCH family models. All these models will be estimated with EViews 9.0. The results of the ARCH test are presented below:

Heteroskedasticity Test: ARCH

F-statistic	4.202031	Prob. F(2,176)	0.0165
Obs*R-squared	8.157777	Prob. Chi-Square(2)	0.0169

From the ARCH test, we reject the null hypothesis and we conclude that there is ARCH effect in our model. It is not allowed from EViews to use ARCH orders greater than 9, thus we will examine all the 9 ARCH models to find which is the most appropriate. Our selection criterion will be the AIC, which is used in this research and the significance of the ARCH terms. The best model is the ARCH (4) and its regression is illustrated:

Dependent Variable: NEWBUILD_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 181 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2
+ C(6)*RESID(-4)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-395459.6	82207.60	-4.810500	0.0000
Variance Equation				
C	1.69E+11	9.41E+10	1.799787	0.0719
RESID(-1)^2	0.685097	0.176791	3.875178	0.0001
RESID(-2)^2	0.247595	0.115577	2.142247	0.0322
RESID(-3)^2	0.170708	0.086377	1.976309	0.0481
RESID(-4)^2	0.217717	0.104932	2.074832	0.0380

R-squared	-0.070212	Mean dependent var	102209.9
Adjusted R-squared	-0.070212	S.D. dependent var	1883384.
S.E. of regression	1948380.	Akaike info criterion	31.29901
Sum squared resid	6.83E+14	Schwarz criterion	31.40504
Log likelihood	-2826.561	Hannan-Quinn criter.	31.34200
Durbin-Watson stat	0.739595		

We can observe that all the ARCH terms are significant at 5% significance level. Their coefficient values signify that the newbuilding prices of VLCC-ULCC tankers are affected by external shocks. We also apply diagnostic tests to examine if the model is valid. The correlation of the square residuals is checked and we approve the null hypothesis which implies that there is no serial correlation in the residuals.

Moreover, we test for heteroscedasticity and we conclude that our model is homoscedastic at 5% significance level. Finally, normality is checked but p-value=0.000407 implies that we reject the null hypothesis which mentions that the residuals are normally distributed. This is not a significant problem, based on the large number of observations. All the diagnostic tests and the lag selection, are illustrated in appendix 6.

5.2.5 GARCH Model

The GARCH model is a combination of ARCH and GARCH terms. We will test all the 81 available combinations of GARCH and ARCH orders, and according to the lowest AIC but also to the best diagnostic tests we will select the most suitable model. The inspection shows that the best model is the GARCH (1, 1). The regression is as follows:

Dependent Variable: NEWBUILD_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 181 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-382765.3	78447.84	-4.879233	0.0000
Variance Equation				
C	3.43E+10	3.44E+10	0.997132	0.3187
RESID(-1)^2	0.505385	0.127208	3.972899	0.0001
GARCH(-1)	0.603552	0.067685	8.917089	0.0000

R-squared	-0.066676	Mean dependent var	102209.9
Adjusted R-squared	-0.066676	S.D. dependent var	1883384.
S.E. of regression	1945159.	Akaike info criterion	31.24594
Sum squared resid	6.81E+14	Schwarz criterion	31.31663
Log likelihood	-2823.758	Hannan-Quinn criter.	31.27460
Durbin-Watson stat	0.742047		

Both ARCH and GARCH are statistically significant since their p-value is almost 0. The ARCH (0.50) and the GARCH (0.60) coefficients signify how much the external shocks affect the newbuilding prices of VLCC and ULCC tankers. The effect is quite strong and their sum (1.10) which is more than 1 implies that their importance in the formulation of the variance value of all previous disrupting terms' observations is elevated. The ARCH test for heteroscedasticity has p-value=0.9483, thus the model is homoscedastic. The correlogram of the residuals signifies that there is no autocorrelation, but the normality once more is not satisfied. Appendix 7 contains all the diagnostic tests.

5.2.6 E-GARCH Model

The E-GARCH model, is another model of the ARCH family. It consists of a mixture of ARCH, GARCH and asymmetric orders. The E-GARCH models examine the relationship of the previous asymmetric effects and the present variability of the dependent variable. Because of the complexity of this model, we will retain the asymmetric order stable to 1. A selection of the most appropriate model will follow based on the AIC, the diagnostic tests and the statistical significance of the variables. It occurred that the best model is the E-GARCH (4, 5, 1). The regression is depicted:

Dependent Variable: NEWBUILD_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 181 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)
*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*ABS(RESID(-3)
/@SQRT(GARCH(-3))) + C(6)*ABS(RESID(-4)/@SQRT(GARCH(-4))) +
C(7)*RESID(-1)/@SQRT(GARCH(-1)) + C(8)*LOG(GARCH(-1)) + C(9)
*LOG(GARCH(-2)) + C(10)*LOG(GARCH(-3)) + C(11)*LOG(GARCH(-4))
+ C(12)*LOG(GARCH(-5))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-266284.8	57255.25	-4.650836	0.0000
Variance Equation				
C(2)	4.769453	0.327041	14.58367	0.0000
C(3)	0.568628	0.196922	2.887584	0.0039
C(4)	1.481259	0.180149	8.222393	0.0000
C(5)	1.604474	0.207018	7.750427	0.0000
C(6)	0.984386	0.123420	7.975930	0.0000
C(7)	0.469346	0.143918	3.261204	0.0011
C(8)	-0.449298	0.026504	-16.95188	0.0000
C(9)	-0.332908	0.032473	-10.25188	0.0000
C(10)	0.350709	0.030069	11.66356	0.0000
C(11)	0.518765	0.026105	19.87251	0.0000
C(12)	0.611116	0.004585	133.2745	0.0000

R-squared	-0.038494	Mean dependent var	102209.9
Adjusted R-squared	-0.038494	S.D. dependent var	1883384.
S.E. of regression	1919291.	Akaike info criterion	31.12821
Sum squared resid	6.63E+14	Schwarz criterion	31.34026
Log likelihood	-2805.103	Hannan-Quinn criter.	31.21418
Durbin-Watson stat	0.762184		

It is noticed that all variables are statistically significant. Consequently, the volatility of newbuilding prices of the ULCC and VLCC crude tankers is affected by asymmetric effects of the past. We conducted the diagnostic tests for heteroscedasticity, autocorrelation and normality. Our model is homoscedastic with p-value=0.9767, no autocorrelation exists and the normality is satisfied with p-value=0.739516. The diagnostic tests are displayed in appendix 8.

5.2.7 VAR Model

The Vector Autoregressive (VAR) model is mainly used to explain the dynamics of economic and financial time series. Its main goal is to specify empirical evidence on the reaction of the variables in different exogenous shocks in order to distinguish between other economic models. It is also applied for forecasting and for structural inferences (Juselius, 2006).

In order to estimate a VAR model, we fist have to define the lag length. All the variables are endogenous and we check the lag length criteria of AIC, SIC and HQ (Hannan Quinn) for the appropriate lag number. AIC suggests 8 lags, SIC 0 lags and HQ 1 lag. We choose 1 lag but the residuals autocorrelation test is not satisfied, because the p-value is lower than 5%, thus rejecting the null hypothesis. The lags selected will be 4, which is a number closer to the reality and between 0 and 8, and the model selected will be the VAR (1, 4). Moreover, we approve the null hypothesis in the residuals correlation test which suggests that no serial correlation exists in our model. This means that the VAR model itself is sufficient to model the time series dynamics. Because the regression table is too large to be included, it is available by the author upon request.

From the regression, it is signified that the model has average fit. Only 50% of the variation of the dependent variable can be explained by the model. The newbuilding prices of the last two periods are significant to the current newbuilding VLCC-ULCC tankers prices. In addition, newbuilding prices are affected by last period's second-hand prices and time charter rates as well as from the spot rates of three periods ago. Finally, oil prices of the previous period have T-statistic above 2 which means that they are also statistically significant to our independent variable.

5.3 Model 2 Newbuilding Market Suezmax category

This subchapter includes the analysis of the newbuilding market model of the Suezmax vessels.

5.3.1 Model 2 Assessment

Dependent Variable: NEWBUILD_PRICES
Method: Least Squares
Date: 07/24/15 Time: 02:56
Sample (adjusted): 2000M02 2015M05
Included observations: 184 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SECOND_PRICES	0.147712	0.036241	4.075857	0.0001
TIMECHARTER1	71.02620	53.68461	1.323027	0.1876
SPOT	6744.162	10857.29	0.621164	0.5353
ORDERBOOK	37644.75	70575.54	0.533397	0.5945
EARNINGS	-15.77532	18.99254	-0.830606	0.4074
STEEL_PROD	0.018156	0.019449	0.933528	0.3519
STEEL_PRICE	9720.058	1869.323	5.199775	0.0000
OIL_PROD	0.031623	0.128323	0.246429	0.8056
OIL_PRICE	-2386.029	17673.57	-0.135005	0.8928
LIBOR	1730280.	444482.9	3.892793	0.0001
INFLATION	30085131	35048013	0.858398	0.3919
GDP	-183405.7	366202.3	-0.500831	0.6171
C	126729.8	90836.42	1.395143	0.1648

R-squared	0.367484	Mean dependent var	111413.0
Adjusted R-squared	0.323097	S.D. dependent var	1441417.
S.E. of regression	1185913.	Akaike info criterion	30.87796
Sum squared resid	2.40E+14	Schwarz criterion	31.10510
Log likelihood	-2827.772	Hannan-Quinn criter.	30.97002
F-statistic	8.279069	Durbin-Watson stat	1.601295
Prob(F-statistic)	0.000000		

The F-statistic is high, and the p-value is less than 0.05 at 5% significance level. Consequently, our model has some validity. The adjusted R-squared indicates that 32.30% of the variation of newbuilding prices of Suezmax tankers is explained by the model. The relationship between the dependent and the independent variables is explained by the coefficients. For each additional unit increase of steel price, the newbuilding prices will increase by 9,720 $, assuming the constancy of the other independent variables. There is sufficient evidence at the 5% significance level to infer that second-hand prices, steel prices and LIBOR are related to newbuilding prices.

5.3.2 Diagnostic Tests

5.3.2.1 Multicollinearity Test

	SECOND_PRI	TIMECHARTE	SPOT	ORDERBOOK	EARNINGS	STEEL_PROD	STEEL_PRICE	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
SECOND_PRI	1.000000	0.380920	0.151822	0.097674	0.106375	0.149345	0.111055	0.240347	0.147388	-0.051495	0.158455	0.267889
TIMECHARTE	0.380920	1.000000	0.554924	0.092290	0.468451	0.058320	-0.019905	0.033683	0.022092	0.193356	0.120871	-0.107476
SPOT	0.151822	0.554924	1.000000	-0.076886	0.949289	0.169705	0.038062	0.057092	0.101575	0.121244	0.047707	-0.105796
ORDERBOOK	0.097674	0.092290	-0.076886	1.000000	-0.051696	0.092958	0.155670	0.025480	-0.081337	0.059328	0.019811	-0.116284
EARNINGS	0.106375	0.468451	0.949289	-0.051696	1.000000	0.205139	0.029190	0.016317	0.047003	0.089899	0.021729	-0.166425
STEEL_PROD	0.149345	0.058320	0.169705	0.092958	0.205139	1.000000	0.026368	-0.014982	0.123970	0.045103	0.124490	0.004823
STEEL_PRICE	0.111055	-0.019905	0.038062	0.155670	0.029190	0.026368	1.000000	0.110367	0.049831	-0.007072	0.124730	0.005896
OIL_PROD	0.240347	0.033683	0.057092	0.025480	0.016317	-0.014982	0.110367	1.000000	0.040263	-0.064293	0.091681	0.189423
OIL_PRICE	0.147388	0.022092	0.101575	-0.081337	0.047003	0.123970	0.049831	0.040263	1.000000	0.066195	0.507805	0.184344
LIBOR	-0.051495	0.193356	0.121244	0.059328	0.089899	0.045103	-0.007072	-0.064293	0.066195	1.000000	0.159686	-0.054721
INFLATION	0.158455	0.120871	0.047707	0.019811	0.021729	0.124490	0.124730	0.091681	0.507805	0.159686	1.000000	0.016149
GDP	0.267889	-0.107476	-0.105796	-0.116284	-0.166425	0.004823	0.005896	0.189423	0.184344	-0.054721	0.016149	1.000000

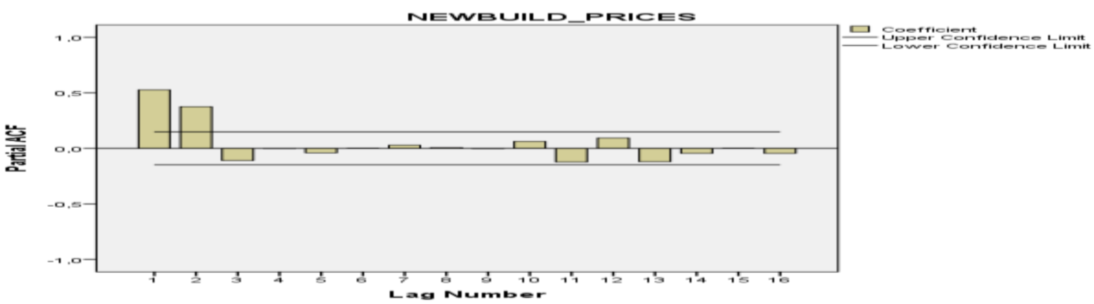
After conducting multicollinearity test, we can observe that the correlation of our variables does not exceed 95%. However, we can see that the correlation of spot and earnings is high at 94.92%. We run again the regression without earnings, but the p-values do not change significantly. Thus, in this case we will keep the independent variable earnings in our model.

5.3.2.2 Heteroscedasticity Test

		Levene's Test for Equality of Variances	
		F	Sig.
Model 2	Equal variances assumed	1,298	,256
	Equal variances not assumed		

In this case Levene's test signifies that homoscedasticity exists. Sig=0.256 at 5 % significance level, and the null hypothesis is approved.

5.3.2.3 Autocorrelation Test



The graph illustrates that there is no autocorrelation in our residuals. As a result, we approve the null hypothesis that no autocorrelation exists.

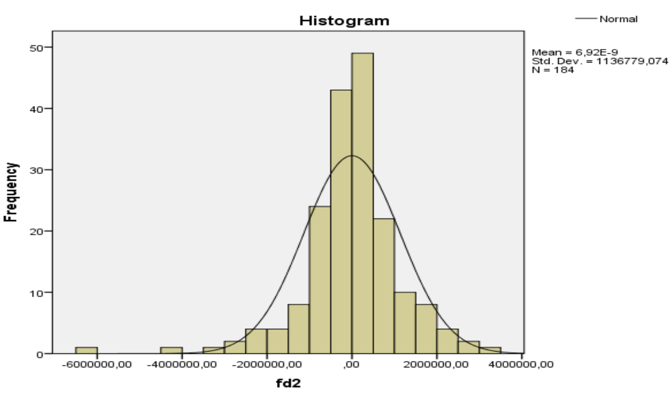
5.3.2.4 Normality Test

One-Sample Kolmogorov-Smirnov Test

		Model 2
N		184
Normal Parameters[a,b]	Mean	,0000
	Std. Deviation	1136779,07383
Most Extreme Differences	Absolute	,096
	Positive	,090
	Negative	-,096
Kolmogorov-Smirnov Z		1,298
Asymp. Sig. (2-tailed)		,069

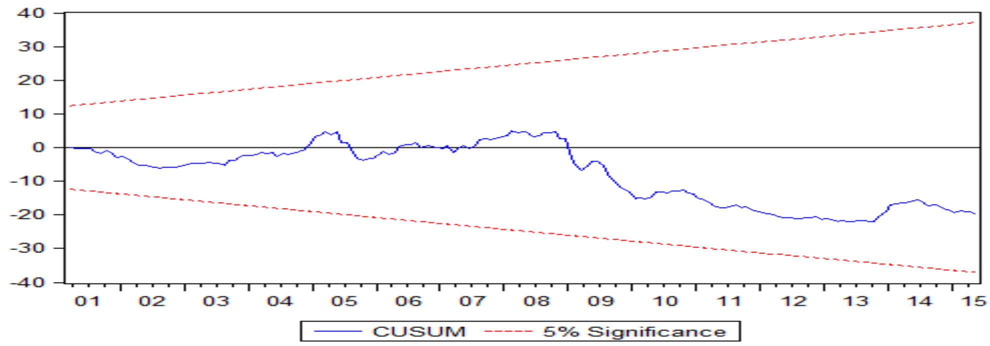
a. Test distribution is Normal.

b. Calculated from data.



In accordance with the above table and graph, the normality test is not violated. We approve the null hypothesis since Asymp.Sig (2-tailed) =0.069 at 5% significance level. H_0 states that the residuals are normal.

5.3.2.5 CUSUM Test



It is depicted that from January 2000 till May 2015, the variables remain stable and within the limits.

5.3.3 ARMA Model

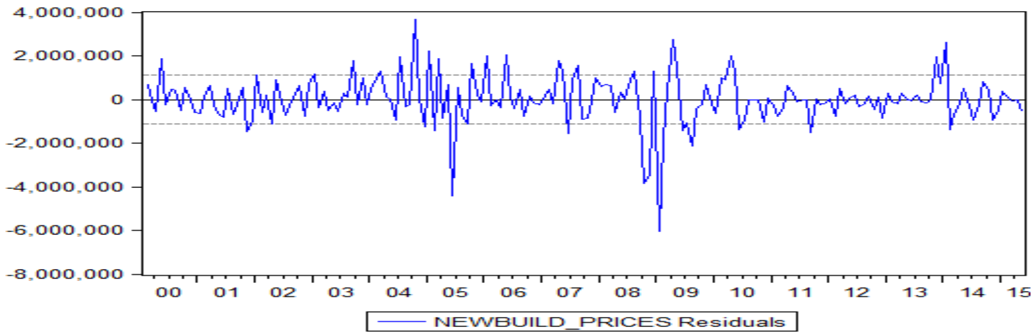
After comparing the AIC values in 64 combinations of p and q, we conclude that the most suitable model with the lowest AIC, is the ARMA (2, 1). The regression outcome is illustrated below.

Dependent Variable: NEWBUILD_PRICES
Method: ARMA Maximum Likelihood (OPG - BHHH)
Included observations: 184
Convergence achieved after 45 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	116875.2	277946.8	0.420495	0.6746
AR(1)	0.095711	0.097413	0.982535	0.3272
AR(2)	0.494761	0.085617	5.778772	0.0000
MA(1)	0.273636	0.115276	2.373748	0.0187
SIGMASQ	1.27E+12	8.24E+10	15.36375	0.0000

R-squared	0.387104	Mean dependent var	111413.0
Adjusted R-squared	0.373408	S.D. dependent var	1441417.
S.E. of regression	1140991.	Akaike info criterion	30.76304
Sum squared resid	2.33E+14	Schwarz criterion	30.85041
Log likelihood	-2825.200	Hannan-Quinn criter.	30.79845
F-statistic	28.26400	Durbin-Watson stat	1.992224
Prob(F-statistic)	0.000000		

It is demonstrated that our model is valid. Moreover, only three out of the 5 independent variables are significant. The model has average fit and its R^2 is 38.71%. The tests of normality and autocorrelation are displayed in appendix 5. The results indicate that there is no autocorrelation and the histogram implies that the normality is not satisfied but this is not a problem. Additionally, the residuals' graph is depicted:



5.3.4 ARCH Model

After selecting the appropriate lags which are 3, we check the ARMA residuals' graph, but also apply the ARCH test to examine if there is ARCH effect in our model. The result of the ARCH test are displayed:

Heteroskedasticity Test: ARCH

F-statistic	11.88351	Prob. F(3,177)	0.0000
Obs*R-squared	30.34437	Prob. Chi-Square(3)	0.0000

It is obvious that we reject the null hypothesis, thus ARCH effect exists in the model. All 9 combinations were considered, and the most suitable model is the ARCH (3) as follows:

Dependent Variable: NEWBUILD_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 184 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	95758.48	89549.18	1.069339	0.2849
		Variance Equation		
C	5.27E+11	9.46E+10	5.567960	0.0000
RESID(-1)^2	0.238368	0.103768	2.297135	0.0216
RESID(-2)^2	0.357841	0.115359	3.101975	0.0019
RESID(-3)^2	0.187951	0.074223	2.532237	0.0113

R-squared	-0.000119	Mean dependent var	111413.0
Adjusted R-squared	-0.000119	S.D. dependent var	1441417.
S.E. of regression	1441503.	Akaike info criterion	30.82202
Sum squared resid	3.80E+14	Schwarz criterion	30.90939
Log likelihood	-2830.626	Hannan-Quinn criter.	30.85743
Durbin-Watson stat	0.944088		

From the p-values of the ARCH terms, can be illustrated that the variance of the current error terms of newbuilding prices of Suezmax vessels is significantly affected by external disturbances. In addition, it was evidenced that our model is homoscedastic (p-value=0.9896) and no autocorrelation exists in the residuals. However, the p-value of the Jarcue-Bera statistics for normality is 0.011479, and no normality exists. These tests but also the lag selection process are included in appendix 6.

5.3.5 GARCH Model

The inspection of all 81 possible combinations of p and q redounds that GARCH (2, 4) is the most appropriate model. Its regression analysis is depicted:

Dependent Variable: NEWBUILD_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 184 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)
+ C(6)*GARCH(-2) + C(7)*GARCH(-3) + C(8)*GARCH(-4)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	43480.30	57582.30	0.755098	0.4502
		Variance Equation		
C	2.42E+11	5.71E+10	4.232279	0.0000
RESID(-1)^2	0.248764	0.088331	2.816267	0.0049
RESID(-2)^2	0.294199	0.120903	2.433349	0.0150
GARCH(-1)	0.447004	0.248462	1.799087	0.0720
GARCH(-2)	-0.130673	0.316497	-0.412874	0.6797
GARCH(-3)	-0.153264	0.271318	-0.564887	0.5722
GARCH(-4)	0.166121	0.121507	1.367177	0.1716

R-squared	-0.002233	Mean dependent var	111413.0
Adjusted R-squared	-0.002233	S.D. dependent var	1441417.
S.E. of regression	1443026.	Akaike info criterion	30.79146
Sum squared resid	3.81E+14	Schwarz criterion	30.93124
Log likelihood	-2824.814	Hannan-Quinn criter.	30.84812
Durbin-Watson stat	0.942096		

The ARCH variables are significant, but only one GARCH variable is significant at 10 % significance level. The significant coefficients' sum is 0.98, is more than 1 and demonstrates that their importance in the formulation of the variance value of all previous disrupting terms' observations is descending. The model is homoscedastic, since we approve the null hypothesis for heteroscedasticity (p-value=0.9484) and no autocorrelation exists in the error terms. Finally, we reject the null hypothesis for normality because of the large number of observations. Appendix 7 contains the tests.

5.3.6 E-GARCH Model

The most suitable model keeping stable the asymmetric term is the E-GARCH (3, 8, 1). The regression analysis is presented below:

Dependent Variable: NEWBUILD_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 184 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)
*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*ABS(RESID(-3)
/@SQRT(GARCH(-3))) + C(6)*RESID(-1)/@SQRT(GARCH(-1)) + C(7)
*LOG(GARCH(-1)) + C(8)*LOG(GARCH(-2)) + C(9)*LOG(GARCH(-3)) +
C(10)*LOG(GARCH(-4)) + C(11)*LOG(GARCH(-5)) + C(12)
*LOG(GARCH(-6)) + C(13)*LOG(GARCH(-7)) + C(14)*LOG(GARCH(-8))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	80285.23	45166.68	1.777532	0.0755
Variance Equation				
C(2)	14.78976	0.014552	1016.336	0.0000
C(3)	0.837686	0.128966	6.495389	0.0000
C(4)	1.255960	0.011519	109.0313	0.0000
C(5)	0.772960	0.117102	6.600766	0.0000
C(6)	-0.550904	0.068668	-8.022703	0.0000
C(7)	-0.199356	0.071509	-2.787868	0.0053
C(8)	-0.167237	0.066432	-2.517426	0.0118
C(9)	0.022242	0.051543	0.431528	0.6661
C(10)	-0.020285	0.038102	-0.532387	0.5945
C(11)	0.209523	0.054597	3.837644	0.0001
C(12)	0.027235	0.077107	0.353212	0.7239
C(13)	-0.122154	0.062037	-1.969067	0.0489
C(14)	0.633485	0.000227	2785.182	0.0000

R-squared	-0.000469	Mean dependent var	111413.0
Adjusted R-squared	-0.000469	S.D. dependent var	1441417.
S.E. of regression	1441755.	Akaike info criterion	30.66217
Sum squared resid	3.80E+14	Schwarz criterion	30.90679
Log likelihood	-2806.920	Hannan-Quinn criter.	30.76132
Durbin-Watson stat	0.943758		

It is signified that most of the variables of the variance equation are statistically significant at 5% significance level. Thus we can imply that the newbuilding price returns of the Suezmax crude vessels are influenced by the asymmetric effects of the past. All the diagnostic tests are valid, consequently the model is homoscedastic, no autocorrelation exists in the residuals and the normality is satisfied. The tables can be obtained in appendix 8.

5.3.7 VAR Model

We need to identify the appropriate lag length. AIC suggest 8 lags, SIC 0 lags and HQ 1 lag. The one lag does not satisfy the residual's autocorrelation test, thus we will choose 4 lags which is between 0 and 8. The autocorrelation test is applied again, but this time we approve the null hypothesis and the VAR (1, 4) model is sufficient to model the dynamics of our time series. The results of the regression, the lag estimation and the autocorrelation test can be made available by the author upon request.
It is illustrated that the model's fit is average and the Suezmax newbuilding prices of the two last periods, as well as the second-hand prices of 3 and 4 months ago, are statistically significant to the determination of the current newbuilding prices of Suezmax tankers. Furthermore, the steel prices of two and four previous periods and the oil prices of the previous month, importantly affect the current newbuilding prices. Finally, last month's LIBOR is also significant to the prices of the new Suezmax crude carriers.

5.4 Model 3 Newbuilding Market Aframax category

Model 3 which contains the newbuilding market model of the Aframax vessels is examined below.

5.4.1 Model 3 Assessment

Dependent Variable: NEWBUILD_PRICES
Method: Least Squares
Date: 07/24/15 Time: 02:57
Sample (adjusted): 2000M02 2015M05
Included observations: 184 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SECOND_PRICES	0.130947	0.042403	3.088193	0.0024
TIMECHARTER1	17.71651	81.55923	0.217223	0.8283
SPOT	-6072.172	9224.782	-0.658246	0.5113
ORDERBOOK	267672.8	97097.80	2.756734	0.0065
EARNINGS	32.70406	24.60305	1.329268	0.1855
STEEL_PROD	-0.008108	0.018158	-0.446512	0.6558
STEEL_PRICE	7159.777	1755.251	4.079061	0.0001
OIL_PROD	0.054708	0.121549	0.450089	0.6532
OIL_PRICE	-10716.61	16995.24	-0.630565	0.5292
LIBOR	1368544.	422703.2	3.237600	0.0014
INFLATION	68212199	33101512	2.060697	0.0408
GDP	-134427.2	343302.0	-0.391571	0.6959
C	119122.8	86452.94	1.377892	0.1700

R-squared	0.316686	Mean dependent var	103260.9
Adjusted R-squared	0.268734	S.D. dependent var	1320111.
S.E. of regression	1128881.	Akaike info criterion	30.77938
Sum squared resid	2.18E+14	Schwarz criterion	31.00653
Log likelihood	-2818.703	Hannan-Quinn criter.	30.87145
F-statistic	6.604244	Durbin-Watson stat	1.412096
Prob(F-statistic)	0.000000		

P-value (F-statistic) indicates that model 3 is statistically significant, and we reject the null hypothesis. The R^2 demonstrates that 31.66% of the variation of the dependent variable is explained by the model. The rest 68.34% is unexplained. By testing the coefficients of the independent variables, we result that at 5% significance level, second-hand Aframax prices, orderbook as percentage of the fleet, steel prices, LIBOR and inflation are linearly related to newbuilding prices of Aframax tankers. There is not enough evidence to conclude that each of the rest variables are linearly related to newbuilding prices.

5.4.2 Diagnostic Tests

5.4.2.1 Multicollinearity Test

	SECOND_PRI	TIMECHARTE	SPOT	ORDERBOOK	EARNINGS	STEEL_PROD	STEEL_PRICE	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
SECOND_PRI	1.000000	0.303097	0.091659	0.130956	0.043733	0.116382	0.111141	0.166289	0.209521	0.050973	0.179475	0.196547
TIMECHARTE	0.303097	1.000000	0.501091	0.051593	0.396245	0.071517	0.026879	0.113020	0.062390	0.243511	0.137469	-0.179652
SPOT	0.091659	0.501091	1.000000	0.021972	0.940827	0.185947	0.035650	0.071438	0.103485	0.134346	0.122001	-0.067378
ORDERBOOK	0.130956	0.051593	0.021972	1.000000	0.043710	0.100288	0.071396	-0.091187	0.057739	0.004181	0.065935	-0.136140
EARNINGS	0.043733	0.396245	0.940827	0.043710	1.000000	0.184547	0.010931	0.052603	0.018271	0.103048	0.087643	-0.091738
STEEL_PROD	0.116382	0.071517	0.185947	0.100288	0.184547	1.000000	0.026368	-0.014982	0.123970	0.045103	0.124490	0.004823
STEEL_PRICE	0.111141	0.026879	0.035650	0.071396	0.010931	0.026368	1.000000	0.110367	0.049831	-0.007072	0.124730	0.005896
OIL_PROD	0.166289	0.113020	0.071438	-0.091187	0.052603	-0.014982	0.110367	1.000000	0.040263	-0.064293	0.091681	0.189423
OIL_PRICE	0.209521	0.062390	0.103485	0.057739	0.018271	0.123970	0.049831	0.040263	1.000000	0.066195	0.507805	0.184344
LIBOR	0.050973	0.243511	0.134346	0.004181	0.103048	0.045103	-0.007072	-0.064293	0.066195	1.000000	0.159686	-0.054721
INFLATION	0.179475	0.137469	0.122001	0.065935	0.087643	0.124490	0.124730	0.091681	0.507805	0.159686	1.000000	0.016149
GDP	0.196547	-0.179652	-0.067378	-0.136140	-0.091738	0.004823	0.005896	0.189423	0.184344	-0.054721	0.016149	1.000000

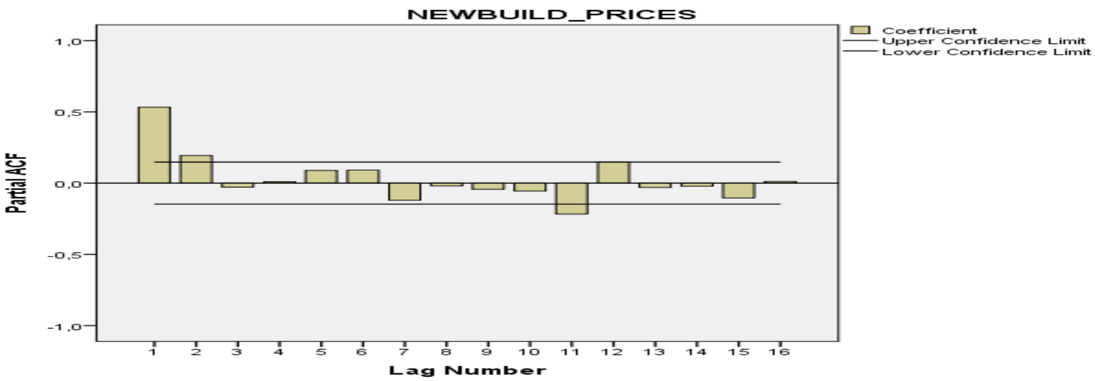
There is no multicollinearity problem in this model above 95%. Earnings and spot rates are again highly correlated at 94.08%. We will keep both variables in our model, since they do not exceed the limit we set.

5.4.2.2 Heteroscedasticity Test

		Levene's Test for Equality of Variances	
		F	Sig.
Model 3	Equal variances assumed	,010	,922
	Equal variances not assumed		

Homoscedasticity exist in this model. This can be revealed from the Sig=0.922. We approve the null hypothesis that homoscedasticity exists and reject the alternative.

5.4.2.3 Autocorrelation Test



The values of the above graph are not auto-correlated. Thus, we can conclude that the model is stationary.

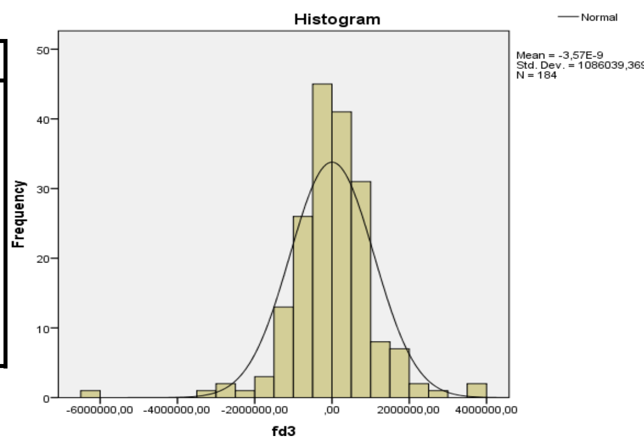
5.4.2.4 Normality Test

One-Sample Kolmogorov-Smirnov Test

		Model 3
N		184
Normal Parameters[a,b]	Mean	,0000
	Std. Deviation	1086039,36873
Most Extreme Differences	Absolute	,093
	Positive	,088
	Negative	-,093
Kolmogorov-Smirnov Z		1,256
Asymp. Sig. (2-tailed)		,085

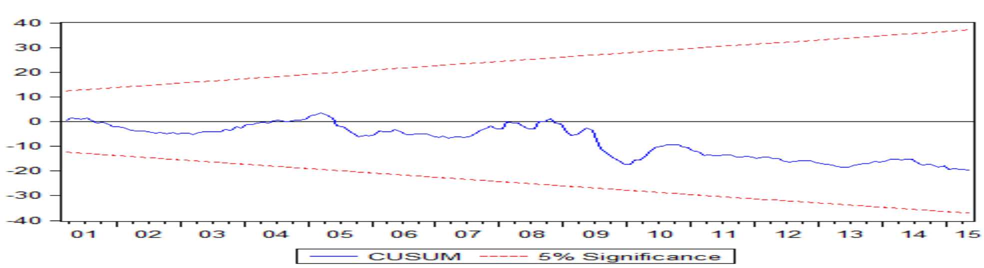
a. Test distribution is Normal.

b. Calculated from data.



The histogram of the residuals indicates that there is normality. This can be verified by the Kolmogorov-Smirnov Test, from which we notice that p-value=0,085 is more than 5%. The null hypothesis is not rejected, and the residuals are normal.

5.4.2.5 CUSUM Test



The CUSUM test indicates that the model's variables keep their stability throughout the tested period.

5.4.3 ARMA Model

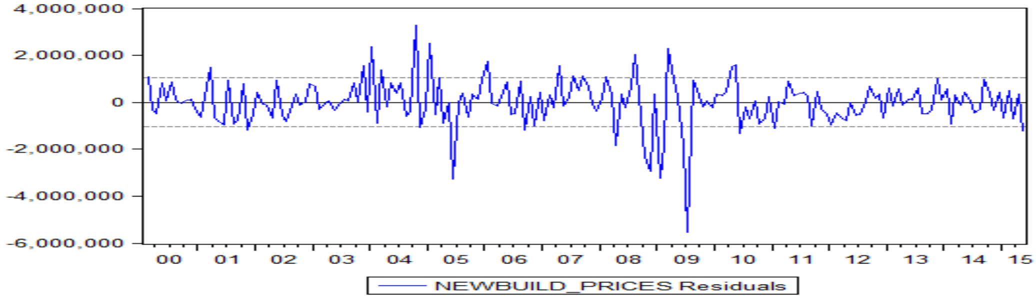
In the newbuilding market model of Aframax tankers, the best ARMA model was the ARMA (7, 6) which has AIC=30.66810. The modes is statistically significant and the regression is demonstrated below.

Dependent Variable: NEWBUILD_PRICES
Method: ARMA Maximum Likelihood (OPG - BHHH)
Included observations: 184
Convergence not achieved after 500 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	105757.9	224815.0	0.470422	0.6387
AR(1)	0.009687	0.200824	0.048234	0.9616
AR(2)	1.182148	0.170227	6.944554	0.0000
AR(3)	0.154952	0.358230	0.432548	0.6659
AR(4)	-0.049918	0.321776	-0.155132	0.8769
AR(5)	-0.584089	0.308830	-1.891299	0.0603
AR(6)	-0.358615	0.186789	-1.919900	0.0566
AR(7)	0.272121	0.135938	2.001800	0.0469
MA(1)	0.454168	1.002508	0.453032	0.6511
MA(2)	-0.872783	1.152233	-0.757471	0.4498
MA(3)	-0.481035	0.305288	-1.575678	0.1170
MA(4)	-0.416778	0.688288	-0.605528	0.5456
MA(5)	0.445495	1.193562	0.373248	0.7094
MA(6)	0.825026	0.756426	1.090690	0.2770
SIGMASQ	9.93E+11	8.61E+11	1.152976	0.2505

R-squared	0.427007	Mean dependent var	103260.9
Adjusted R-squared	0.379540	S.D. dependent var	1320111.
S.E. of regression	1039843.	Akaike info criterion	30.66810
Sum squared resid	1.83E+14	Schwarz criterion	30.93019
Log likelihood	-2806.465	Hannan-Quinn criter.	30.77433
F-statistic	8.995881	Durbin-Watson stat	1.986292
Prob(F-statistic)	0.000000		

Only two variables are significant at 5% significance level, while four variables are significant at 10% significance level. The model's fit is average, and it is characterized by non-normality. According to the correlogram of the residuals no autocorrelation exists. Appendix 5 contains all the aforementioned tests. The below graph presents the fluctuations of the residuals:



5.4.4 ARCH Model

The AIC for the lag selection implied that the appropriate number of lags is 2. We check the residuals' graph and conduct the ARCH test to examine if there is ARCH effect in the best ARMA model. The result is illustrated:

Heteroskedasticity Test: ARCH

F-statistic	0.985895	Prob. F(2,179)	0.3751
Obs*R-squared	1.982994	Prob. Chi-Square(2)	0.3710

It is observed that p-value=0.3710. We do not reject the null hypothesis, which mentions that there is not ARCH effect. As a result, we will not continue with the estimation of the ARCH family models.

5.4.5 VEC Model

In the Vector Error Correction model, the causality is expressed by dynamics. The variables adjust to deviations from the equilibrium, and there are variables that bear the main burden of this adjustment and others that not adjust at all. In general, VEC model includes error correction characteristics to a multi factor model such as VAR.

In order to estimate a VEC model, we have to meet some requirements. First of all, VEC model automatically converts the variables in their first differences, which must be stationary. As a result, we run VEC model with the original data, and the model transforms the data to their first differences. We already, applied ADF test in chapter 4, and we resulted that the variables are stationary in their first differences. Then, we have to select the appropriate number of lags and run the Johansen Cointegration test. Both, lag selection and JC test were applied in chapter 4 and the results are depicted in appendix 2. The lag selection process signifies 2 lags, while 6 cointegrating equations are indicated at 5% significance level. All the requirements are being met, and we can estimate the VEC model. The analysis of the model is too large to be included in this thesis, but it can be available by the author upon request.

From the results, we estimate the equation with dependent variable the newbuilding prices. The regression is presented in appendix 9. The six cointegrating equations displayed are the error correction terms, which can be also defined as speed of adjustment towards long run equilibrium. We have long run causality if the coefficient of the error correction term is negative and its p-value is statistically significant at 5% significance level. From the 6 equations, only one has negative coefficient and p-value less than 5%. These means that there is one correction term, in which the variables have long run causality on newbuilding prices of Aframax tankers.
Additionally, we have to define if short run causality exists. For this reason, we will apply Wald test to the variables of every coefficient. For example we have C(9)*second_prices(-1) and C(10)*second_prices(-2). The (-1) and (-2) are the lags, while C(9) and C(10) are the coefficients. In order to apply Wald test we set the null hypothesis C(9)=C(10)=0. The results of the Wald test for second-hand prices are presented:

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	1.150622	(2, 149)	0.3192
Chi-square	2.301245	2	0.3164

Null Hypothesis: C(9)=C(10)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(9)	0.065002	0.046117
C(10)	0.034951	0.045274

Restrictions are linear in coefficients.

Since, p-value=0.3164 we accept the null hypothesis. This means that C(9) and C(10) jointly cannot affect newbuilding prices, thus there is no short run causality coming from second-hand prices to newbuilding prices of Aframax tankers. We follow the same process for all the variables, and the Wald tests for the rest variables can be available by the author upon request. The results signify that only for time charter rates of 1 year and oil prices there is short run causality to newbuilding prices.

Finally, we must test the model specifications to check if our regression model is valid. Thus, we conduct Breusch-Godfrey Serial Correlation LM test, ARCH test for ARCH effect and normality test. The results, which are included in appendix 9 illustrate that there is no ARCH effect and correlation in our model. However, the normality test is not satisfied. This creates us some doubts about the model, but we can still accept it.

5.5 Model 4 Second-hand Market VLCC-ULCC category

VLCC-ULCC crude tanker model of the second-hand market is investigated below.

5.5.1 Model 4 Assessment

Similarly with the newbuilding market for ULCC-VLCC, we run the model with either earnings or spot rates, and concluded that the model with spot rates gives better results. We cannot include them both because multicollinearity exists. As a result we drop earnings, which also has higher p-value.

Dependent Variable: SECOND_PRICES
Method: Least Squares
Date: 07/25/15 Time: 13:32
Sample (adjusted): 2000M02 2015M05
Included observations: 184 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NEWBUILD_PRICES	0.688297	0.133615	5.151335	0.0000
TIMECHARTER1	578.7717	92.29282	6.271038	0.0000
SPOT	-28529.90	14842.03	-1.922237	0.0562
ORDERBOOK	483142.6	235877.8	2.048275	0.0420
OIL_PROD	0.242009	0.382396	0.632875	0.5276
OIL_PRICE	176421.3	52586.68	3.354868	0.0010
LIBOR	-3902483.	1397916.	-2.791642	0.0058
INFLATION	-25047678	1.05E+08	-0.238257	0.8120
GDP	5212286.	1050290.	4.962710	0.0000
C	-208998.0	274591.5	-0.761123	0.4476

R-squared	0.456349	Mean dependent var	130434.8
Adjusted R-squared	0.428229	S.D. dependent var	4753986.
S.E. of regression	3594753.	Akaike info criterion	33.08066
Sum squared resid	2.25E+15	Schwarz criterion	33.25539
Log likelihood	-3033.421	Hannan-Quinn criter.	33.15148
F-statistic	16.22867	Durbin-Watson stat	2.189053
Prob(F-statistic)	0.000000		

We reject the null hypothesis that all the coefficients are equal to 0. As a result, the model has some validity at 5% significance level. R^2 defines that 45% of the variation of second-hand prices is explained by the model. The independent variables that are significant and affect the dependent variable are the newbuilding prices, the time charter rates of 1 year, the orderbook as percentage of the fleet, the oil prices, the LIBOR and the GDP. The result of the regression analysis signifies that spot rates almost became significant. Specifically, a 1% increase of LIBOR will decrease the second-hand prices of VLCC-ULCC tankers by 3,902,483 $, keeping the other independent variables fixed.

5.5.2 Diagnostic Tests

5.5.2.1 Multicollinearity Test

	NEWBUILD_P	TIMECHARTE	SPOT	ORDERBOOK	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
NEWBUILD_P	1.000000	0.104983	-0.017612	0.253854	0.063676	0.114558	0.314105	0.198655	-0.067740
TIMECHARTE	0.104983	1.000000	0.692062	0.032854	0.114385	0.090617	0.209783	0.113113	-0.072720
SPOT	-0.017612	0.692062	1.000000	0.005801	0.085674	0.118484	0.161977	0.057469	-0.020009
ORDERBOOK	0.253854	0.032854	0.005801	1.000000	-0.026345	0.007802	0.105996	0.105095	-0.189328
OIL_PROD	0.063676	0.114385	0.085674	-0.026345	1.000000	0.040263	-0.064293	0.091681	0.189423
OIL_PRICE	0.114558	0.090617	0.118484	0.007802	0.040263	1.000000	0.066195	0.507805	0.184344
LIBOR	0.314105	0.209783	0.161977	0.105996	-0.064293	0.066195	1.000000	0.159686	-0.054721
INFLATION	0.198655	0.113113	0.057469	0.105095	0.091681	0.507805	0.159686	1.000000	0.016149
GDP	-0.067740	-0.072720	-0.020009	-0.189328	0.189423	0.184344	-0.054721	0.016149	1.000000

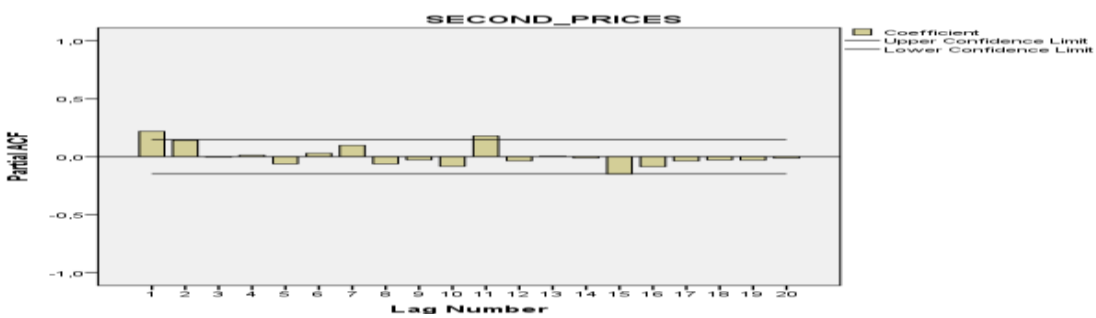
After running the equation for multicollinearity, we can notice that our independent variables are not highly correlated, and no multicollinearity exists.

5.5.2.2 Heteroscedasticity Test

		Levene's Test for Equality of Variances	
		F	Sig.
Model 4	Equal variances assumed	0,208	,649
	Equal variances not assumed		

Our model is homoscedastic. We can observe that p-value=0.649, thus we are confident to approve the null hypothesis that homoscedasticity exists.

5.5.2.3 Autocorrelation Test



The graph signifies that there is stationarity. We reject the alternative hypothesis and approve the null hypothesis, which states that there is not autocorrelation.

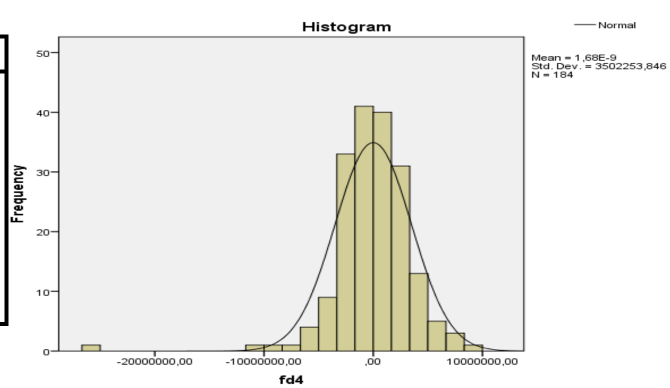
5.5.2.4 Normality Test

One-Sample Kolmogorov-Smirnov Test

		Model 4
N		184
Normal Parameters[a,b]	Mean	,0000
	Std. Deviation	3502253,84632
Most Extreme Differences	Absolute	,106
	Positive	,067
	Negative	-,106
Kolmogorov-Smirnov Z		1,438
Asymp. Sig. (2-tailed)		,032

a. Test distribution is Normal.

b. Calculated from data.



The histogram depicts normality. However, from the Kolmogorov-Smirnov Test we reject the null hypothesis because p-value=0.032 which is lower than the 5% significance level. We remove the extreme value 105 and repeat the test. The results which are illustrated below, signify that normality exists. We will further estimate the model without this extreme value.

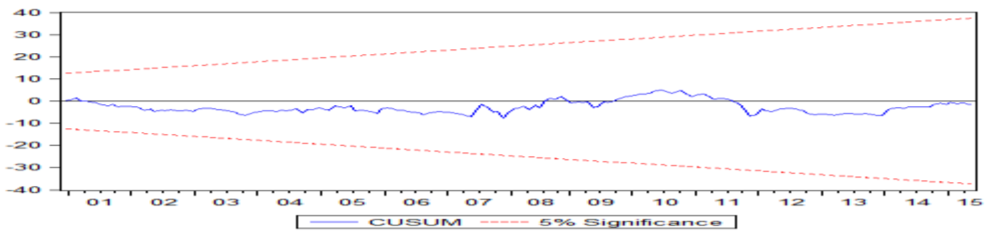
One-Sample Kolmogorov-Smirnov Test

		Model 4
N		183
Normal Parameters[a,b]	Mean	140252,8589
	Std. Deviation	2948533,58965
Most Extreme Differences	Absolute	,058
	Positive	,051
	Negative	-,058
Kolmogorov-Smirnov Z		,789
Asymp. Sig. (2-tailed)		,563

a. Test distribution is Normal.

b. Calculated from data.

5.5.2.5 CUSUM Test



The variables' stability is verified by the above graph. It is observed that the variables fluctuate without exceeding the 5% significance interval.

5.5.3 ARMA Model

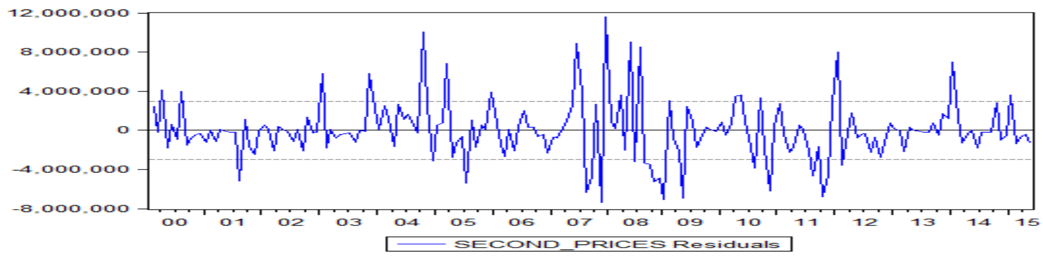
In model 4, after testing 64 times all the combinations of the autoregressive and moving average terms, the most suitable model is the ARMA (1, 1). The regression is as follows:

Dependent Variable: SECOND_PRICES
Method: ARMA Maximum Likelihood (OPG - BHHH)
Included observations: 183
Convergence achieved after 15 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	402884.9	434540.7	0.927151	0.3551
AR(1)	0.679625	0.115584	5.879923	0.0000
MA(1)	-0.414735	0.143509	-2.889958	0.0043
SIGMASQ	8.72E+12	6.48E+11	13.45791	0.0000

R-squared	0.116407	Mean dependent var	393442.6
Adjusted R-squared	0.101598	S.D. dependent var	3150678.
S.E. of regression	2986340.	Akaike info criterion	32.67941
Sum squared resid	1.60E+15	Schwarz criterion	32.74956
Log likelihood	-2986.166	Hannan-Quinn criter.	32.70785
F-statistic	7.860664	Durbin-Watson stat	2.022160
Prob(F-statistic)	0.000059		

The model appears to be valid and its fit is bad. Only the 11.64% of the variation of second-hand prices of VLCC and ULCC tanker vessels is explained by the model. It is demonstrated that apart from C, all the independent variables are significant.
From the diagnostic tests, no autocorrelation exists at 5% significance level. The normality is not satisfied in this model probably due to the large number of observations. Appendix 5 exposes the diagnostic tests' results. The residuals are displayed below:



5.5.4 ARCH Model

First of all, the lag number is defined to be 2. After a brief examination of the residuals' graph in the best ARMA which was estimated previously, we apply the ARCH test:

Heteroskedasticity Test: ARCH

F-statistic	2.747724	Prob. F(2,178)	0.0668
Obs*R-squared	5.420714	Prob. Chi-Square(2)	0.0665

At 5% there is no ARCH effect, but we reject the null hypothesis at 10% significance level. We will assume that our significance level is 10% and we will continue with the estimation of the ARCH family models. The 9 possible combinations indicate that ARCH (7) is the best model. The regression analysis is depicted:

Dependent Variable: SECOND_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 183 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2 + C(7)*RESID(-5)^2 + C(8)*RESID(-6)^2 + C(9) *RESID(-7)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	201770.2	133547.7	1.510847	0.1308
		Variance Equation		
C	4.82E+12	5.46E+11	8.829425	0.0000
RESID(-1)^2	0.158069	0.070554	2.240387	0.0251
RESID(-2)^2	0.164114	0.054486	3.012052	0.0026
RESID(-3)^2	0.018569	0.039457	0.470615	0.6379
RESID(-4)^2	0.113397	0.071024	1.596598	0.1104
RESID(-5)^2	0.123127	0.053902	2.284297	0.0224
RESID(-6)^2	-0.065468	0.031906	-2.051912	0.0402
RESID(-7)^2	-0.069690	0.020103	-3.466710	0.0005

R-squared	-0.003721	Mean dependent var	393442.6
Adjusted R-squared	-0.003721	S.D. dependent var	3150678.
S.E. of regression	3156535.	Akaike info criterion	32.61183
Sum squared resid	1.81E+15	Schwarz criterion	32.76967
Log likelihood	-2974.983	Hannan-Quinn criter.	32.67581
Durbin-Watson stat	1.378354		

It is detected that 5 ARCH variables are significant. This implies that the second-hand prices of VLCC-ULCC tankers are affected by external shocks and effects.

The normality is not satisfied in this model, but this is not considered an important problem as it is usual in large samples. Nevertheless, the model is homoscedastic and no autocorrelation exists in the residuals. Appendix 6 contains all the aforementioned tests.

5.5.5 GARCH Model

The inspection of all 81 possible combinations of ARCH and GARCH orders, concluded that GARCH (5, 2) is the model with the lowest AIC and the most significant variables.

Dependent Variable: SECOND_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 183 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2 + C(7)*RESID(-5)^2 + C(8)*GARCH(-1) + C(9) *GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	129265.3	105473.1	1.225576	0.2204
		Variance Equation		
C	3.55E+12	8.92E+11	3.976713	0.0001
RESID(-1)^2	0.186991	0.071075	2.630877	0.0085
RESID(-2)^2	0.100206	0.067015	1.495278	0.1348
RESID(-3)^2	0.027689	0.033682	0.822078	0.4110
RESID(-4)^2	0.187007	0.096300	1.941920	0.0521
RESID(-5)^2	0.191118	0.098252	1.945188	0.0518
GARCH(-1)	0.177829	0.236284	0.752609	0.4517
GARCH(-2)	-0.255929	0.095787	-2.671860	0.0075

R-squared	-0.007069	Mean dependent var	393442.6
Adjusted R-squared	-0.007069	S.D. dependent var	3150678.
S.E. of regression	3161794.	Akaike info criterion	32.63864
Sum squared resid	1.82E+15	Schwarz criterion	32.79649
Log likelihood	-2977.436	Hannan-Quinn criter.	32.70262
Durbin-Watson stat	1.373772		

One GARCH and three ARCH variables are statistically significant at 10% significant level. Their values demonstrate how much the external shocks affect the second-hand prices of VLCC and ULCC tankers. On the other hand, their coefficients' sum (0.3) which is less than 1 illustrates that their importance in the formulation of the variance value of all previous disrupting terms' observations is descending. The model' residuals are homoscedastic and not auto-correlated. The normality is not satisfied in this model. Appendix 7 concentrates the above diagnostic tests.

5.5.6 E-GARCH Model

After careful consideration, it is entailed that E-GARCH (5, 4, 1) is the most suitable model. Its regression analysis is illustrated below:

Dependent Variable: SECOND_PRICES
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Included observations: 183 after adjustments
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)
*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*ABS(RESID(-3)
/@SQRT(GARCH(-3))) + C(6)*ABS(RESID(-4)/@SQRT(GARCH(-4))) +
C(7)*ABS(RESID(-5)/@SQRT(GARCH(-5))) + C(8)*RESID(-1)
/@SQRT(GARCH(-1)) + C(9)*LOG(GARCH(-1)) + C(10)*LOG(GARCH(
-2)) + C(11)*LOG(GARCH(-3)) + C(12)*LOG(GARCH(-4))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	81945.10	50034.52	1.637771	0.1015
		Variance Equation		
C(2)	38.30017	5.6E-103	6.9E+103	0.0000
C(3)	0.235846	0.139699	1.688241	0.0914
C(4)	0.282544	0.153940	1.835419	0.0664
C(5)	0.593556	0.115216	5.151661	0.0000
C(6)	1.046776	0.135127	7.746582	0.0000
C(7)	0.297066	0.127654	2.327111	0.0200
C(8)	0.110507	0.078725	1.403718	0.1604
C(9)	0.210095	0.000716	293.6281	0.0000
C(10)	0.020183	0.027611	0.730969	0.4648
C(11)	-0.342433	0.004629	-73.97764	0.0000
C(12)	-0.249043	0.023164	-10.75111	0.0000

R-squared	-0.009828	Mean dependent var	393442.6
Adjusted R-squared	-0.009828	S.D. dependent var	3150678.
S.E. of regression	3166123.	Akaike info criterion	32.44457
Sum squared resid	1.82E+15	Schwarz criterion	32.65503
Log likelihood	-2956.678	Hannan-Quinn criter.	32.52988
Durbin-Watson stat	1.370018		

Most of the variables are statistically significant, and from this we can conclude that the volatility in the returns of the second-hand Aframax crude tankers it is critically affected by the asymmetric effects of the past. The diagnostic tests signify that the model is homoscedastic. We also approve the null hypothesis for autocorrelation, thus no autocorrelation exists in the error terms. The normality's test is not satisfied in this model. The tables of the diagnostic tests are presented in appendix 8.

<u>5.5.7 VAR Model</u>

The lag estimation process indicates that 2 lags are the most suitable number, according to AIC. There is not autocorrelation in the residuals, which means that the VAR (1, 2) itself is adequate to model the time series dynamics. The tests and the regression analysis are not included because of their large size but they can be made available by the author upon request.

The model's fit is low and only 35% of the variation can be explained by the model. It is demonstrated that newbuilding prices of the last two months are statistically significant to the VLCC-ULCC second-hand prices of this period. The F-statistic of the time charter rates of the previous period is also above two, which indicates its significance to second-hand prices. There are no other variables that have an impact in the estimation of the current month's VLCC-ULCC second-hand prices.

5.6 Model 5 Second-hand Market Suezmax category

Model's 5 data analysis and results are presented in this subchapter.

5.6.1 Model 5 Assessment

Dependent Variable: SECOND_PRICES
Method: Least Squares
Date: 07/24/15 Time: 03:00
Sample (adjusted): 2000M02 2015M05
Included observations: 184 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NEWBUILD_PRICES	0.602574	0.135488	4.447440	0.0000
TIMECHARTER1	507.4774	99.89100	5.080311	0.0000
SPOT	-24307.64	21751.35	-1.117523	0.2653
ORDERBOOK	113085.6	140209.2	0.806549	0.4210
EARNINGS	33.64379	37.86093	0.888615	0.3754
OIL_PROD	0.552282	0.254528	2.169826	0.0314
OIL_PRICE	34073.59	35459.20	0.960924	0.3379
LIBOR	-2621405.	906963.0	-2.890310	0.0043
INFLATION	31175578	70440378	0.442581	0.6586
GDP	2858328.	706042.8	4.048378	0.0001
C	-131704.2	183202.5	-0.718899	0.4732

R-squared	0.379607	Mean dependent var	125000.0
Adjusted R-squared	0.343746	S.D. dependent var	2951451.
S.E. of regression	2390956.	Akaike info criterion	32.27021
Sum squared resid	9.89E+14	Schwarz criterion	32.46240
Log likelihood	-2957.859	Hannan-Quinn criter.	32.34811
F-statistic	10.58554	Durbin-Watson stat	2.009260
Prob(F-statistic)	0.000000		

This model is statistically significant and this can be derived from the high value of F-statistic as well as the low price of the p-value (F-statistic) which is less than 5%. Thus we approve the alternative hypothesis that at least one coefficient of the independent variables is other than zero. The coefficient of determination demonstrates that 37.96% of the second-hand prices are explained by the model, whereas the rest 62.04% remains unexplained. Newbuilding prices, time charter rates of 1 year, oil production, LIBOR and GDP are linearly related to the dependent variable because their p-value is less than 0.05, thus rejecting the null hypothesis that their coefficient is 0.

5.6.2 Diagnostic Tests

5.6.2.1 Multicollinearity Test

	NEWBUILD_P	TIMECHARTE	SPOT	ORDERBOOK	EARNINGS	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
NEWBUILD_P	1.000000	0.283934	0.138726	0.150428	0.091883	0.116552	0.106780	0.268467	0.212169	0.035699
TIMECHARTE	0.283934	1.000000	0.554924	0.092290	0.468451	0.033683	0.022092	0.193356	0.120871	-0.107476
SPOT	0.138726	0.554924	1.000000	-0.076886	0.949289	0.057092	0.101575	0.121244	0.047707	-0.105796
ORDERBOOK	0.150428	0.092290	-0.076886	1.000000	-0.051696	0.025480	-0.081337	0.059328	0.019811	-0.116284
EARNINGS	0.091883	0.468451	0.949289	-0.051696	1.000000	0.016317	0.047003	0.089899	0.021729	-0.166425
OIL_PROD	0.116552	0.033683	0.057092	0.025480	0.016317	1.000000	0.040263	-0.064293	0.091681	0.189423
OIL_PRICE	0.106780	0.022092	0.101575	-0.081337	0.047003	0.040263	1.000000	0.066195	0.507805	0.184344
LIBOR	0.268467	0.193356	0.121244	0.059328	0.089899	-0.064293	0.066195	1.000000	0.159686	-0.054721
INFLATION	0.212169	0.120871	0.047707	0.019811	0.021729	0.091681	0.507805	0.159686	1.000000	0.016149
GDP	0.035699	-0.107476	-0.105796	-0.116284	-0.166425	0.189423	0.184344	-0.054721	0.016149	1.000000

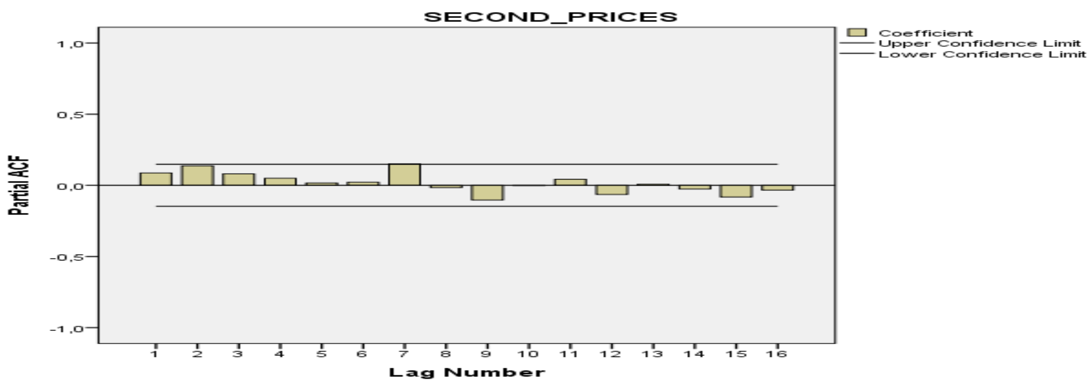
In this model earnings and spot rates are highly correlated. Nevertheless, they do not exceed the 95% limit. We run the regression without earnings, but the p-value of spot rates does not change significantly, thus we will not drop any of these two variables. No multicollinearity occurs in our model.

5.6.2.2 Heteroscedasticity Test

		Levene's Test for Equality of Variances	
		F	Sig.
Model 5	Equal variances assumed	,270	,604
	Equal variances not assumed		

Our residuals are homoscedastic, and this can be clarified by the Sig=0.604 which is more than 0.05 at 5% significance level.

5.6.2.3 Autocorrelation Test



We can notice that there are no observations that exceed the limits. Consequently, there is no autocorrelation in our model and stationarity exists.

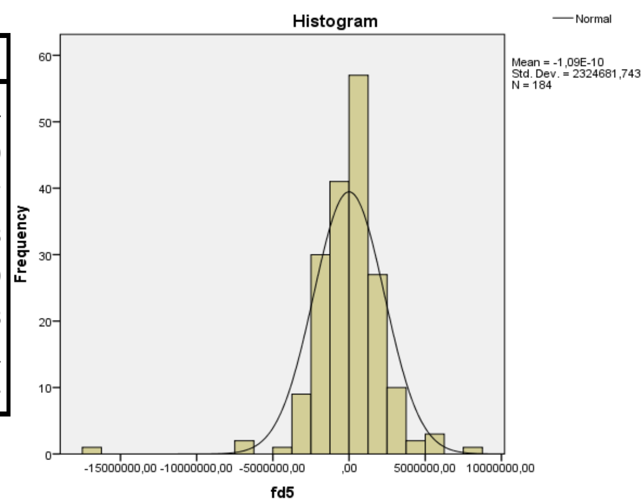
5.6.2.4 Normality Test

One-Sample Kolmogorov-Smirnov Test

		Model 5
N		184
Normal Parameters[a,b]	Mean	,0000
	Std. Deviation	2324681,74317
Most Extreme Differences	Absolute	,098
	Positive	,069
	Negative	-,098
Kolmogorov-Smirnov Z		1,334
Asymp. Sig. (2-tailed)		,057

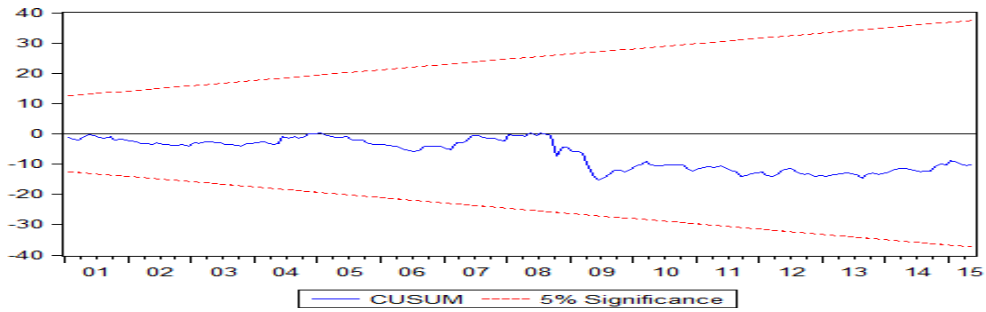
a. Test distribution is Normal.

b. Calculated from data.



The normality of model 5 is not violated, as can be derived from the Kolmogorov-Smirnov Test but also from the histogram of the residuals. We approve the null hypothesis that normality exists.

5.6.2.5 CUSUM Test



The graph reveals that the variables retain their stability, at 5% significance interval, during the sample period.

5.6.3 ARMA Model

In this case, ARMA (1, 1) has the lowest AIC value. However, it was not valid and our next selection is the ARMA (3, 3). The regression of this model is illustrated below:

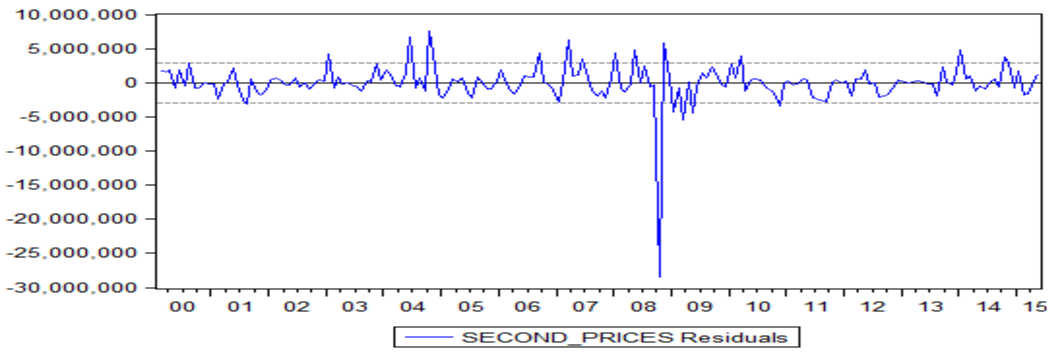
Dependent Variable: SECOND_PRICES
Method: ARMA Maximum Likelihood (OPG - BHHH)
Included observations: 184
Convergence not achieved after 500 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	158567.8	552012.9	0.287254	0.7743
AR(1)	1.298319	0.224488	5.783474	0.0000
AR(2)	-1.284042	0.140139	-9.162622	0.0000
AR(3)	0.767625	0.190683	4.025666	0.0001
MA(1)	-1.227160	0.245389	-5.000872	0.0000
MA(2)	1.346704	0.197517	6.818175	0.0000
MA(3)	-0.752677	0.252067	-2.986018	0.0032
SIGMASQ	8.02E+12	1.03E+12	7.760863	0.0000

R-squared	0.074512	Mean dependent var	125000.0
Adjusted R-squared	0.037702	S.D. dependent var	2951451.
S.E. of regression	2895278.	Akaike info criterion	32.64984
Sum squared resid	1.48E+15	Schwarz criterion	32.78962
Log likelihood	-2995.786	Hannan-Quinn criter.	32.70650
F-statistic	2.024266	Durbin-Watson stat	2.043376
Prob(F-statistic)	0.054480		

Inverted AR Roots	.85	.22-.92i	.22+.92i
Inverted MA Roots	.76	.23+.97i	.23-.97i

The fit of this model is bad. Nevertheless, only C is insignificant and the rest seven independent variables are statistically significant. The null hypothesis is approved in the autocorrelation test. As a result, there is no autocorrelation in the residuals. Finally, the normality test is not valid, but this is not considered to be an important problem. Appendix 5 contains all the diagnostic tables. The graph below presents the residuals:



5.6.4 ARCH Model

The appropriate number of lags is 2. Moreover, the residuals' graph does not illustrate that periods of high volatility are followed by periods of high volatility and vice versa. We also apply the ARCH test and the results are depicted below:

Heteroskedasticity Test: ARCH

F-statistic	0.078430	Prob. F(2,179)	0.9246
Obs*R-squared	0.159350	Prob. Chi-Square(2)	0.9234

From the high p-value=0.9234 it is implied that there is no ARCH effect. Both methods suggest that we cannot continue with the estimation of the ARCH family models.

5.6.5 VEC Model

In chapter 4, we found that the variables are stationary when converted to their first differences. We also found that 2 is the suitable lag number, while the JC test indicated 3 cointegrating equations. As a result, we are authorized to apply the VEC model. Because of the large VEC model's table size and the big number of Wald tests (due the big number of variables) we will not include them in our thesis, but they are available by the author upon request.

It is illustrated from the estimated equation with the Least Squares method with dependent variable the second-hand prices of Suezmax tankers (appendix 9), that from the three cointegrating equations only one is statistically significant with negative coefficient. This means that there is one error correction term in which the variables has a long run causality on second-hand prices of Aframax crude tankers.

We conduct the Wald test, and define that there is short run causality from oil prices and GDP to second-hand prices of Aframax tankers. Moreover, the ARCH test signifies that there is no ARCH effect. Nevertheless, our model seems to be correlated and the non-normal (Appendix 9). The results specify that the regression model is not good.

5.7 Model 6 Second-hand Market Aframax category

The second-hand market model of the Aframax category is examined as follows.

5.7.1 Model 6 Assessment

Dependent Variable: SECOND_PRICES
Method: Least Squares
Date: 07/24/15 Time: 03:01
Sample (adjusted): 2000M02 2015M05
Included observations: 184 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NEWBUILD_PRICES	0.404657	0.124107	3.260552	0.0013
TIMECHARTER1	572.7034	135.7539	4.218689	0.0000
SPOT	-5693.444	16111.66	-0.353374	0.7242
ORDERBOOK	221870.7	172543.8	1.285880	0.2002
EARNINGS	-10.40086	43.07824	-0.241441	0.8095
OIL_PROD	0.214029	0.211687	1.011064	0.3134
OIL_PRICE	43389.67	29583.37	1.466691	0.1443
LIBOR	-799814.7	757535.2	-1.055812	0.2925
INFLATION	15035701	58541663	0.256838	0.7976
GDP	1918957.	583812.0	3.286944	0.0012
C	-35182.70	151684.4	-0.231947	0.8169

R-squared	0.261728	Mean dependent var	103260.9
Adjusted R-squared	0.219053	S.D. dependent var	2238557.
S.E. of regression	1978240.	Akaike info criterion	31.89123
Sum squared resid	6.77E+14	Schwarz criterion	32.08343
Log likelihood	-2922.994	Hannan-Quinn criter.	31.96913
F-statistic	6.133085	Durbin-Watson stat	2.255823
Prob(F-statistic)	0.000000		

From the results and especially from Prob (F-statistic), we approve the alternative hypothesis that at least one coefficient of the independent variables is not equal to 0. This points out that our model have some validity. R^2 reveals that 26.17% of the second-hand prices are explained by the model. The rest 73.83% remains unknown. An increase of 1% in the GDP will increase the second-hand prices by 1,918,957 $. Newbuilding prices, time charter rates of 1 year and GDP are statistically significant and linearly related to the second-hand prices of the Aframax tankers, while weak relationship exists among the dependent variable and the oil prices and the orderbook as percentage of the fleet. There is not enough evidence at 5% significance level that the rest independent variables are linearly related with second-hand prices.

5.7.2 Diagnostic Tests

5.7.2.1 Multicollinearity Test

	NEWBUILD_P	TIMECHARTE	SPOT	ORDERBOOK	EARNINGS	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
NEWBUILD_P	1.000000	0.214267	0.195096	0.244859	0.196403	0.079384	0.098560	0.257648	0.257834	-0.037969
TIMECHARTE	0.214267	1.000000	0.501091	0.051593	0.396245	0.113020	0.062390	0.243511	0.137469	-0.179652
SPOT	0.195096	0.501091	1.000000	0.021972	0.940827	0.071438	0.103485	0.134346	0.122001	-0.067378
ORDERBOOK	0.244859	0.051593	0.021972	1.000000	0.043710	-0.091187	0.057739	0.004181	0.065935	-0.136140
EARNINGS	0.196403	0.396245	0.940827	0.043710	1.000000	0.052603	0.018271	0.103048	0.087643	-0.091738
OIL_PROD	0.079384	0.113020	0.071438	-0.091187	0.052603	1.000000	0.040263	-0.064293	0.091681	0.189423
OIL_PRICE	0.098560	0.062390	0.103485	0.057739	0.018271	0.040263	1.000000	0.066195	0.507805	0.184344
LIBOR	0.257648	0.243511	0.134346	0.004181	0.103048	-0.064293	0.066195	1.000000	0.159686	-0.054721
INFLATION	0.257834	0.137469	0.122001	0.065935	0.087643	0.091681	0.507805	0.159686	1.000000	0.016149
GDP	-0.037969	-0.179652	-0.067378	-0.136140	-0.091738	0.189423	0.184344	-0.054721	0.016149	1.000000

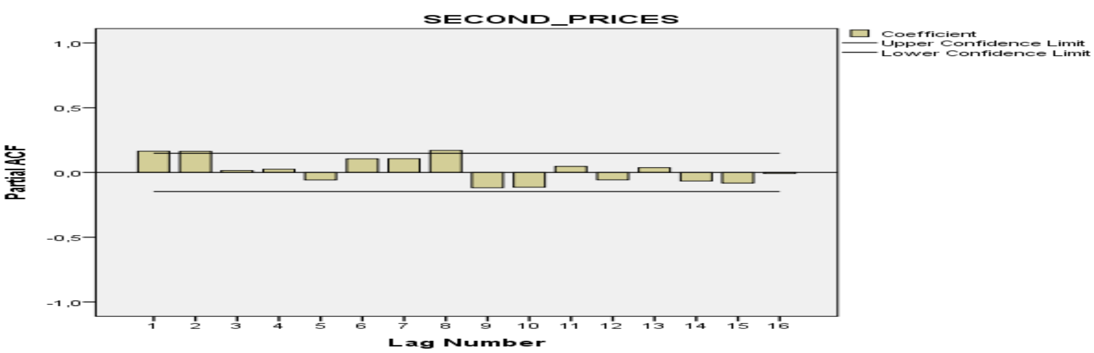
The independent variables are not correlated, since their correlation with one another does not surpass the 95% limit. Earnings and spot rates are again highly correlated, however if we drop earnings there is not considerable change in spot rates' p-value. No multicollinearity exists, and we will continue our analysis with the independent variables.

5.7.2.2 Heteroscedasticity Test

		Levene's Test for Equality of Variances	
		F	Sig.
Model 6	Equal variances assumed	,141	,708
	Equal variances not assumed		

The Sig in model 6 equals 0.708. That indicates that can reject the alternative hypothesis and approve the null hypothesis for homoscedasticity.

5.7.2.3 Autocorrelation Test



It is depicted from the graph that no autocorrelation exists. The model is stationary, since the majority of the residuals is within the limits. Thus, we approve the null that there is no autocorrelation.

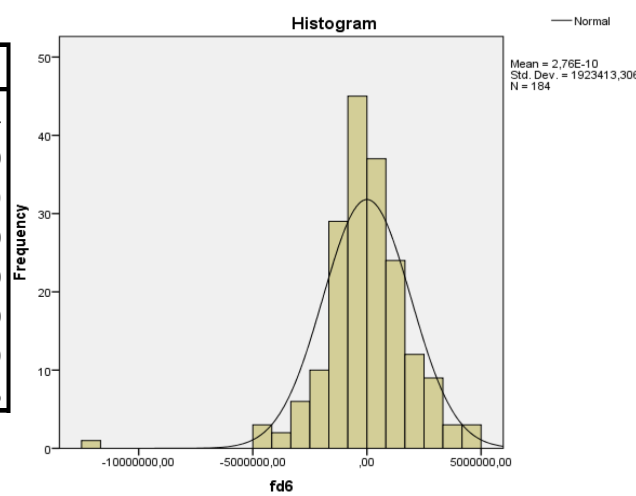
5.7.2.4 Normality Test

One-Sample Kolmogorov-Smirnov Test

		Model 6
N		184
Normal Parameters[a,b]	Mean	,0000
	Std. Deviation	1923413,30579
Most Extreme Differences	Absolute	,080
	Positive	,060
	Negative	-,080
Kolmogorov-Smirnov Z		1,079
Asymp. Sig. (2-tailed)		,195

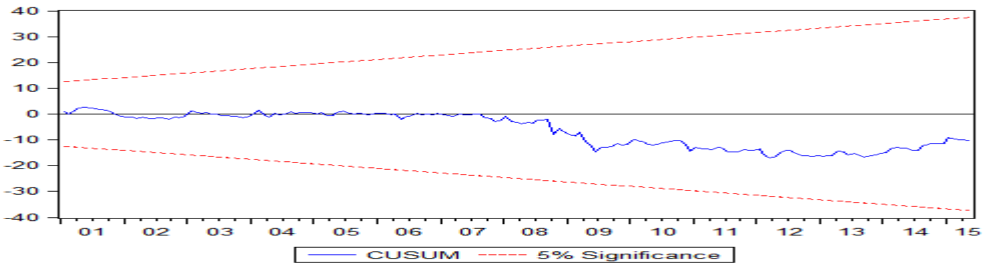
a. Test distribution is Normal.

b. Calculated from data.



The statistics indicate that we approve the null hypothesis at 5% significance level. Moreover, the histogram of the residuals is normal and confirms the null hypothesis that the model is normal.

5.7.2.5 CUSUM Test



It is illustrated that the variables are within the upper and lower limits at 5% significance level. As a result, their stability is being preserved.

5.7.3 ARMA Model

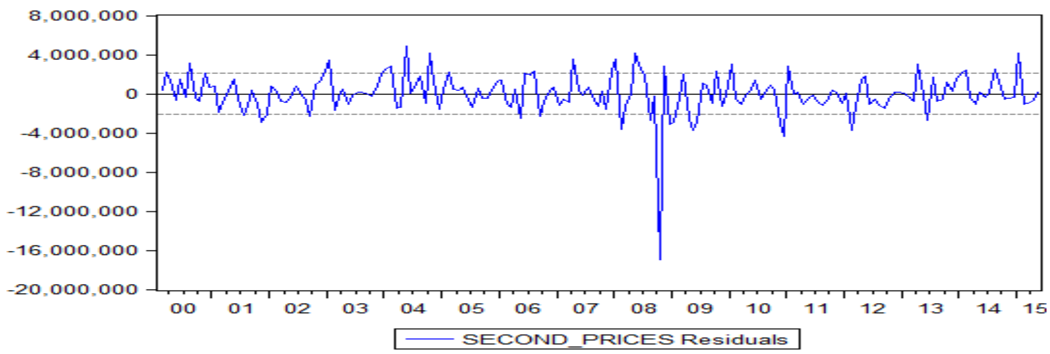
After testing 64 possible combinations of p and q, the model with the lowest AIC is the ARMA (2, 4). The AIC=32.04510 and the regression is depicted below.

Dependent Variable: SECOND_PRICES
Method: ARMA Maximum Likelihood (OPG - BHHH)
Included observations: 184
Convergence achieved after 111 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	112131.8	280135.5	0.400277	0.6894
AR(1)	0.203103	0.072377	2.806197	0.0056
AR(2)	-0.873520	0.055957	-15.61060	0.0000
MA(1)	-0.081087	2.638536	-0.030732	0.9755
MA(2)	1.113312	20.76368	0.053618	0.9573
MA(3)	0.194105	5.160238	0.037615	0.9700
MA(4)	0.205104	5.664838	0.036206	0.9712
SIGMASQ	4.31E+12	5.78E+13	0.074596	0.9406

R-squared	0.135102	Mean dependent var	103260.9
Adjusted R-squared	0.100702	S.D. dependent var	2238557.
S.E. of regression	2122853.	Akaike info criterion	32.04510
Sum squared resid	7.93E+14	Schwarz criterion	32.18488
Log likelihood	-2940.149	Hannan-Quinn criter.	32.10175
F-statistic	3.927446	Durbin-Watson stat	2.004121
Prob(F-statistic)	0.000524		

The model is statistically significant but it does not fit well. Only the 13.51% of the variation of second-hand prices of Aframax tankers can be explained by the model. Additionally, it is observed that only two independent variables are significant. Moreover, the correlogram of the residuals signifies that there is not autocorrelation at 5% significance level. The normality is not satisfied because of the large number of observations. Appendix 5 contains the tables and graphs of the diagnostic tests. The residuals' graph is illustrated:



5.7.4 ARCH Model

It was indicated that the suitable lags are 2. We conduct the ARCH test to check if there is ARCH effect in the best ARMA which was estimated previously.

Heteroskedasticity Test: ARCH

F-statistic	0.106003	Prob. F(2,179)	0.8995
Obs*R-squared	0.215304	Prob. Chi-Square(2)	0.8979

We cannot reject the null hypothesis at 5% significance level, thus there is no ARCH effect in our model. We will not continue with the estimation of the ARCH family models.

5.7.5 VEC Model

It is defined from chapter 4 that the variables are stationary in their first differences. Furthermore, the lag selection indicated 2 lags and the JC test resulted 6 cointegrating equations. Thus, we apply VEC model but its resulting table as well as the Wald tests, are not included due to their large size. However, they can be available by the author upon request.

We can see from the regression with dependent variable the second-hand prices (appendix 9) that three error terms are statistically significant with negative coefficient at 5% significance level. Consequently, there is long run causality from the independent variables to the second-hand prices of Aframax tankers. In other words, the independent variables are influencing second-hand prices in the long run.

From the Wald tests for every variable, we conclude that newbuilding prices, time charter rates of 1 year and oil prices influence the newbuilding prices in the short run or there is short run causality from these variables to the second-hand Aframax prices.

In order to check if the regression is valid, we apply ARCH test which results that there is not ARCH effect in our model. Moreover, no serial correlation exists but the normality criterion is not satisfied. However, we can still imply that our model if valid.

Chapter 6 Discussion

6.1 Introduction

In this chapter, the models' results will be concentrated and discussed. Specifically, the statistically significant variables will be mentioned. Moreover, ARMA, ARCH family models, VAR and VEC models will be compared according to the Akaike Information Criterion, and the best model will be selected. Finally, a description of the VAR and VEC models characteristics will be illustrated.

6.2 Model 1 Newbuilding Market VLCC-ULCC category

The newbuilding prices of VLCC-ULCC tankers are mainly affected by second-hand prices, steel prices, LIBOR and GDP. Multicollinearity occurs between earnings and spot rates, thus we drop earnings from our independent variables. The model is estimated with the least squares method, and it is valid. We signify that ARMA (1, 2) is the most appropriate and conclude that there is ARCH effect. Consequently, we estimate the ARCH family models. All possible combinations (according to EViews limits), were tested and resulted that the best models are the ARCH (4), GARCH (1, 1) and E-GARCH (4, 5, 1). We compare their AIC in order to find which of them is the most suitable to our research. The AIC results are depicted in table 8.

Table 8: Comparison of models based on AIC

	ARMA	ARCH	GARCH	E-GARCH	VAR
AIC	31.24893	31.29901	31.24594	31.12821	31.16317

Source: Compiled by author

E-GARCH, has the lowest AIC value. This means, that from E-GARCH we can define every price according to the previous with more reliability than the other models. Finally, we estimate VAR model with 4 lags. Newbuilding and second-hand prices, time charter rates, spot rates and oil prices of previous periods affect the current newbuilding prices of VLCC-ULCC crude carriers.

6.3 Model 2 Newbuilding Market Suezmax category

The regression analysis of Suezmax vessels, indicates that second-hand prices, steel prices and LIBOR are significant for the estimation of newbuilding prices at 5% significance level. ARMA (2, 1) appears to be the best, and the ARCH test illustrates that there is ARCH effect. Therefore, we estimate the ARCH family models to check if the newbuilding prices are affected by external shocks and previous asymmetric effects, as well as if the importance in the formulation of the variance value of all previous disrupting terms' observations is descending or ascending. ARCH (3), GARCH (2, 4) and E-GARCH (3, 8, 1) arise to be the most appropriate models with the lowest AIC and at the same time with valid diagnostic tests.

Table 9: Comparison of models based on AIC

	ARMA	ARCH	GARCH	E-GARCH	VAR
AIC	30.76304	30.82202	30.79146	30.66217	30.70264

Source: Compiled by author

From the AIC table above, it is demonstrated that E-GARCH is the most suitable model, with which we can proceed to forecast with less errors. In other words, there is a good relationship between the values formed over the periods, and it is quite useful for further research. The VAR (1, 4) is estimated and newbuilding and second-hand prices, steel prices, oil prices and LIBOR of previous months have T-statistics above 2, which means that they affect the newbuilding prices of Suezmax tankers.

6.4 Model 3 Newbuilding Market Aframax category

In the Aframax newbuilding market, it is illustrated that second-hand prices, orderbook as percentage of the fleet, steel prices, LIBOR and inflation have p-value below 5%. This indicates that they are statistically significant and influence the newbuilding prices of Aframax tankers. ARMA (7, 6) is the most applicable model, but the ARCH test results that the model has no ARCH effect. Consequently, we do not proceed with the estimation of the ARCH family models but we estimate the VEC model.

Table 10: Comparison of models based on AIC

	ARMA	VEC
AIC	30.66810	30.46833

Source: Compiled by author

The VEC model has the lowest AIC between these two, thus it is the most suitable model. Forecasts with less forecasting errors can be applied using this multivariate model. It is resulted that there is long run causality on newbuilding prices of Aframax vessels coming from the rest variables. Additionally, we check if there is short run causality. The outcome of the Wald tests illustrate that time charter rates of 1 year and oil prices cause effects in the short run to newbuilding prices of Aframax tankers.

6.5 Model 4 Second-hand Market VLCC-ULCC category

In the second-hand market of VLCC-ULCC tankers, we encountered that multicollinearity exists between earnings and spot rates. Consequently, we drop earnings from our model and repeat the regression. VLCC-ULCC tankers' second-hand prices are affected by many factors. More specifically, these are newbuilding prices, 1 years' time charter rates, spot rates, orderbook as percentage of the fleet, oil prices, LIBOR and GDP. ARCH test is conducted to ARMA (1, 1) which is the best combination, and it is found that there is ARCH effect in our model. As a result, ARCH (7), GARCH (5, 2) and E-GARCH (5, 4, 1) are the most appropriate models according to AIC value and diagnostic tests. Their AIC values are presented below:

Table 11: Comparison of models based on AIC

	ARMA	ARCH	GARCH	E-GARCH	VAR
AIC	32.67941	32.61183	32.63864	32.44457	32.55990

Source: Compiled by author

Similarly to model 1 and 2, E-GARCH is the autoregressive model with the lowest AIC. By using E-GARCH, we can predict second-hand prices of VLCC-ULCC tankers with more reliability and less forecasting errors. VAR (1, 2) is modelled and is signified that only newbuilding prices and time charter rates of the previous two months are significant and affect the second-hand prices of VLCC-ULCC tankers.

6.6 Model 5 Second-hand Market Suezmax category

The second-hand prices of Suezmax crude carriers are influenced by the newbuilding prices, time charter rates of 1 year, oil production as well as LIBOR and GDP at 5% significance level. ARMA (1, 1) has the lowest AIC, however the diagnostic tests indicate that it is not valid. Thus, we select ARMA (3, 3) which has the second lowest AIC and it is valid. The ARCH test indicates that there is no ARCH effect in our model, consequently we will only estimate VEC model.

Table 12: Comparison of models based on AIC

	ARMA	VEC
AIC	32.64984	32.45822

Source: Compiled by author

We compare ARMA (3, 3) and VEC and conclude that VEC has the lowest AIC value. Consequently, we will select this as the most appropriate model. It appears to be long run causality from the variables to the second-hand prices of Suezmax vessels. The Wald test demonstrates short run causality from oil prices and GDP to second-hand prices of Suezmax tankers. Nevertheless, the diagnostic tests indicate that our model is not valid.

6.7 Model 6 Second-hand Market Aframax category

The last category tested is the second-hand market of Aframax crude carries. Newbuilding prices, 1 years' time charter rates and GDP occur to be statistically significant and affect the second-hand prices of Aframax tankers. ARMA (2, 4) is the most appropriate model, and the ARCH test illustrates that there is no ARCH effect in this model. Thus, we estimate VEC model and conclude that three error correction terms are statistically significant. This means that there is long run causality from the variables to the second-hand prices. Moreover, Wald tests for every variable's coefficient signify that there is short run causality that comes from newbuilding prices, time charter rates and oil prices and affects the second-hand prices of Aframax crude carriers.

Table 13: Comparison of models based on AIC

	ARMA	VEC
AIC	32.04510	30.45769

Source: Compiled by author

Their comparison indicates that VEC has the smallest AIC value. We can use this model to forecast the second-hand prices of Aframax tankers with less forecasting errors.

Chapter 7 Conclusions and Recommendations

7.1 Conclusions

Taking everything into consideration, this thesis deals with the newbuilding and second-hand market of crude carriers. Three tanker categories are researched, and different models are estimated per category. Specifically, we research the VLCC-ULCC, the Suezmax and the Aframax tankers and analyze the factors that affect the shipowners' decisions to choose between newbuilding and second-hand crude carriers.

We build the econometric model starting from the academic literature review which, provides us with the appropriate variables for our newbuilding and second-hand models. It is signified that all variables are stationary to their first differences according to the ADF test and cointegrating equations exist in 6 models. All models are firstly estimated with the least squares method, and the significant variables for each tanker category are derived and summarized in chapter 6.

In order to answer the second sub-research question for the best econometric model, the appropriate ARMA model is estimated and it is further researched for ARCH effect. Newbuilding market models of VLCC-ULCC and Suezmax tankers as well as second-hand market model of VLCC-ULCC crude carriers reveal ARCH effect. ARCH family models are estimated for these three categories, and the results illustrate that our variables are vulnerable to external shocks and previous asymmetric effects. E-GARCH model appears to be the best in all three categories according to its AIC value. However, VAR model is also estimated for these categories and the variables of previous periods that affect our independent variables are illustrated in chapter 6.

The newbuilding market model of Aframax tankers and second-hand market model of Suezmax and Aframax crude carriers do not present ARCH effect. Thus, VEC model is estimated in this case. It is demonstrated that long run and short run causality exist in all three models to the dependent variable. VEC models result to have the lowest AIC values and thus they are the most suitable in order to proceed to forecast with less predicting errors. However, according to its diagnostic tests VEC model for second-hand Suezmax tankers is not valid.

Finally, always with respect to the main research question, we conclude that shipowners must have in mind the current economic situation as well as the current phase of the shipping cycle. More specifically, the newbuilding market of VLCC-ULCC tankers is influenced by second-hand prices, steel prices, GDP and LIBOR. Newbuilding prices of Suezmax crude carriers are affected by second-hand prices, steel prices and LIBOR, while the prices of new Aframax tankers are altered by second-hand prices, orderbook as percentage of the fleet, steel prices, LIBOR and inflation. We can infer that in the newbuilding market of crude carriers the most significant variables that affect all the tanker types are the second-hand prices, steel prices and LIBOR.

On the other side, the second-hand market of VLCC-ULCC crude tankers is mainly affected by newbuilding prices, time charter and spot rates, orderbook as percentage of the fleet, oil prices, LIBOR and GDP. The second-hand prices of Suezmax tankers are affected by newbuilding prices, time charter rates of 1 year, oil production, LIBOR and GDP. Moreover, the prices of used Aframax crude carriers are affected by newbuilding prices, time charter rates of 1 year and GDP.

Consequently, the most critical variables that affect all three tanker types in the Sale & Purchase market are the newbuilding prices, the 1 years' time charter rates and the GDP.

Thus, we come to the conclusion that the newbuilding and the second-hand market of crude carriers are inseparable, meaning that fluctuations in tanker prices of the one market directly affects the other market. Shipowners, must take into consideration all the factors discussed above and must proceed to forecasts using the E-GARCH models which found to be the most suitable. Buyers of second-hand vessels must detect the right time to conduct their investments. In order to do so, they do not only have to check the second-hand market but also the newbuilding market. Intense mobility in the newbuilding market will relatively affect the second-hand market of crude carriers. Charter rates increase as the price of the vessel increases. As a result, through this study charterers can forecast the vessel prices and find out the appropriate time to charter the vessels, thus increasing their revenues.

7.2 Limitations

This study was subject to a number of limitations. First of all, the time available for this research was limited and this affected the examined field. Moreover, we could not find available data before 2000, thus our study included data for 14 and a half years. It is not a short period, but long term economic and shipping cycles could not be taken into consideration. Furthermore, the economic indicators, inflation and GDP are only considered for the OECD countries. Different values across the world could arrive to different conclusions.

7.3 Recommendations for Further Research

An interesting recommendation for future research would be to examine and compare other vessel types such as bulks and containers. Then, we could compare the results with our finding and check whether or not the same variables affect all the markets. Moreover, we could forecast the newbuilding and second hand prices and conclude with the model with the least forecasting errors.

In addition, we could conduct a similar research to the second-hand market, but this time we could research second-hand prices of different ages and not only 5 year old vessels as used in this research. Furthermore, an analysis of the shipping markets could be implemented and their correlation could be estimated. We should add that scrap market are slightly researched until today, thus an analysis of the recycling market could add value to our study.

Bibliography

Alizadeh, A. and Nomikos, N. (2003). The price-volume relationship in the sale and purchase market for dry bulk vessels. *Maritime Policy & Management*, 30(4), pp.321-337.

Alizadeh, A. and Nomikos, N. (2006). Trading strategies in the market for tankers. *Maritime Policy & Management*, 33(2), pp.119-140.

Beenstock, M. (1985). A theory of ship prices. *Maritime Policy & Management*, 12(3), pp.215-225.

Beenstock, M. and Vergottis, A. (1989). An econometric model of the world tanker market. *Journal of Transport Economics and Policy*, 23(3), pp.263-280.

Beenstock, M. and Vergottis, A. (1993). *Econometric modelling of world shipping*. London: Chapman & Hall.

Clarkson Research Services Ltd. (2010). Monthly Reviews. Various Issues. *Shipping Intelligence Network.*

Cullinane, K. (1995). A portfolio analysis of market investments in dry bulk shipping. *Transportation Research Part B: Methodological*, 29(3), pp.181-200.

Dickey, D. A. & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, 74(366a), pp.427-431.

Dickey, D. A. & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), pp.1057-1072.

Dikos, G. and Marcus, H.S. (2003). The term structure of second-hand prices: a structural partial equilibrium model. *Maritime Economics & Logistics*, 5(3), pp.251-267.

Dikos, G. (2004). New building prices: demand inelastic or perfectly competitive?. *Maritime Economics & Logistics*, 6(4), pp.312-321.

Glen, D. and Martin, B. (1998). Conditional modelling of tanker market risk using route specific freight rates. *Maritime Policy & Management*, 25(2), pp.117-128.

Glen, D. (1997). The market for second-hand ships: Further results on efficiency using cointegration analysis. *Maritime Policy & Management*, 24(3), pp.245-260.

Goulielmos, A. (2009). Risk analysis of the Aframax freight market and of its new building and second hand prices, 1976-2008 and 1984-2008. *IJSTL*, 1(1), p.74.

Hale, C. and Vanags, A. (1992). The market for second-hand ships: some results on efficiency using cointegration. *Maritime Policy & Management*, 19(1), pp.31-39.

Haralambides, H., Tsolakis, S. and Cridland, C. (2004). 3. ECONOMETRIC MODELLING OF NEWBUILDING AND SECONDHAND SHIP PRICES. *Research in Transportation Economics*, 12, pp.65-105.

Harrington, S. and Niehaus, G. (2004). *Risk management and insurance*. Boston, Mass.: McGraw-Hill.

Hawdon, D. (1978). Tanker freight rates in the short and long run. *Applied Economics, 10(3),* pp.203-218.

Jin, D. (1993). Supply and demand of new oil tankers. *Maritime Policy & Management*, 20(3), pp.215-227.

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*, 59(6), pp.1551.

Juselius, K. (2006). *The cointegrated VAR model*. Oxford: Oxford University Press.

Kavussanos, M. (1996). Measuring risk differences among segments of the tanker freight markets. No 18. Discussion paper.

Kavussanos, M. (1997). The dynamics of time-varying volatilities in different size second-hand ship prices of the dry-cargo sector. *Applied Economics*, 29(4), pp.433-443.

Kavussanos, M. and Alizadeh-M, A. (2002). Seasonality patterns in tanker spot freight rate markets. *Economic Modelling*, 19(5), pp.747-782.

Kavussanos, M. (2003). Time varying risk among segments of the tanker freight markets. *Maritime Economics & Logistics*, 5(3), pp.227-250.

Kim, I. (2002). Ten years after the enactment of the Oil Pollution Act of 1990: a success or a failure. *Marine Policy*, 26(3), pp.197-207.

Knapp, S., Kumar, S. and Remijn, A. (2008). Econometric analysis of the ship demolition market. *Marine Policy*, 32(6), pp.1023-1036.

Koopmans, T.C. (1939). Tanker freight rates and tankship building: An analysis of cyclical fluctuations, by Dr. T. Koopmans. No 27, De erven F. Bohn NV.

Lun, Y., Hilmola, O., Goulielmos, A., Lai, K. and Cheng, T.E. (2013). “The Tanker Shipping Market.” *Oil transport management*. London: Springer, pp.13-25.

Lun, Y. and Quaddus, M. (2009). An empirical model of the bulk shipping market. *IJSTL*, 1(1), p.37.

Merikas, A., Merika, A. and Koutroubousis, G. (2008). Modelling the investment decision of the entrepreneur in the tanker sector: choosing between a second-hand vessel and a newly built one. *Maritime Policy & Management*, 35(5), pp.433-447.

OECD (2015), Quarterly GDP (indicator). Doi: 10.1787/b86d1fc8-en

Scarsi, R. (2007). The bulk shipping business: market cycles and shipowners' biases. *Maritime Policy & Management*, 34(6), pp.577-590.

Statista, (2015). *Statista – The Statistics Portal.* [Online] Available at: http://www.statista.com/

Stopford, M. (2009). *Maritime economics*. London: Routledge.

Strandenes, S.P. (1986). *Norship: A simulation model of markets in bulk shipping*. Discussion Chapter 11. Norwegian School of Economics and Business Administration, Bergen, Norway.

Strandenes, S.P. (2002). "Economics of the Markets for Ships." *The Handbook of Maritime Economics and Business*. Hoboken: Taylor and Francis, pp.217-234.

Syriopoulos, T. and Roumpis, E. (2006). Price and volume dynamics in second-hand dry bulk and tanker shipping markets. *Maritime Policy & Management*, 33(5), pp.497-518.

Tinbergen, J. (1931). Ein Schiffbauzyklus?. *Weltwirtschaftliches Archiv*, 34, pp.152-164.

UNCTAD, (2015). *UNCTADstat.* [Online] Available at: http://unctadstat.unctad.org/EN/

Veenstra, A. (1999). *Quantitative analysis of shipping markets*. Delft: Delft University Press.

Washington, S., Karlaftis, M. and Mannering, F. (2010). *Statistical and Econometric Methods for Transportation Data Analysis, Second Edition.* Hoboken: CRC Press.

Wijnolst, N., Wergeland, T. and Levander, K. (2009). *Shipping innovation*. Amsterdam: IOS Press.

Xekalaki, E. and Degiannakis, S. (2010). *ARCH models for financial applications.* Chichester: John Wiley & Sons.

Appendices

All the below tables and graphs, have been compiled by the author from EViews.

Appendix 1 Descriptive Statistics of Data

The descriptive statistics of data on levels for every model are presented below and are compiled by author from EViews.

Model 1 Newbuilding Market VLCC-ULCC category

Column1	NEWBUILD PRICES	SECOND PRICES	TIME CHARTER1	SPOT	ORDERBOOK	EARNINGS	STEEL_PROD	STEEL_PRICE	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
Mean	1.02E+08	85240541	38748.8	77.9176	24.36581	46481.28	1.02E+08	597.9153	84836162	66.73363	2.358842	0.02417	0.435994
Median	98000000	79000000	37500	64.5	19.08046	40907.92	1.05E+08	613.75	85140000	63.1975	1.6378	0.023	0.5691
Maximum	1.62E+08	1.65E+08	81250	273.558	53.56415	204361.1	1.42E+08	1350	96110000	137.19	6.9562	0.048	1.2534
Minimum	62500000	53000000	18000	30.2917	9.744409	772.2109	64529000	300	73960000	18.58	0.3227	-0.006	-2.2245
Std. Dev.	25557037	27389903	14187.92	41.0624	10.85869	34930.45	22993342	227.5511	5505814	33.22507	2.052078	0.009924	0.576666
Skewness	0.438333	0.917485	0.512443	1.5856	0.801507	1.5727	-0.053662	0.968662	-0.147802	0.209524	0.760207	-0.215285	-3.01382
Kurtosis	2.383756	2.978408	2.687362	6.18217	2.410607	6.660719	1.66999	5.093625	2.155409	1.698309	2.205021	3.461834	14.53973
Jarque-Bera	8.851493	25.95843	8.850212	155.575	22.48551	179.561	13.72426	62.71879	6.172183	14.41458	22.69065	3.073174	1306.545
Probability	0.011965	0.000002	0.011973	0	0.000013	0	0.001047	0	0.04568	0.000741	0.000012	0.215114	0
Sum	1.88E+10	1.58E+10	7168529	14414.8	4507.675	8599037	1.89E+10	110614.3	1.57E+10	12345.72	436.3857	4.471476	80.6589
Sum Sq. Dev.	1.20E+17	1.38E+17	3.70E+10	310246	21695.65	2.25E+11	9.73E+16	9527431	5.58E+15	203118.5	774.8285	0.018121	61.18809
Observations	185	185	185	185	185	185	185	185	185	185	185	185	185

Model 2 Newbuilding Market Suezmax category

Column1	NEWBUILD PRICES	SECOND PRICES	TIME CHARTER1	SPOT	ORDERBOOK	EARNINGS	STEEL_PROD	STEEL_PRICE	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
Mean	64337838	58729730	28810.69	115.1723	25.44774	38278.38	1.02E+08	597.9153	84836162	66.73363	2.358842	0.02417	0.435994
Median	64000000	54000000	29100	100.0861	23.24723	33842.69	1.05E+08	613.75	85140000	63.1975	1.6378	0.023	0.5691
Maximum	1.00E+08	1.05E+08	53875	360.3977	48.73239	140515.8	1.42E+08	1350	96110000	137.19	6.9562	0.048	1.2534
Minimum	43000000	36000000	15246	51.36096	7.926829	3319.464	64529000	300	73960000	18.58	0.3227	-0.006	-2.2245
Std. Dev.	14167383	17861254	8941.46	52.39679	9.687637	24565.39	22993342	227.5511	5505814	33.22507	2.052078	0.009924	0.576666
Skewness	0.543581	0.82739	0.141561	1.370656	0.328759	1.095217	-0.053662	0.968662	-0.147802	0.209524	0.760207	-0.215285	-3.01382
Kurtosis	2.64642	2.683081	2.021513	5.500601	2.20791	4.59233	1.66999	5.093625	2.155409	1.698309	2.205021	3.461834	14.53973
Jarque-Bera	10.07433	21.8819	7.998128	106.1267	8.168804	56.52919	13.72426	62.71879	6.172183	14.41458	22.69065	3.073174	1306.545
Probability	0.006492	0.000018	0.018333	0	0.016833	0	0.001047	0	0.04568	0.000741	0.000012	0.215114	0
Sum	1.19E+10	1.09E+10	5329977	21306.88	4707.832	7081500	1.89E+10	110614.3	1.57E+10	12345.72	436.3857	4.471476	80.6589
Sum Sq. Dev.	3.69E+16	5.87E+16	1.47E+10	505158	17268.46	1.11E+11	9.73E+16	9527431	5.58E+15	203118.5	774.8285	0.018121	61.18809
Observations	185	185	185	185	185	185	185	185	185	185	185	185	185

Model 3 Newbuilding Market Aframax category

Column1	NEWBUILD PRICES	SECOND PRICES	TIME CHARTER1	SPOT	ORDERBOOK	EARNINGS	STEEL_PROD	STEEL_PRICE	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
Mean	52904054	44764865	21605.64	140.9417	20.92815	28604.09	1.02E+08	597.9153	84836162	66.73363	2.358842	0.02417	0.435994
Median	53500000	40500000	19700	129.6802	22.36364	26197.13	1.05E+08	613.75	85140000	63.1975	1.6378	0.023	0.5691
Maximum	82500000	79000000	38250	365.3147	41.39344	87862.54	1.42E+08	1350	96110000	137.19	6.9562	0.048	1.2534
Minimum	33500000	26000000	13000	65.08333	5.474453	3793.109	64529000	300	73960000	18.58	0.3227	-0.006	-2.2245
Std. Dev.	11930359	14448658	6157.867	55.87024	10.13378	17157.05	22993342	227.5511	5505814	33.22507	2.052078	0.009924	0.576666
Skewness	0.276908	0.661291	0.339473	1.123339	0.339996	0.798417	-0.053662	0.968662	-0.147802	0.209524	0.760207	-0.215285	-3.01382
Kurtosis	2.481536	2.198253	1.971204	4.242384	2.235445	3.279229	1.66999	5.093625	2.155409	1.698309	2.205021	3.461834	14.53973
Jarque-Bera	4.436283	18.4385	11.71195	50.80622	8.070105	20.25632	13.72426	62.71879	6.172183	14.41458	22.69065	3.073174	1306.545
Probability	0.108811	0.000099	0.002863	0	0.017685	0.00004	0.001047	0	0.04568	0.000741	0.000012	0.215114	0
Sum	9.79E+09	8.28E+09	3997043	26074.21	3871.708	5291756	1.89E+10	110614.3	1.57E+10	12345.72	436.3857	4.471476	80.6589
Sum Sq. Dev.	2.62E+16	3.84E+16	6.98E+09	574353	18895.61	5.42E+10	9.73E+16	9527431	5.58E+15	203118.5	774.8285	0.018121	61.18809
Observations	185	185	185	185	185	185	185	185	185	185	185	185	185

Model 4 Second-hand Market VLCC-ULCC category

Column1	SECOND PRICES	NEWBUILD PRICES	SPOT	TIME CHARTER1	ORDERBOOK	EARNINGS	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
Mean	85240541	1.02E+08	77.91762	38748.8	24.36581	46481.28	84836162	66.73363	2.358842	0.02417	0.435994
Median	79000000	98000000	64.5	37500	19.08046	40907.92	85140000	63.1975	1.6378	0.023	0.5691
Maximum	1.65E+08	1.62E+08	273.5577	81250	53.56415	204361.1	96110000	137.19	6.9562	0.048	1.2534
Minimum	53000000	62500000	30.29167	18000	9.744409	772.2109	73960000	18.58	0.3227	-0.006	-2.2245
Std. Dev.	27389903	25557037	41.06238	14187.92	10.85869	34930.45	5505814	33.22507	2.052078	0.009924	0.576666
Skewness	0.917485	0.438333	1.585599	0.512443	0.801507	1.5727	-0.147802	0.209524	0.760207	-0.215285	-3.01382
Kurtosis	2.978408	2.383756	6.182174	2.687362	2.410607	6.660719	2.155409	1.698309	2.205021	3.461834	14.53973
Jarque-Bera	25.95843	8.851493	155.5752	8.850212	22.48551	179.561	6.172183	14.41458	22.69065	3.073174	1306.545
Probability	0.000002	0.011965	0	0.011973	0.000013	0	0.04568	0.000741	0.000012	0.215114	0
Sum	1.58E+10	1.88E+10	14414.76	7168529	4507.675	8599037	1.57E+10	12345.72	436.3857	4.471476	80.6589
Sum Sq. Dev.	1.38E+17	1.20E+17	310245.8	3.70E+10	21695.65	2.25E+11	5.58E+15	203118.5	774.8285	0.018121	61.18809
Observations	185	185	185	185	185	185	185	185	185	185	185

Model 5 Second-hand Market Suezmax category

Column1	SECOND PRICES	NEWBUILD PRICES	TIME CHARTER1	SPOT	ORDERBOOK	EARNINGS	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
Mean	58729730	64337838	28810.69	115.1723	25.44774	38278.38	84836162	66.73363	2.358842	0.02417	0.435994
Median	54000000	64000000	29100	100.0861	23.24723	33842.69	85140000	63.1975	1.6378	0.023	0.5691
Maximum	1.05E+08	1.00E+08	53875	360.3977	48.73239	140515.8	96110000	137.19	6.9562	0.048	1.2534
Minimum	36000000	43000000	15246	51.36096	7.926829	3319.464	73960000	18.58	0.3227	-0.006	-2.2245
Std. Dev.	17861254	14167383	8941.46	52.39679	9.687637	24565.39	5505814	33.22507	2.052078	0.009924	0.576666
Skewness	0.82739	0.543581	0.141561	1.370656	0.328759	1.095217	-0.147802	0.209524	0.760207	-0.215285	-3.01382
Kurtosis	2.683081	2.64642	2.021513	5.500601	2.20791	4.59233	2.155409	1.698309	2.205021	3.461834	14.53973
Jarque-Bera	21.8819	10.07433	7.998128	106.1267	8.168804	56.52919	6.172183	14.41458	22.69065	3.073174	1306.545
Probability	0.000018	0.006492	0.018333	0	0.016833	0	0.04568	0.000741	0.000012	0.215114	0
Sum	1.09E+10	1.19E+10	5329977	21306.88	4707.832	7081500	1.57E+10	12345.72	436.3857	4.471476	80.6589
Sum Sq. Dev.	5.87E+16	3.69E+16	1.47E+10	505158	17268.46	1.11E+11	5.58E+15	203118.5	774.8285	0.018121	61.18809
Observations	185	185	185	185	185	185	185	185	185	185	185

Model 6 Second-hand Market Aframax category

Column1	SECOND PRICES	NEWBUILD PRICES	TIME CHARTER1	SPOT	ORDERBOOK	EARNINGS	OIL_PROD	OIL_PRICE	LIBOR	INFLATION	GDP
Mean	44764865	52904054	21605.64	140.9417	20.92815	28604.09	84836162	66.73363	2.358842	0.02417	0.435994
Median	40500000	53500000	19700	129.6802	22.36364	26197.13	85140000	63.1975	1.6378	0.023	0.5691
Maximum	79000000	82500000	38250	365.3147	41.39344	87862.54	96110000	137.19	6.9562	0.048	1.2534
Minimum	26000000	33500000	13000	65.08333	5.474453	3793.109	73960000	18.58	0.3227	-0.006	-2.2245
Std. Dev.	14448658	11930359	6157.867	55.87024	10.13378	17157.05	5505814	33.22507	2.052078	0.009924	0.576666
Skewness	0.661291	0.276908	0.339473	1.123339	0.339996	0.798417	-0.147802	0.209524	0.760207	-0.215285	-3.01382
Kurtosis	2.198253	2.481536	1.971204	4.242384	2.235445	3.279229	2.155409	1.698309	2.205021	3.461834	14.53973
Jarque-Bera	18.4385	4.436283	11.71195	50.80622	8.070105	20.25632	6.172183	14.41458	22.69065	3.073174	1306.545
Probability	0.000099	0.108811	0.002863	0	0.017685	0.00004	0.04568	0.000741	0.000012	0.215114	0
Sum	8.28E+09	9.79E+09	3997043	26074.21	3871.708	5291756	1.57E+10	12345.72	436.3857	4.471476	80.6589
Sum Sq. Dev.	3.84E+16	2.62E+16	6.98E+09	574353	18895.61	5.42E+10	5.58E+15	203118.5	774.8285	0.018121	61.18809
Observations	185	185	185	185	185	185	185	185	185	185	185

Appendix 2 Lag Estimation and Johansen Cointegration Test

In this appendix 2 tables exist for each model. The first table depicts the VAR lag order selection criteria and the second table presents the JC test.

Model 1 Newbuilding Market VLCC-ULCC category

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-18733.85	NA	9.42e+75	211.8289	212.0621	211.9235
1	-16133.35	4789.635	1.11e+64	184.3542	187.6201*	185.6787*
2	-15941.46	325.2398	8.77e+63	184.0955	190.3940	186.6500
3	-15760.78	279.6922	8.26e+63	183.9636	193.2947	187.7479
4	-15536.05	314.8783	5.08e+63	183.3339	195.6975	188.3481
5	-15337.89	248.5374	4.67e+63	183.0044	198.4006	189.2485
6	-15132.09	227.8849	4.53e+63*	182.5886	201.0175	190.0627
7	-14942.04	182.5414	6.41e+63	182.3507	203.8121	191.0546
8	-14675.01	217.2388*	5.01e+63	181.2431*	205.7371	191.1769

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.512847	600.9316	NA	NA
At most 1 *	0.442571	469.3222	334.9837	0.0000
At most 2 *	0.376280	362.3734	285.1425	0.0000
At most 3 *	0.334966	275.9875	239.2354	0.0003
At most 4 *	0.244450	201.3386	197.3709	0.0313
At most 5	0.213422	150.0421	159.5297	0.1459
At most 6	0.189207	106.1104	125.6154	0.4095
At most 7	0.127339	67.72757	95.75366	0.7935
At most 8	0.104706	42.80151	69.81889	0.8928
At most 9	0.058307	22.56113	47.85613	0.9676
At most 10	0.039061	11.56729	29.79707	0.9458
At most 11	0.020761	4.275724	15.49471	0.8801
At most 12	0.002383	0.436523	3.841466	0.5088

**MacKinnon-Haug-Michelis (1999) p-values

Model 2 Newbuilding Market Suezmax category

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-18477.01	NA	5.17e+74	208.9267	209.1600	209.0213
1	-15966.49	4623.907	1.68e+63	182.4688	185.7347*	183.7933*
2	-15771.76	330.0443	1.29e+63	182.1781	188.4766	184.7325
3	-15553.62	337.6813	7.95e+62	181.6229	190.9539	185.4072
4	-15338.11	301.9564	5.42e+62	181.0973	193.4610	186.1116
5	-15146.40	240.4534	5.36e+62	180.8407	196.2370	187.0848
6	-14998.07	164.2547	9.97e+62	181.0742	199.5031	188.5483
7	-14750.06	238.2035	7.33e+62	180.1814	201.6429	188.8854
8	-14476.10	222.8797*	5.30e+62*	178.9955*	203.4895	188.9293

* indicates lag order selected by the criterion

Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.479299	532.5430	NA	NA
At most 1 *	0.380662	413.1209	334.9837	0.0000
At most 2 *	0.334673	325.4449	285.1425	0.0003
At most 3 *	0.281900	250.8765	239.2354	0.0134
At most 4	0.248048	190.2768	197.3709	0.1062
At most 5	0.210566	138.1067	159.5297	0.3951
At most 6	0.157004	94.83831	125.6154	0.7548
At most 7	0.123371	63.58328	95.75366	0.8948
At most 8	0.081369	39.48749	69.81889	0.9549
At most 9	0.056234	23.95607	47.85613	0.9434
At most 10	0.048432	13.36459	29.79707	0.8742
At most 11	0.022609	4.279800	15.49471	0.8797
At most 12	0.000518	0.094838	3.841466	0.7581

**MacKinnon-Haug-Michelis (1999) p-values

Model 3 Newbuilding Market Aframax category

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-18178.67	NA	1.78e+73	205.5556	205.7889	205.6502
1	-15701.87	4561.784	8.44e+61	179.4788	182.7447*	180.8033*
2	-15484.52	368.3937	5.02e+61	178.9324	185.2309	181.4868
3	-15329.29	240.3043	6.30e+61	179.0880	188.4190	182.8723
4	-15083.08	344.9617	3.04e+61	178.2156	190.5793	183.2299
5	-14888.08	244.5797*	2.89e+61*	177.9218	193.3181	184.1659
6	-14731.81	173.0409	4.92e+61	178.0657	196.4946	185.5397
7	-14543.64	180.7283	7.11e+61	177.8491	199.3105	186.5530
8	-14338.07	167.2444	1.11e+62	177.4359*	201.9299	187.3697

Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.453603	580.9286	NA	NA
At most 1 *	0.377771	470.3215	334.9837	0.0000
At most 2 *	0.357226	383.4978	285.1425	0.0000
At most 3 *	0.317702	302.6189	239.2354	0.0000
At most 4 *	0.270335	232.6600	197.3709	0.0003
At most 5 *	0.226243	174.9840	159.5297	0.0054
At most 6 *	0.213619	128.0449	125.6154	0.0353
At most 7	0.159317	84.06747	95.75366	0.2419
At most 8	0.149183	52.30960	69.81889	0.5357
At most 9	0.067749	22.74451	47.85613	0.9650
At most 10	0.031502	9.906487	29.79707	0.9816
At most 11	0.020937	4.048800	15.49471	0.8996
At most 12	0.000965	0.176651	3.841466	0.6743

**MacKinnon-Haug-Michelis (1999) p-values

Model 4 Second-hand Market VLCC-ULCC category

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-14780.49	NA	1.07e+59	167.1355	167.3329	167.2155
1	-12380.66	4474.259	7.03e+47	141.3860	143.7546*	142.3466*
2	-12243.26	239.0870	5.92e+47*	141.2007	145.7406	143.0419
3	-12124.08	192.5754	6.27e+47	141.2213	147.9324	143.9431
4	-12003.25	180.2271	6.76e+47	141.2231	150.1056	144.8255
5	-11884.47	162.3991	7.83e+47	141.2482	152.3019	145.7312
6	-11731.79	189.7689	6.61e+47	140.8903	154.1153	146.2538
7	-11591.07	157.4192	6.97e+47	140.6674	156.0637	146.9115
8	-11435.92	154.2720*	7.02e+47	140.2816*	157.8491	147.4063

Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.488484	390.5127	285.1425	0.0000
At most 1 *	0.285090	267.8339	239.2354	0.0013
At most 2 *	0.262713	206.4193	197.3709	0.0164
At most 3	0.206110	150.6449	159.5297	0.1374
At most 4	0.188527	108.4066	125.6154	0.3425
At most 5	0.157095	70.17710	95.75366	0.7166
At most 6	0.090533	38.90229	69.81889	0.9623
At most 7	0.052925	21.53615	47.85613	0.9797
At most 8	0.037000	11.58508	29.79707	0.9453
At most 9	0.020552	4.685696	15.49471	0.8412
At most 10	0.004827	0.885419	3.841466	0.3467

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Model 5 Second-hand Market Suezmax category

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-14494.62	NA	4.23e+57	163.9053	164.1027	163.9853
1	-12211.95	4255.811	1.04e+47	139.4797	141.8484*	140.4403*
2	-12075.90	236.7555	8.94e+46	139.3096	143.8495	141.1508
3	-11941.30	217.4785	7.95e+46*	139.1560	145.8672	141.8778
4	-11847.05	140.5785	1.16e+47	139.4582	148.3407	143.0606
5	-11721.14	172.1545	1.24e+47	139.4027	150.4564	143.8856
6	-11614.77	132.2022	1.76e+47	139.5681	152.7931	144.9316
7	-11469.50	162.5157	1.77e+47	139.2937	154.6900	145.5379
8	-11305.27	163.2974*	1.60e+47	138.8053*	156.3728	145.9300

Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.417906	379.3253	285.1425	0.0000
At most 1 *	0.328139	280.2996	239.2354	0.0002
At most 2 *	0.275586	207.5199	197.3709	0.0142
At most 3	0.253627	148.5221	159.5297	0.1694
At most 4	0.151855	94.98921	125.6154	0.7507
At most 5	0.122584	64.84841	95.75366	0.8681
At most 6	0.082893	40.91675	69.81889	0.9325
At most 7	0.062991	25.08159	47.85613	0.9165
At most 8	0.040496	13.17509	29.79707	0.8835
At most 9	0.028012	5.610080	15.49471	0.7410
At most 10	0.002241	0.410647	3.841466	0.5216

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Model 6 Second-hand Market Aframax category

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-14199.52	NA	1.51e+56	160.5708	160.7682	160.6509
1	-11923.08	4244.214	3.99e+45	136.2155	138.5842*	137.1762*
2	-11774.09	259.2525	2.95e+45*	135.8993	140.4392	137.7405
3	-11659.80	184.6648	3.30e+45	135.9752	142.6864	138.6970
4	-11528.41	195.9834	3.16e+45	135.8577*	144.7401	139.4601
5	-11412.74	158.1442*	3.79e+45	135.9179	146.9717	140.4009
6	-11298.46	142.0424	4.94e+45	135.9939	149.2189	141.3574
7	-11174.83	138.2941	6.32e+45	135.9642	151.3605	142.2083
8	-11052.54	121.6021	9.23e+45	135.9496	153.5171	143.0743

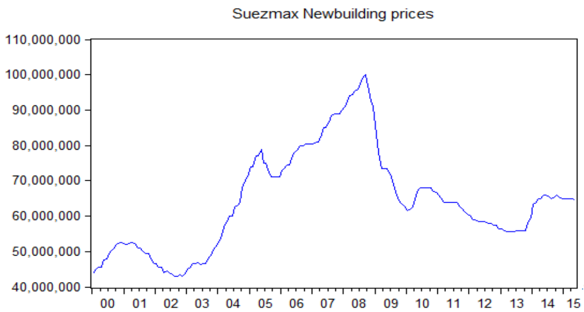
Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

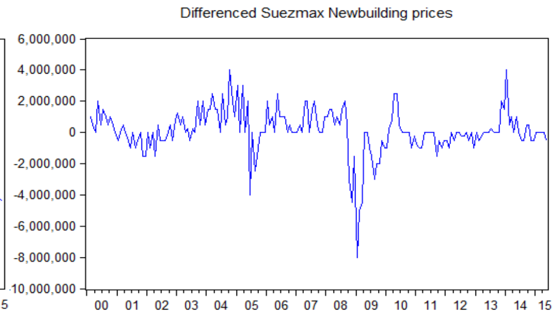
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.382777	408.8766	285.1425	0.0000
At most 1 *	0.291914	320.5744	239.2354	0.0000
At most 2 *	0.272617	257.4048	197.3709	0.0000
At most 3 *	0.268592	199.1555	159.5297	0.0001
At most 4 *	0.209938	141.9161	125.6154	0.0035
At most 5 *	0.204665	98.79331	95.75366	0.0304
At most 6	0.160594	56.88789	69.81889	0.3431
At most 7	0.067697	24.85171	47.85613	0.9226
At most 8	0.040156	12.02389	29.79707	0.9310
At most 9	0.019722	4.523653	15.49471	0.8571
At most 10	0.004789	0.878463	3.841466	0.3486

Trace test indicates 6 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

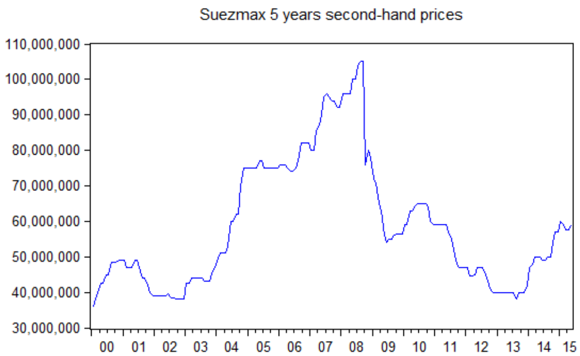
Appendix 3 Suezmax Data Observations' Graphs

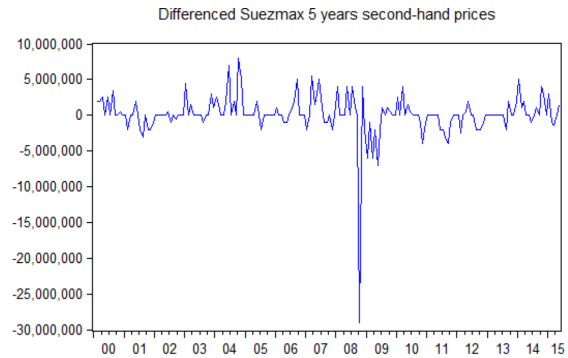
Newbuildings' prices



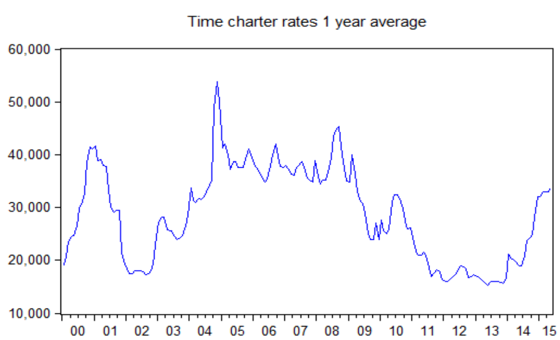


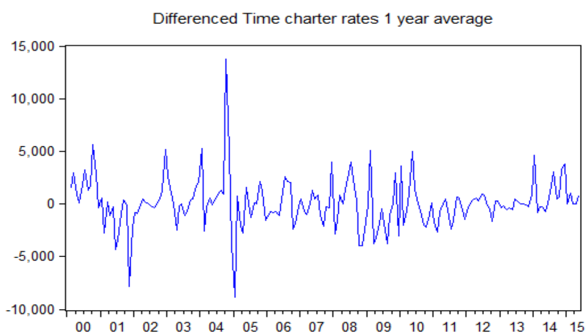
Second-hand prices



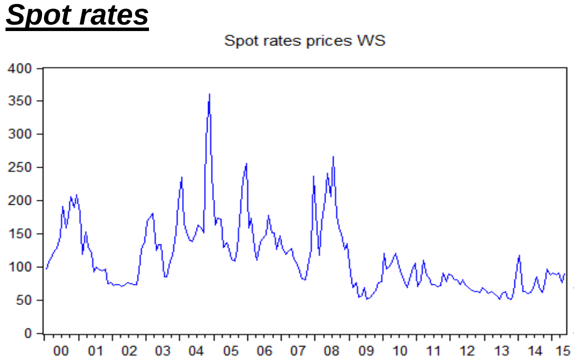


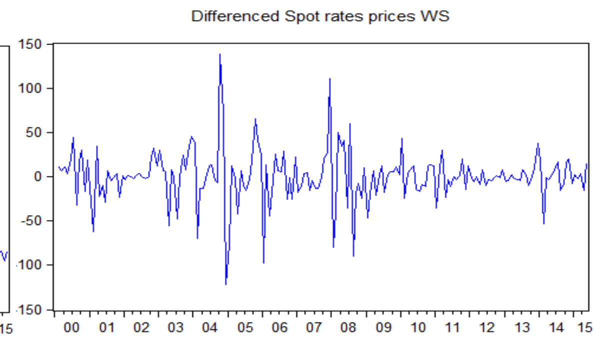
Time charter rates of 1 year



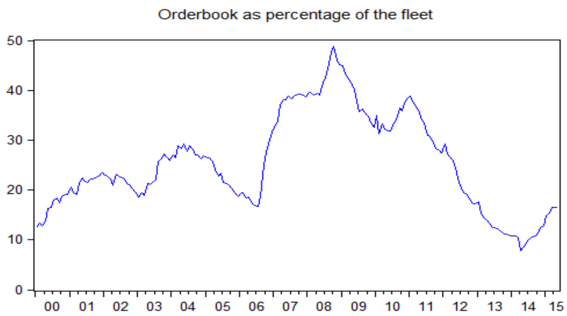


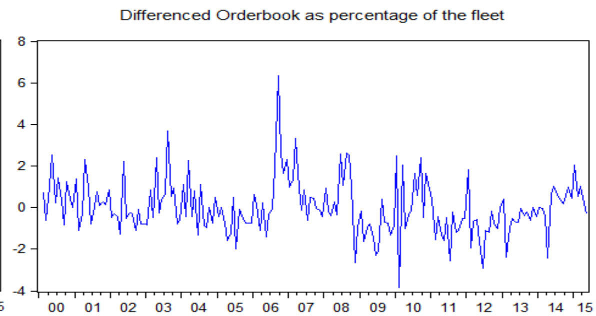
Spot rates



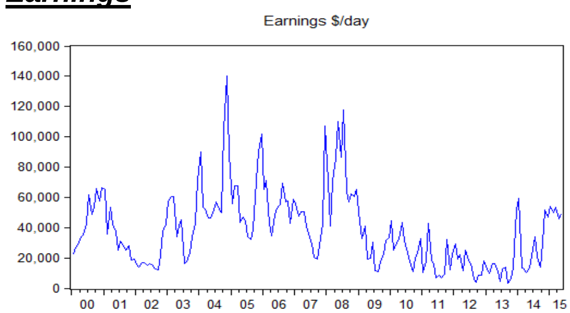


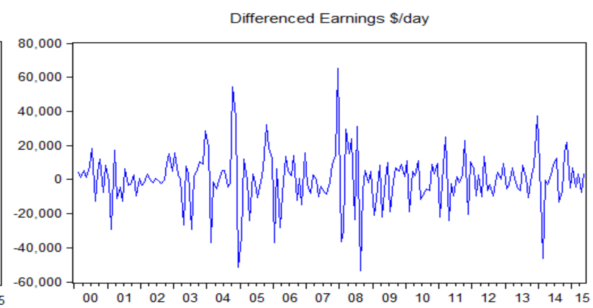
Orderbook





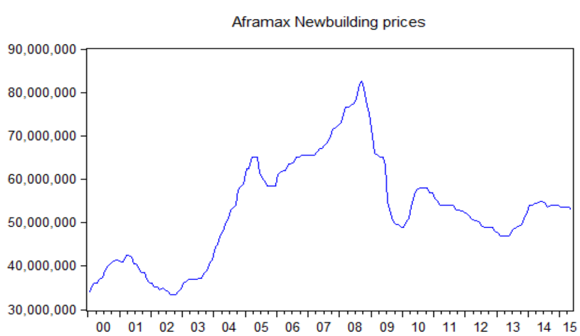
Earnings

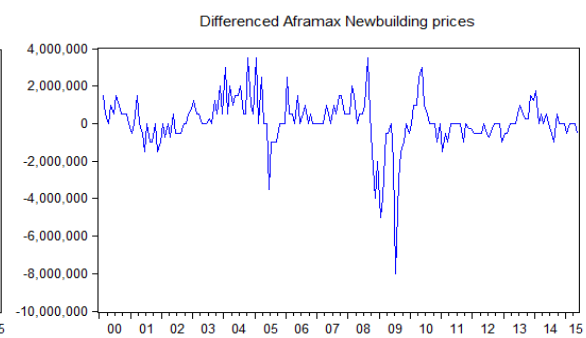




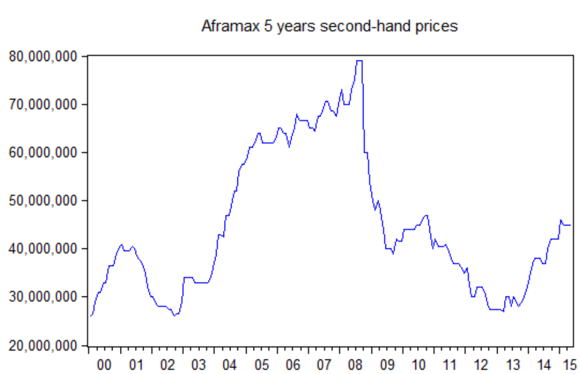
Appendix 4 Aframax Data Observations' Graphs

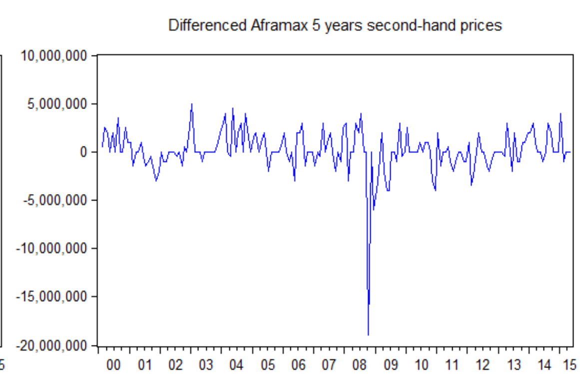
Newbuildings' prices



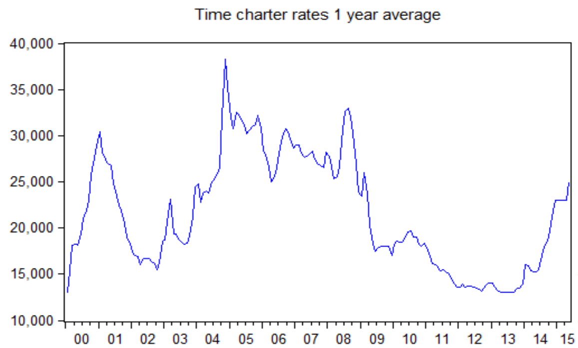


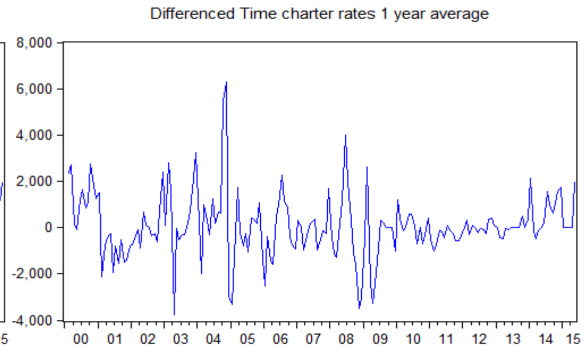
Second-hand prices



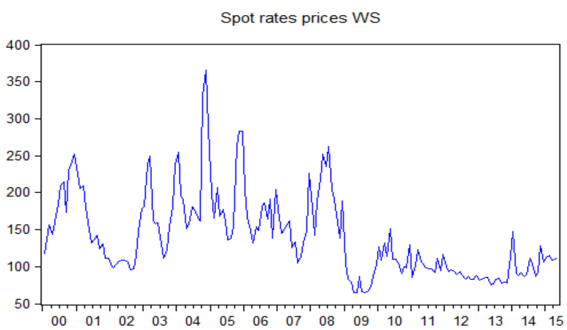


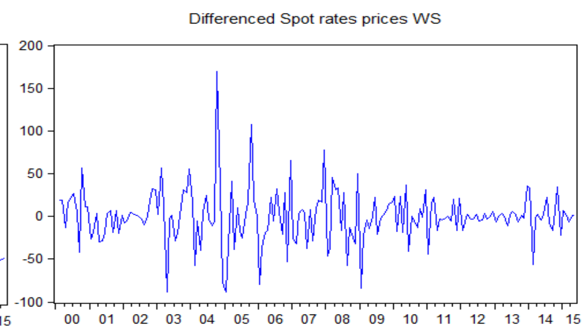
Time charter rates of 1 year



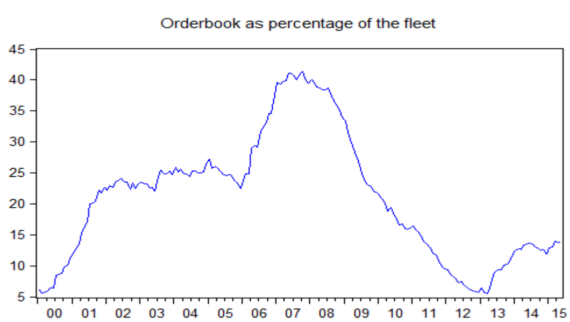


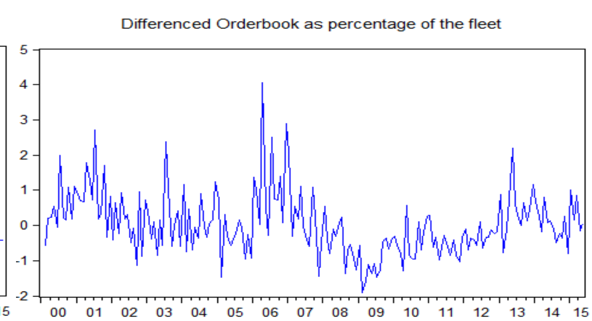
Spot rates



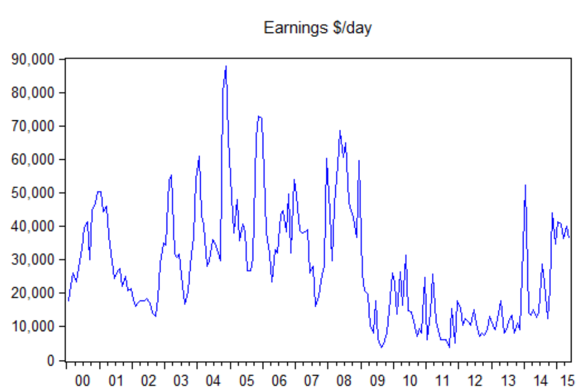


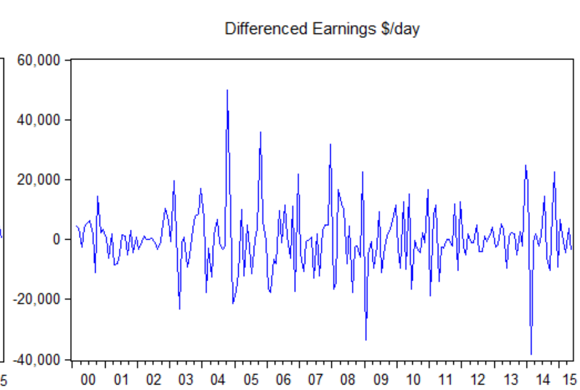
Orderbook





Earnings





Appendix 5 ARMA Models Diagnostic Tests

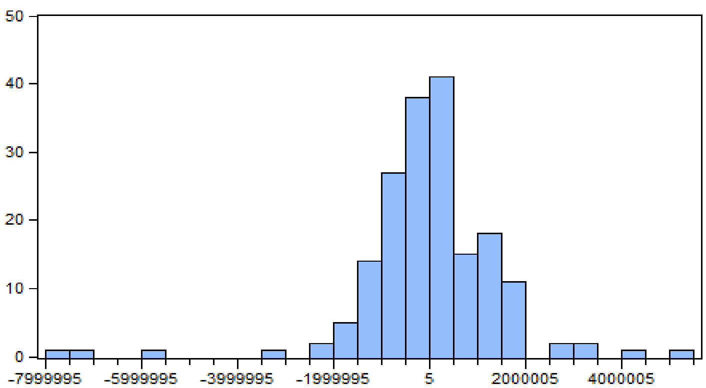
Model 1 Newbuilding Market VLCC-ULCC category

Correlogram of Residuals

Included observations: 181
Q-statistic probabilities adjusted for 3 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.002	0.002	0.0010	
		2	0.006	0.006	0.0081	
		3	-0.013	-0.013	0.0380	
		4	0.072	0.073	1.0213	0.312
		5	-0.033	-0.033	1.2243	0.542
		6	-0.050	-0.051	1.6962	0.638
		7	-0.016	-0.013	1.7445	0.783
		8	-0.033	-0.038	1.9470	0.856
		9	-0.041	-0.037	2.2649	0.894
		10	0.149	0.158	6.5816	0.474
		11	0.023	0.021	6.6867	0.571
		12	0.082	0.082	7.9887	0.535
		13	-0.084	-0.083	9.3950	0.495
		14	-0.030	-0.063	9.5733	0.569
		15	0.019	0.023	9.6464	0.647
		16	-0.056	-0.058	10.285	0.670
		17	-0.129	-0.113	13.665	0.475
		18	-0.123	-0.106	16.755	0.334
		19	-0.025	-0.027	16.881	0.393
		20	0.040	0.030	17.204	0.441
		21	0.001	0.013	17.205	0.509
		22	-0.023	-0.056	17.311	0.569
		23	-0.044	-0.044	17.713	0.606
		24	0.068	0.060	18.696	0.605
		25	0.105	0.109	21.052	0.518
		26	0.053	0.070	21.651	0.541
		27	-0.131	-0.122	25.354	0.387
		28	-0.056	-0.033	26.036	0.406
		29	0.018	0.037	26.104	0.457
		30	-0.014	-0.024	26.145	0.511
		31	0.024	0.024	26.269	0.558
		32	0.016	0.009	26.329	0.608
		33	-0.032	-0.038	26.563	0.646
		34	-0.001	-0.019	26.564	0.694
		35	-0.011	-0.085	26.589	0.737
		36	0.020	-0.060	26.681	0.773

Histogram – Normality Test



Series: Residuals
Sample 2000M02 2015M05
Observations 181

Mean	-8874.206
Median	2409.155
Maximum	5398642.
Minimum	-7780488.
Std. Dev.	1438260.
Skewness	-1.358836
Kurtosis	12.12385
Jarque-Bera	683.5046
Probability	0.000000

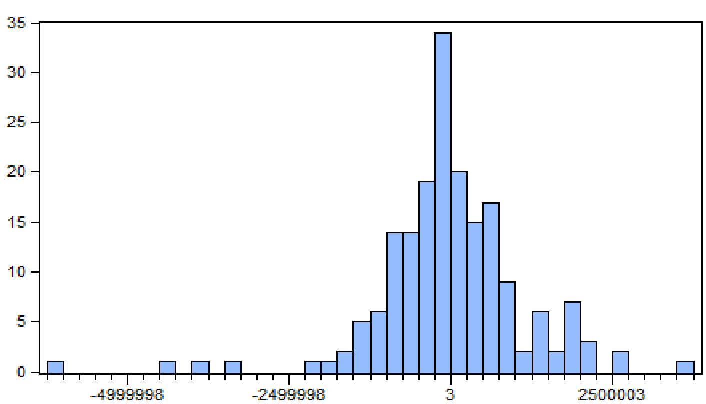
Model 2 Newbuilding Market Suezmax category

Correlogram of Residuals

Included observations: 184
Q-statistic probabilities adjusted for 3 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.002	0.002	0.0009	
		2	0.014	0.014	0.0394	
		3	0.019	0.019	0.1085	
		4	-0.002	-0.002	0.1093	0.741
		5	-0.037	-0.038	0.3739	0.829
		6	-0.033	-0.033	0.5843	0.900
		7	0.014	0.015	0.6227	0.961
		8	-0.040	-0.038	0.9366	0.968
		9	0.026	0.027	1.0699	0.983
		10	0.056	0.055	1.6811	0.975
		11	-0.077	-0.079	2.8446	0.944
		12	0.144	0.144	6.9585	0.641
		13	-0.082	-0.090	8.3115	0.598
		14	-0.005	-0.003	8.3166	0.685
		15	-0.005	-0.001	8.3218	0.760
		16	0.012	0.009	8.3494	0.820
		17	-0.108	-0.105	10.722	0.708
		18	-0.120	-0.112	13.709	0.548
		19	0.004	-0.010	13.712	0.620
		20	0.026	0.048	13.854	0.677
		21	-0.043	-0.048	14.245	0.713
		22	0.034	0.012	14.495	0.754
		23	-0.114	-0.106	17.236	0.638
		24	0.109	0.086	19.770	0.536
		25	0.087	0.114	21.398	0.496
		26	0.042	0.031	21.782	0.533
		27	-0.014	-0.006	21.828	0.590
		28	0.041	0.028	22.190	0.625
		29	-0.099	-0.101	24.351	0.556
		30	-0.055	-0.020	25.019	0.573
		31	0.067	0.058	26.012	0.572
		32	-0.101	-0.122	28.296	0.502
		33	0.002	0.047	28.297	0.555
		34	0.046	-0.011	28.786	0.580
		35	-0.038	-0.042	29.126	0.613
		36	0.011	-0.026	29.156	0.659

Histogram – Normality Test



Series: Residuals
Sample 2000M02 2015M05
Observations 184

Mean	-5771.235
Median	-39659.28
Maximum	3675667.
Minimum	-6036895.
Std. Dev.	1128437.
Skewness	-0.993541
Kurtosis	8.923599
Jarque-Bera	299.2876
Probability	0.000000

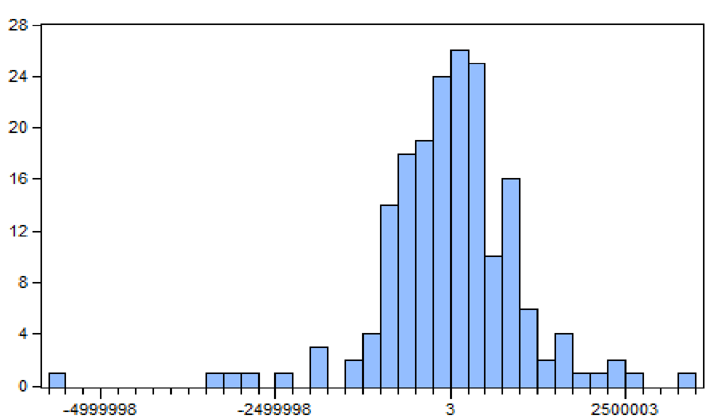
Model 3 Newbuilding Market Aframax category

Correlogram of Residuals

Included observations: 184
Q-statistic probabilities adjusted for 13 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.001	-0.001	0.0001	
		2	0.004	0.004	0.0026	
		3	-0.016	-0.016	0.0510	
		4	0.014	0.014	0.0859	
		5	0.009	0.009	0.1016	
		6	0.015	0.014	0.1432	
		7	0.044	0.044	0.5132	
		8	-0.016	-0.016	0.5654	
		9	0.014	0.014	0.6049	
		10	-0.015	-0.014	0.6496	
		11	-0.103	-0.105	2.7443	
		12	0.015	0.015	2.7862	
		13	0.031	0.031	2.9817	
		14	0.044	0.040	3.3731	0.066
		15	0.040	0.045	3.6891	0.158
		16	-0.074	-0.074	4.8060	0.187
		17	-0.078	-0.076	6.0620	0.195
		18	-0.001	0.007	6.0622	0.300
		19	0.035	0.027	6.3151	0.389
		20	0.015	0.016	6.3591	0.498
		21	0.000	-0.003	6.3591	0.607
		22	-0.080	-0.094	7.7134	0.563
		23	-0.050	-0.041	8.2398	0.605
		24	0.007	0.018	8.2496	0.691
		25	0.019	0.028	8.3241	0.759
		26	0.027	0.038	8.4871	0.810
		27	-0.091	-0.115	10.284	0.741
		28	0.010	-0.013	10.305	0.800
		29	-0.057	-0.045	11.024	0.808
		30	-0.000	0.017	11.024	0.855
		31	0.074	0.105	12.254	0.834
		32	0.006	0.002	12.261	0.874
		33	-0.004	-0.047	12.264	0.907
		34	0.022	0.010	12.371	0.929
		35	0.010	0.017	12.393	0.949
		36	0.069	0.114	13.488	0.941

Histogram – Normality Test



Series: Residuals
Sample 2000M02 2015M05
Observations 184

Mean	-4441.623
Median	28446.29
Maximum	3272910.
Minimum	-5544151.
Std. Dev.	999265.9
Skewness	-1.016583
Kurtosis	8.942739
Jarque-Bera	302.4493
Probability	0.000000

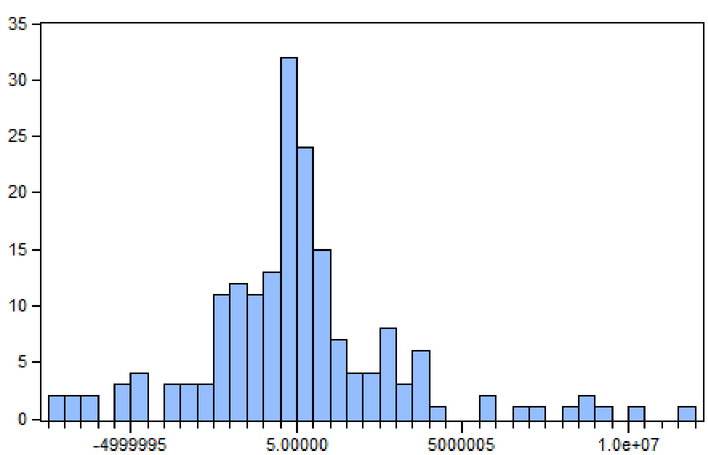
Model 4 Second-hand Market VLCC-ULCC category

Correlogram of Residuals

Included observations: 183
Q-statistic probabilities adjusted for 2 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.014	-0.014	0.0339	
		2	0.045	0.045	0.4189	
		3	-0.021	-0.020	0.5033	0.478
		4	-0.017	-0.020	0.5585	0.756
		5	0.017	0.019	0.6139	0.893
		6	-0.073	-0.072	1.6332	0.803
		7	0.056	0.053	2.2428	0.815
		8	0.004	0.012	2.2457	0.896
		9	-0.056	-0.064	2.8596	0.898
		10	0.029	0.027	3.0188	0.933
		11	0.044	0.055	3.3947	0.947
		12	0.024	0.012	3.5080	0.967
		13	0.078	0.082	4.7145	0.944
		14	-0.099	-0.099	6.6690	0.879
		15	0.015	-0.002	6.7152	0.916
		16	-0.119	-0.099	9.6016	0.791
		17	-0.128	-0.134	12.926	0.608
		18	-0.020	-0.024	13.004	0.672
		19	0.005	0.027	13.011	0.735
		20	0.010	-0.016	13.031	0.790
		21	-0.002	0.012	13.031	0.837
		22	0.029	0.026	13.204	0.868
		23	0.029	0.009	13.387	0.894
		24	0.075	0.092	14.600	0.879
		25	0.006	0.007	14.609	0.908
		26	-0.020	-0.042	14.691	0.929
		27	-0.042	-0.011	15.082	0.939
		28	0.016	0.028	15.139	0.955
		29	-0.052	-0.033	15.726	0.958
		30	-0.065	-0.066	16.658	0.955
		31	0.058	0.035	17.409	0.955
		32	-0.024	-0.042	17.539	0.966
		33	0.152	0.136	22.735	0.859
		34	-0.042	-0.061	23.140	0.874
		35	0.059	0.028	23.940	0.876
		36	-0.099	-0.101	26.184	0.829

Histogram – Normality Test



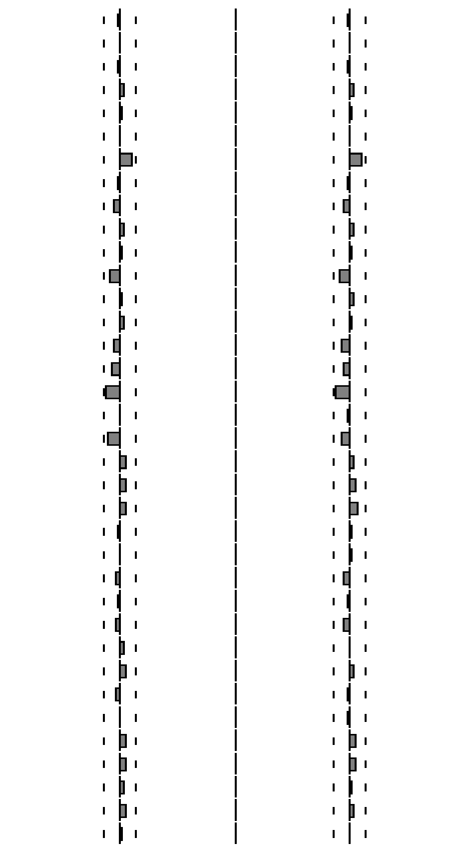
Series: Residuals
Sample 2000M02 2015M05
Observations 183

Mean	-11095.99
Median	-191227.4
Maximum	11561114
Minimum	-7395536.
Std. Dev.	2961604.
Skewness	0.788098
Kurtosis	5.655707
Jarque-Bera	72.72095
Probability	0.000000

Model 5 Second-hand Market Suezmax category

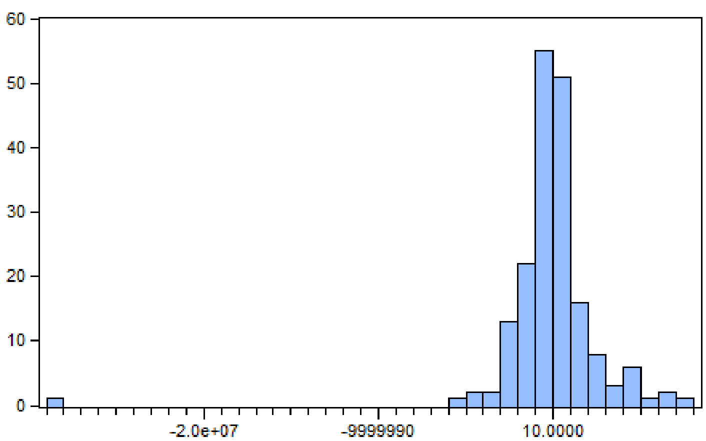
Correlogram of Residuals

Included observations: 184
Q-statistic probabilities adjusted for 6 ARMA terms



Lag	AC	PAC	Q-Stat	Prob
1	-0.023	-0.023	0.1019	
2	0.006	0.006	0.1097	
3	-0.012	-0.011	0.1349	
4	0.030	0.030	0.3070	
5	0.021	0.022	0.3896	
6	-0.008	-0.007	0.4006	
7	0.103	0.103	2.4394	0.118
8	-0.023	-0.019	2.5412	0.281
9	-0.052	-0.056	3.0675	0.381
10	0.027	0.028	3.2156	0.522
11	0.021	0.017	3.3050	0.653
12	-0.091	-0.097	4.9636	0.548
13	0.022	0.025	5.0610	0.653
14	0.027	0.021	5.2029	0.736
15	-0.063	-0.067	6.0089	0.739
16	-0.074	-0.062	7.1344	0.713
17	-0.121	-0.129	10.129	0.519
18	0.006	-0.011	10.136	0.604
19	-0.103	-0.081	12.319	0.502
20	0.045	0.037	12.748	0.546
21	0.046	0.046	13.190	0.588
22	0.044	0.074	13.605	0.628
23	-0.011	0.014	13.631	0.693
24	0.002	0.013	13.632	0.753
25	-0.043	-0.054	14.030	0.782
26	-0.021	-0.015	14.122	0.824
27	-0.031	-0.052	14.327	0.855
28	0.026	-0.001	14.470	0.884
29	0.045	0.036	14.924	0.897
30	-0.027	-0.010	15.085	0.918
31	-0.001	-0.019	15.085	0.939
32	0.052	0.054	15.702	0.943
33	0.054	0.048	16.370	0.946
34	0.033	0.014	16.615	0.956
35	0.044	0.037	17.068	0.961
36	0.012	-0.007	17.102	0.971

Histogram – Normality Test



Series: Residuals
Sample 2000M02 2015M05
Observations 184

Mean	-16762.27
Median	-43554.35
Maximum	7567480.
Minimum	-28438776
Std. Dev.	2839315.
Skewness	-5.153260
Kurtosis	56.34049
Jarque-Bera	22627.65
Probability	0.000000

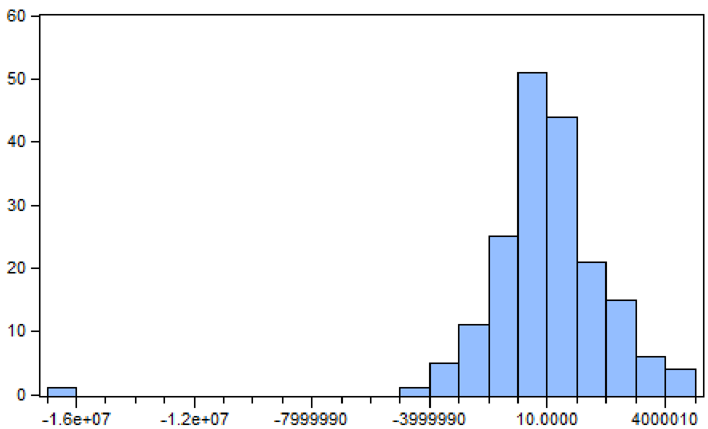
Model 6 Second-hand Market Aframax category

Correlogram of Residuals

Included observations: 184
Q-statistic probabilities adjusted for 6 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.002	-0.002	0.0009	
		2	-0.004	-0.004	0.0040	
		3	-0.016	-0.016	0.0551	
		4	0.023	0.023	0.1557	
		5	0.002	0.002	0.1566	
		6	0.095	0.095	1.8932	
		7	0.019	0.020	1.9610	0.161
		8	0.166	0.169	7.3393	0.025
		9	-0.015	-0.010	7.3824	0.061
		10	-0.012	-0.012	7.4124	0.116
		11	0.000	0.004	7.4124	0.192
		12	-0.120	-0.143	10.266	0.114
		13	0.043	0.039	10.639	0.155
		14	0.046	0.009	11.059	0.198
		15	-0.035	-0.044	11.305	0.255
		16	-0.058	-0.077	11.987	0.286
		17	-0.047	-0.049	12.449	0.331
		18	-0.002	0.024	12.449	0.410
		19	0.067	0.066	13.378	0.419
		20	-0.109	-0.074	15.874	0.321
		21	0.027	0.024	16.025	0.380
		22	0.011	0.014	16.050	0.450
		23	0.029	0.055	16.231	0.508
		24	0.010	0.026	16.252	0.575
		25	0.051	0.066	16.810	0.603
		26	-0.006	0.013	16.817	0.665
		27	-0.038	-0.080	17.129	0.703
		28	-0.028	-0.014	17.296	0.747
		29	-0.017	-0.048	17.357	0.791
		30	-0.043	-0.054	17.768	0.814
		31	0.021	0.009	17.864	0.848
		32	0.085	0.040	19.499	0.815
		33	0.051	0.055	20.088	0.827
		34	-0.052	-0.031	20.702	0.838
		35	-0.095	-0.062	22.788	0.786
		36	-0.026	-0.017	22.944	0.818

Histogram – Normality Test



Series: Residuals
Sample 2000M02 2015M05
Observations 184

Mean	-8754.490
Median	-51445.05
Maximum	4848877.
Minimum	-16961296
Std. Dev.	2081837.
Skewness	-2.767769
Kurtosis	25.50507
Jarque-Bera	4117.924
Probability	0.000000

Appendix 6 ARCH Models Diagnostic Tests

Model 1 Newbuilding Market VLCC-ULCC category

Correlogram of Residuals

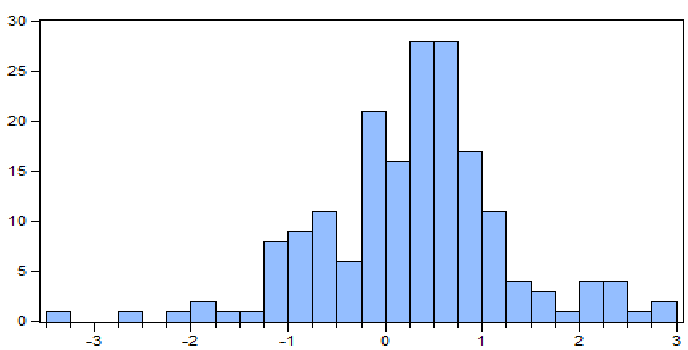
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.028	-0.028	0.1492	0.699
		2	-0.002	-0.003	0.1498	0.928
		3	-0.024	-0.024	0.2599	0.967
		4	-0.056	-0.058	0.8535	0.931
		5	-0.017	-0.020	0.9065	0.970
		6	-0.076	-0.079	2.0040	0.919
		7	-0.001	-0.009	2.0041	0.960
		8	0.088	0.083	3.4866	0.900
		9	0.073	0.074	4.5263	0.873
		10	0.038	0.035	4.7994	0.904
		11	-0.030	-0.027	4.9792	0.932
		12	-0.015	-0.010	5.0223	0.957
		13	-0.062	-0.053	5.7786	0.954
		14	0.116	0.133	8.4255	0.866
		15	-0.049	-0.032	8.9020	0.883
		16	0.073	0.069	9.9797	0.868
		17	-0.020	-0.037	10.058	0.901
		18	-0.040	-0.047	10.377	0.919
		19	0.115	0.111	13.080	0.834
		20	0.015	0.053	13.126	0.872
		21	0.069	0.086	14.101	0.865
		22	0.084	0.090	15.583	0.836
		23	-0.097	-0.100	17.542	0.782
		24	-0.006	-0.031	17.550	0.824
		25	-0.030	-0.001	17.738	0.853
		26	0.037	0.063	18.033	0.875
		27	0.149	0.188	22.819	0.695
		28	-0.057	-0.085	23.534	0.706
		29	0.111	0.085	26.239	0.613
		30	-0.032	-0.089	26.465	0.651
		31	-0.044	-0.029	26.886	0.678
		32	-0.066	-0.012	27.862	0.676
		33	0.018	0.054	27.931	0.718
		34	0.114	0.141	30.850	0.623
		35	-0.010	-0.075	30.872	0.668
		36	0.004	-0.077	30.875	0.711

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.068541	Prob. F(2,176)	0.9338
Obs*R-squared	0.139309	Prob. Chi-Square(2)	0.9327

Histogram – Normality Test



Series: Standardized Residuals
Sample 2000M02 2015M05
Observations 181

Mean	0.299737
Median	0.373015
Maximum	2.901176
Minimum	-3.362155
Std. Dev.	0.961237
Skewness	-0.207482
Kurtosis	4.377628
Jarque-Bera	15.61167
Probability	0.000407

Model 2 Newbuilding Market Suezmax category

Correlogram of Residuals

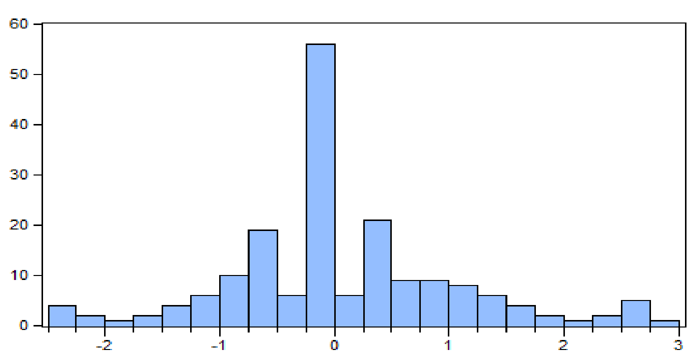
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.002	0.002	0.0007	0.979
		2	0.026	0.026	0.1276	0.938
		3	0.001	0.001	0.1279	0.988
		4	-0.028	-0.029	0.2796	0.991
		5	-0.062	-0.062	1.0164	0.961
		6	-0.047	-0.046	1.4412	0.963
		7	0.051	0.055	1.9447	0.963
		8	0.123	0.126	4.8902	0.769
		9	0.011	0.006	4.9139	0.842
		10	0.040	0.026	5.2305	0.875
		11	0.100	0.097	7.2024	0.782
		12	-0.082	-0.075	8.5466	0.741
		13	-0.023	-0.010	8.6501	0.799
		14	-0.110	-0.098	11.066	0.681
		15	0.178	0.184	17.458	0.292
		16	-0.035	-0.039	17.713	0.341
		17	0.004	-0.010	17.716	0.407
		18	0.087	0.058	19.286	0.374
		19	0.105	0.093	21.591	0.305
		20	-0.104	-0.093	23.870	0.248
		21	0.056	0.076	24.519	0.269
		22	0.025	0.035	24.656	0.314
		23	-0.070	-0.088	25.688	0.316
		24	-0.090	-0.082	27.425	0.285
		25	-0.049	-0.040	27.941	0.311
		26	0.061	-0.002	28.745	0.323
		27	0.031	0.057	28.953	0.363
		28	0.065	0.061	29.886	0.369
		29	-0.105	-0.142	32.340	0.305
		30	0.078	0.032	33.675	0.294
		31	-0.084	-0.015	35.270	0.273
		32	0.098	0.141	37.417	0.234
		33	-0.049	-0.058	37.965	0.253
		34	0.024	-0.009	38.101	0.288
		35	-0.047	-0.017	38.617	0.309
		36	0.005	-0.026	38.622	0.352

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.038385	Prob. F(3,177)	0.9899
Obs*R-squared	0.117679	Prob. Chi-Square(3)	0.9896

Histogram – Normality Test



Series: Standardized Residuals
Sample 2000M02 2015M05
Observations 184

Mean	0.069575
Median	-0.086507
Maximum	2.857839
Minimum	-2.499264
Std. Dev.	1.000305
Skewness	0.308379
Kurtosis	3.885994
Jarque-Bera	8.934552
Probability	0.011479

Model 4 Second-hand Market VLCC-ULCC category

Correlogram of Residuals

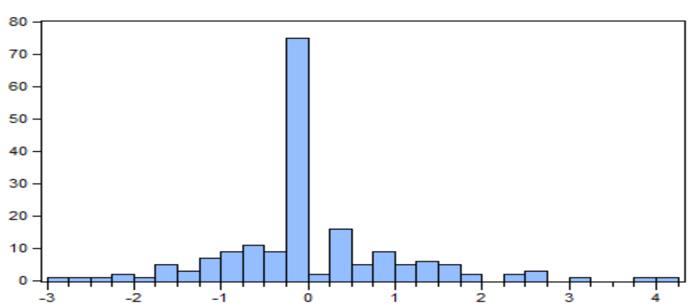
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.001	0.001	0.0001	0.991
		2	-0.044	-0.044	0.3664	0.833
		3	-0.026	-0.026	0.4898	0.921
		4	-0.055	-0.057	1.0638	0.900
		5	0.060	0.058	1.7503	0.883
		6	0.038	0.032	2.0245	0.917
		7	-0.014	-0.011	2.0615	0.956
		8	-0.088	-0.086	3.5491	0.895
		9	0.004	0.011	3.5518	0.938
		10	-0.018	-0.026	3.6137	0.963
		11	0.188	0.182	10.538	0.483
		12	0.030	0.019	10.714	0.554
		13	-0.026	0.001	10.846	0.624
		14	-0.039	-0.032	11.150	0.674
		15	-0.042	-0.022	11.500	0.716
		16	-0.020	-0.049	11.579	0.772
		17	0.063	0.051	12.400	0.775
		18	-0.004	-0.013	12.404	0.826
		19	-0.082	-0.047	13.795	0.795
		20	-0.104	-0.110	16.022	0.715
		21	0.047	0.062	16.492	0.741
		22	-0.015	-0.074	16.540	0.788
		23	-0.045	-0.065	16.968	0.811
		24	-0.044	-0.058	17.375	0.832
		25	-0.083	-0.049	18.862	0.804
		26	-0.040	-0.052	19.214	0.827
		27	0.106	0.113	21.641	0.755
		28	-0.051	-0.100	22.204	0.772
		29	0.018	0.040	22.271	0.809
		30	-0.096	-0.109	24.310	0.758
		31	-0.045	0.023	24.761	0.778
		32	0.161	0.118	30.584	0.538
		33	0.022	0.040	30.698	0.582
		34	0.027	0.028	30.860	0.622
		35	-0.025	0.018	31.002	0.662
		36	-0.024	-0.003	31.134	0.699

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.175251	Prob. F(2,178)	0.8394
Obs*R-squared	0.355708	Prob. Chi-Square(2)	0.8371

Histogram – Normality Test



Series: Standardized Residuals
Sample 2000M02 2015M05
Observations 183

Mean	0.044972
Median	-0.081306
Maximum	4.086067
Minimum	-2.779984
Std. Dev.	1.031669
Skewness	0.787808
Kurtosis	5.506112
Jarque-Bera	66.81916
Probability	0.000000

Appendix 7 GARCH Models Diagnostic Tests

Model 1 Newbuilding Market VLCC-ULCC category

Correlogram of Residuals

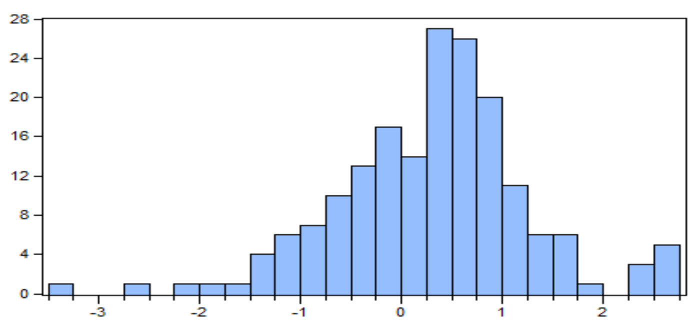
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.021	0.021	0.0775	0.781
		2	0.011	0.011	0.1000	0.951
		3	-0.062	-0.062	0.8138	0.846
		4	-0.049	-0.046	1.2545	0.869
		5	-0.035	-0.032	1.4801	0.915
		6	-0.083	-0.085	2.7901	0.835
		7	-0.072	-0.076	3.7770	0.805
		8	0.079	0.078	4.9795	0.760
		9	0.084	0.071	6.3370	0.706
		10	0.050	0.029	6.8181	0.743
		11	-0.049	-0.055	7.2856	0.776
		12	-0.056	-0.052	7.8960	0.793
		13	-0.055	-0.050	8.4861	0.811
		14	0.110	0.126	10.883	0.695
		15	-0.062	-0.048	11.651	0.705
		16	0.086	0.087	13.130	0.663
		17	-0.002	-0.015	13.131	0.727
		18	-0.016	-0.048	13.183	0.781
		19	0.070	0.071	14.185	0.773
		20	0.005	0.037	14.191	0.821
		21	0.030	0.061	14.371	0.853
		22	0.031	0.034	14.570	0.880
		23	-0.078	-0.081	15.831	0.862
		24	-0.009	-0.029	15.847	0.894
		25	-0.036	-0.021	16.127	0.911
		26	-0.005	0.014	16.133	0.933
		27	0.125	0.157	19.482	0.852
		28	-0.069	-0.103	20.517	0.845
		29	0.054	0.045	21.153	0.854
		30	-0.030	-0.082	21.349	0.877
		31	-0.053	-0.045	21.974	0.884
		32	-0.075	-0.038	23.210	0.872
		33	0.033	0.071	23.449	0.890
		34	0.052	0.078	24.055	0.897
		35	-0.018	-0.095	24.125	0.917
		36	-0.024	-0.077	24.255	0.932

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.052261	Prob. F(2,176)	0.9491
Obs*R-squared	0.106240	Prob. Chi-Square(2)	0.9483

Histogram – Normality Test



Series: Standardized Residuals
Sample 2000M02 2015M05
Observations 181

Mean	0.300396
Median	0.336365
Maximum	2.693857
Minimum	-3.296846
Std. Dev.	0.958265
Skewness	-0.240649
Kurtosis	4.304642
Jarque-Bera	14.58361
Probability	0.000681

Model 2 Newbuilding Market Suezmax category

Correlogram of Residuals

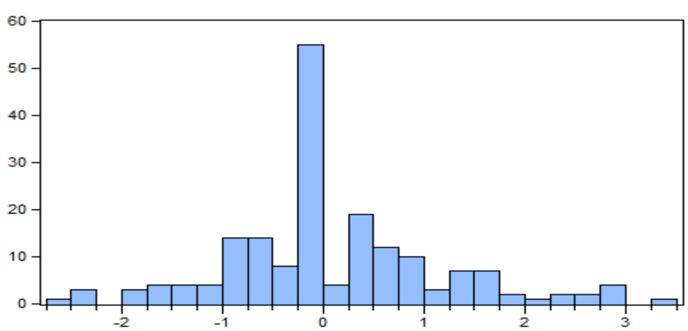
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.039	-0.039	0.2908	0.590
		2	0.018	0.016	0.3487	0.840
		3	-0.007	-0.006	0.3581	0.949
		4	-0.021	-0.022	0.4395	0.979
		5	-0.028	-0.029	0.5872	0.989
		6	-0.036	-0.038	0.8355	0.991
		7	-0.045	-0.048	1.2347	0.990
		8	0.061	0.058	1.9528	0.982
		9	-0.064	-0.060	2.7544	0.973
		10	0.017	0.007	2.8095	0.986
		11	0.156	0.158	7.6242	0.747
		12	-0.090	-0.085	9.2445	0.682
		13	-0.004	-0.018	9.2472	0.754
		14	-0.102	-0.100	11.362	0.657
		15	0.107	0.112	13.681	0.550
		16	-0.042	-0.038	14.043	0.595
		17	-0.023	-0.017	14.151	0.656
		18	0.055	0.059	14.781	0.677
		19	0.118	0.101	17.680	0.544
		20	-0.101	-0.080	19.805	0.470
		21	0.097	0.075	21.761	0.413
		22	0.069	0.082	22.772	0.415
		23	-0.050	-0.053	23.309	0.443
		24	-0.109	-0.106	25.871	0.360
		25	-0.084	-0.051	27.385	0.337
		26	0.086	0.053	28.977	0.312
		27	0.056	0.086	29.653	0.330
		28	0.009	0.025	29.672	0.379
		29	-0.097	-0.140	31.766	0.330
		30	0.102	0.061	34.097	0.277
		31	-0.078	-0.017	35.463	0.266
		32	0.158	0.152	41.076	0.131
		33	-0.039	-0.047	41.414	0.149
		34	0.000	-0.023	41.414	0.179
		35	-0.040	0.029	41.777	0.200
		36	-0.036	-0.043	42.076	0.225

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.117475	Prob. F(3,177)	0.9498
Obs*R-squared	0.359674	Prob. Chi-Square(3)	0.9484

Histogram – Normality Test



Series: Standardized Residuals	
Sample 2000M02 2015M05	
Observations 184	
Mean	0.113368
Median	-0.042039
Maximum	3.251004
Minimum	-2.501080
Std. Dev.	1.054907
Skewness	0.384718
Kurtosis	3.820066
Jarque-Bera	9.694798
Probability	0.007849

Model 4 Second-hand Market VLCC-ULCC category

Correlogram of Residuals

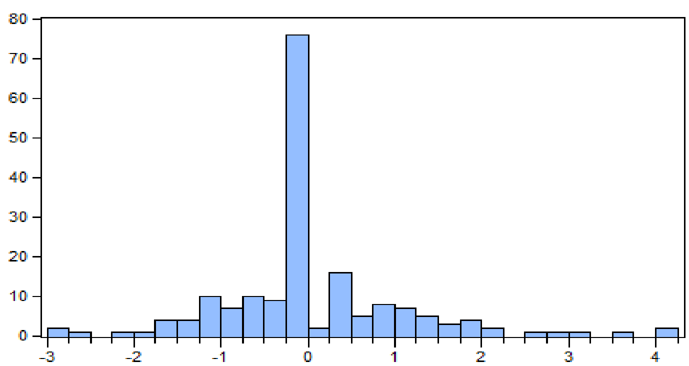
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.001	-0.001	0.0004	0.984
		2	-0.053	-0.053	0.5354	0.765
		3	-0.012	-0.012	0.5611	0.905
		4	-0.065	-0.068	1.3655	0.850
		5	-0.029	-0.031	1.5239	0.910
		6	-0.035	-0.044	1.7648	0.940
		7	-0.051	-0.057	2.2675	0.944
		8	-0.071	-0.083	3.2411	0.918
		9	-0.017	-0.031	3.2968	0.951
		10	-0.009	-0.028	3.3116	0.973
		11	0.154	0.141	7.9963	0.714
		12	0.022	0.007	8.0904	0.778
		13	-0.007	-0.001	8.0996	0.837
		14	-0.023	-0.032	8.2095	0.878
		15	-0.036	-0.028	8.4742	0.903
		16	-0.034	-0.038	8.7059	0.925
		17	0.049	0.053	9.1867	0.934
		18	-0.022	-0.017	9.2845	0.953
		19	-0.079	-0.059	10.569	0.938
		20	-0.078	-0.088	11.833	0.922
		21	0.057	0.052	12.503	0.925
		22	-0.041	-0.088	12.863	0.937
		23	-0.068	-0.088	13.835	0.932
		24	-0.030	-0.063	14.030	0.946
		25	-0.040	-0.049	14.378	0.955
		26	-0.024	-0.052	14.500	0.966
		27	0.123	0.107	17.774	0.910
		28	-0.062	-0.117	18.611	0.910
		29	0.010	0.004	18.633	0.930
		30	-0.069	-0.105	19.702	0.924
		31	-0.047	-0.032	20.195	0.932
		32	0.155	0.112	25.606	0.781
		33	0.023	0.032	25.723	0.813
		34	-0.013	-0.008	25.763	0.844
		35	-0.019	-0.009	25.846	0.870
		36	-0.024	-0.024	25.981	0.891

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.256300	Prob. F(2,178)	0.7742
Obs*R-squared	0.519742	Prob. Chi-Square(2)	0.7712

Histogram – Normality Test



Series: Standardized Residuals	
Sample 2000M02 2015M05	
Observations 183	
Mean	0.079058
Median	-0.052675
Maximum	4.244989
Minimum	-2.811103
Std. Dev.	1.064389
Skewness	0.880447
Kurtosis	5.965378
Jarque-Bera	90.69336
Probability	0.000000

Appendix 8 E-GARCH Models Diagnostic Tests

Model 1 Newbuilding Market VLCC-ULCC category

Correlogram of Residuals

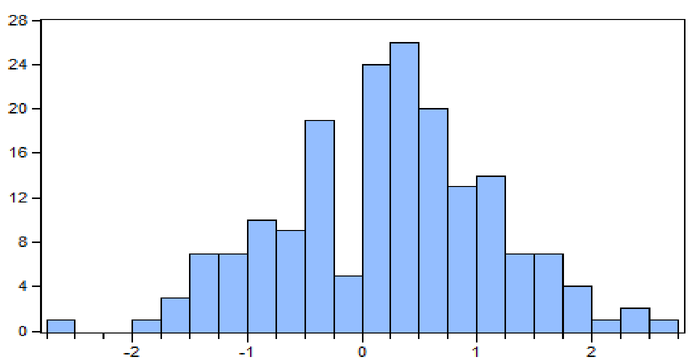
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.002	-0.002	0.0008	0.977
		2	-0.016	-0.016	0.0487	0.976
		3	-0.014	-0.014	0.0855	0.994
		4	0.045	0.044	0.4608	0.977
		5	-0.029	-0.030	0.6238	0.987
		6	-0.094	-0.093	2.2966	0.891
		7	-0.042	-0.042	2.6260	0.917
		8	-0.003	-0.009	2.6276	0.956
		9	-0.026	-0.028	2.7582	0.973
		10	0.128	0.136	5.9354	0.821
		11	-0.079	-0.083	7.1470	0.787
		12	-0.062	-0.073	7.9033	0.793
		13	0.014	0.011	7.9434	0.847
		14	0.112	0.096	10.426	0.730
		15	0.018	0.028	10.490	0.788
		16	0.055	0.086	11.096	0.804
		17	-0.039	-0.051	11.406	0.835
		18	-0.056	-0.089	12.037	0.845
		19	0.008	0.019	12.051	0.883
		20	0.066	0.067	12.937	0.880
		21	-0.022	0.018	13.038	0.907
		22	0.036	0.073	13.304	0.924
		23	-0.096	-0.128	15.246	0.886
		24	-0.023	-0.089	15.356	0.910
		25	0.089	0.123	17.055	0.880
		26	0.026	0.047	17.202	0.903
		27	0.003	0.046	17.205	0.926
		28	-0.104	-0.099	19.527	0.881
		29	0.056	-0.022	20.220	0.886
		30	0.096	0.047	22.248	0.845
		31	-0.064	-0.000	23.154	0.844
		32	-0.111	-0.086	25.916	0.767
		33	0.024	0.058	26.040	0.800
		34	0.056	0.026	26.752	0.807
		35	0.059	0.002	27.552	0.811
		36	-0.076	-0.073	28.874	0.795

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.023219	Prob. F(2,176)	0.9771
Obs*R-squared	0.047218	Prob. Chi-Square(2)	0.9767

Histogram – Normality Test



Series: Standardized Residuals
Sample 2000M02 2015M05
Observations 181

Mean	0.224349
Median	0.289953
Maximum	2.579160
Minimum	-2.535370
Std. Dev.	0.921081
Skewness	-0.134563
Kurtosis	2.912844
Jarque-Bera	0.603519
Probability	0.739516

Model 2 Newbuilding Market Suezmax category

Correlogram of Residuals

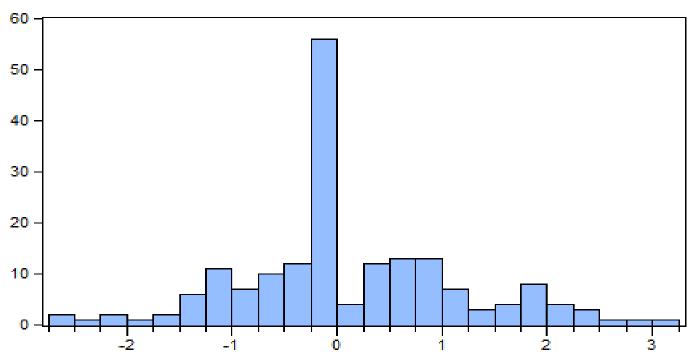
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.005	0.005	0.0041	0.949
		2	0.016	0.016	0.0513	0.975
		3	0.030	0.030	0.2248	0.973
		4	0.068	0.068	1.1085	0.893
		5	0.028	0.027	1.2568	0.939
		6	0.008	0.005	1.2680	0.973
		7	-0.016	-0.021	1.3180	0.988
		8	0.019	0.013	1.3907	0.994
		9	-0.078	-0.082	2.5699	0.979
		10	0.026	0.025	2.7008	0.988
		11	0.050	0.054	3.1942	0.988
		12	0.058	0.062	3.8734	0.986
		13	-0.046	-0.040	4.2977	0.988
		14	0.075	0.072	5.4234	0.979
		15	0.057	0.048	6.0711	0.979
		16	-0.120	-0.138	8.9889	0.914
		17	0.016	0.017	9.0444	0.939
		18	0.060	0.052	9.7875	0.939
		19	-0.032	-0.035	10.003	0.953
		20	-0.036	-0.024	10.281	0.963
		21	0.026	0.048	10.423	0.973
		22	-0.077	-0.099	11.673	0.964
		23	0.134	0.143	15.486	0.876
		24	-0.093	-0.084	17.331	0.834
		25	-0.059	-0.091	18.080	0.839
		26	0.030	0.036	18.269	0.866
		27	0.012	0.029	18.302	0.894
		28	0.065	0.077	19.234	0.891
		29	-0.006	-0.031	19.242	0.915
		30	-0.023	0.007	19.358	0.932
		31	0.030	0.024	19.560	0.945
		32	-0.005	-0.021	19.565	0.958
		33	-0.016	-0.038	19.625	0.968
		34	0.046	0.073	20.117	0.972
		35	0.011	-0.016	20.143	0.979
		36	-0.076	-0.052	21.472	0.974

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.068527	Prob. F(3,177)	0.9766
Obs*R-squared	0.209982	Prob. Chi-Square(3)	0.9760

Histogram – Normality Test



Series: Standardized Residuals
Sample 2000M02 2015M05
Observations 184

Mean	0.107506
Median	-0.089843
Maximum	3.164263
Minimum	-2.607927
Std. Dev.	1.054501
Skewness	0.312061
Kurtosis	3.374332
Jarque-Bera	4.060672
Probability	0.131291

Model 4 Second-hand Market VLCC-ULCC category

Correlogram of Residuals

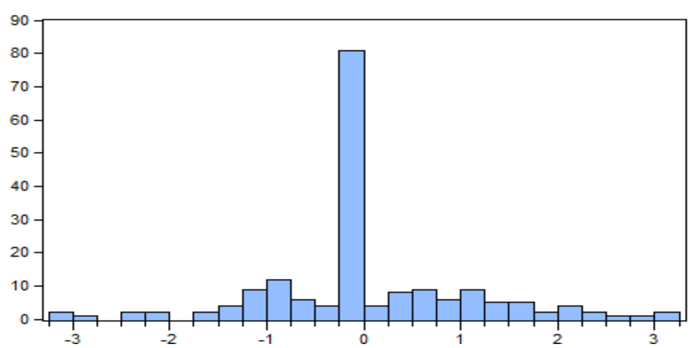
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.044	-0.044	0.3606	0.548
		2	-0.013	-0.015	0.3932	0.821
		3	0.011	0.010	0.4180	0.937
		4	-0.039	-0.038	0.7005	0.951
		5	0.107	0.104	2.8768	0.719
		6	-0.025	-0.017	2.9945	0.810
		7	0.014	0.017	3.0330	0.882
		8	-0.087	-0.091	4.4888	0.811
		9	0.043	0.046	4.8499	0.847
		10	-0.023	-0.037	4.9494	0.895
		11	0.037	0.047	5.2251	0.920
		12	0.039	0.029	5.5206	0.938
		13	-0.021	0.007	5.6102	0.959
		14	0.012	-0.005	5.6409	0.975
		15	-0.073	-0.062	6.7117	0.965
		16	0.048	0.029	7.1832	0.970
		17	0.029	0.031	7.3518	0.979
		18	-0.039	-0.038	7.6674	0.983
		19	-0.052	-0.054	8.2241	0.984
		20	-0.125	-0.117	11.490	0.933
		21	0.047	0.029	11.959	0.941
		22	-0.006	-0.011	11.966	0.958
		23	-0.107	-0.115	14.369	0.916
		24	0.020	0.023	14.457	0.936
		25	-0.093	-0.077	16.324	0.905
		26	0.005	-0.009	16.331	0.928
		27	0.165	0.165	22.226	0.726
		28	-0.077	-0.071	23.511	0.707
		29	0.041	0.050	23.873	0.735
		30	-0.039	-0.038	24.211	0.762
		31	-0.041	-0.035	24.594	0.786
		32	-0.009	-0.026	24.612	0.821
		33	0.089	0.087	26.386	0.786
		34	-0.036	-0.041	26.677	0.810
		35	0.017	0.054	26.743	0.840
		36	0.057	0.051	27.490	0.845

Heteroscedasticity Test

Heteroskedasticity Test: ARCH

F-statistic	0.192611	Prob. F(2,178)	0.8250
Obs*R-squared	0.390869	Prob. Chi-Square(2)	0.8225

Histogram – Normality Test



Series: Standardized Residuals
Sample 2000M02 2015M05
Observations 183

Mean	0.056927
Median	-0.041017
Maximum	3.247884
Minimum	-3.199670
Std. Dev.	1.045231
Skewness	0.159257
Kurtosis	4.503888
Jarque-Bera	18.01888
Probability	0.000122

Appendix 9 VEC Models Diagnostic Tests

<u>Model 3 Newbuilding Market Aframax category</u>

<u>Regression Analysis</u>

Dependent Variable: D(NEWBUILD_PRICES)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 07/30/15 Time: 18:05
Sample (adjusted): 2000M04 2015M05
Included observations: 182 after adjustments

D(NEWBUILD_PRICES) = C(1)*(NEWBUILD_PRICES(-1) - 0.403755811792*STEEL_PROD(-1) - 107741.542952*STEEL_PRICE(-1) + 1.29116989444*OIL_PROD(-1) + 281478.420816*OIL_PRICE(-1) - 150755.962364*LIBOR(-1) + 249427713.493*INFLATION(-1) - 3337340.38765*GDP(-1) - 79655036.7843) + C(2)*(SECOND_PRICES(-1) - 0.489025444186*STEEL_PROD(-1) - 138079.526546*STEEL_PRICE(-1) + 1.23273041917*OIL_PROD(-1) + 571446.130258*OIL_PRICE(-1) - 1133456.77202*LIBOR(-1) + 257684018.211*INFLATION(-1) - 7807598.70321*GDP(-1) - 55042691.8951) + C(3)*(TIMECHARTER1(-1) + 0.000203272918698*STEEL_PROD(-1) - 46.3823162568*STEEL_PRICE(-1) - 0.00117444364589*OIL_PROD(-1) + 254.848267131*OIL_PRICE(-1) - 214.311160674*LIBOR(-1) - 64431.3877424*INFLATION(-1) - 6102.30273667*GDP(-1) + 72646.3831533) + C(4)*(SPOT(-1) + 5.61929888408E-06*STEEL_PROD(-1) + 0.0455332194804*STEEL_PRICE(-1) - 2.07782444614E-05*OIL_PROD(-1) - 0.184119648222*OIL_PRICE(-1) - 13.5059256184*LIBOR(-1) - 207.379504113*INFLATION(-1) - 1.31315566974*GDP(-1) + 1068.58816381) + C(5)*(ORDERBOOK(-1) - 1.0960818413E-06*STEEL_PROD(-1) - 0.163607950457*STEEL_PRICE(-1) + 6.72999408161E-06*OIL_PROD(-1) + 0.438880078113*OIL_PRICE(-1) + 3.41000704294*LIBOR(-1) + 865.559220989*INFLATION(-1) - 3.93463244667*GDP(-1) - 438.268150305) + C(6)*(EARNINGS(-1) + 0.00058246159168*STEEL_PROD(-1) - 19.4542484581*STEEL_PRICE(-1) - 0.00358552315183*OIL_PROD(-1) + 375.074747676*OIL_PRICE(-1) - 3443.30588646*LIBOR(-1) - 45529.3229312*INFLATION(-1) + 13242.4468734*GDP(-1) + 205920.050958) + C(7)*D(NEWBUILD_PRICES(-1)) + C(8)*D(NEWBUILD_PRICES(-2)) + C(9)*D(SECOND_PRICES(-1)) + C(10)*D(SECOND_PRICES(-2)) + C(11)*D(TIMECHARTER1(-1)) + C(12)*D(TIMECHARTER1(-2)) + C(13)*D(SPOT(-1)) + C(14)*D(SPOT(-2)) + C(15)*D(ORDERBOOK(-1)) + C(16)*D(ORDERBOOK(-2)) + C(17)*D(EARNINGS(-1)) + C(18)*D(EARNINGS(-2)) + C(19)*D(STEEL_PROD(-1)) + C(20)*D(STEEL_PROD(-2)) + C(21)*D(STEEL_PRICE(-1)) + C(22)*D(STEEL_PRICE(-2)) + C(23)*D(OIL_PROD(-1)) + C(24)*D(OIL_PROD(-2)) + C(25)*D(OIL_PRICE(-1)) + C(26)*D(OIL_PRICE(-2)) + C(27)*D(LIBOR(-1)) + C(28)*D(LIBOR(-2)) + C(29)*D(INFLATION(-1)) + C(30)*D(INFLATION(-2)) + C(31)*D(GDP(-1)) + C(32)*D(GDP(-2)) + C(33)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.166630	0.040904	-4.073688	0.0001
C(2)	0.068585	0.032068	2.138707	0.0341
C(3)	-75.30637	50.24654	-1.498737	0.1361
C(4)	11423.80	6020.842	1.897376	0.0597
C(5)	66419.01	17162.30	3.870053	0.0002
C(6)	-19.79968	17.87009	-1.107979	0.2697
C(7)	0.246373	0.083678	2.944315	0.0038
C(8)	0.172733	0.083491	2.068869	0.0403
C(9)	0.065002	0.046117	1.409503	0.1608
C(10)	0.034951	0.045274	0.771993	0.4413
C(11)	5.099835	83.85822	0.060815	0.9516
C(12)	211.5864	85.23006	2.482533	0.0142
C(13)	-241.2802	8726.031	-0.027651	0.9780
C(14)	-16813.99	8623.785	-1.949722	0.0531
C(15)	-32460.03	96554.01	-0.336185	0.7372
C(16)	-87178.82	99373.46	-0.877285	0.3817
C(17)	-11.61760	25.23487	-0.460379	0.6459
C(18)	29.23642	23.84691	1.226005	0.2221
C(19)	0.000504	0.021928	0.022972	0.9817
C(20)	0.017754	0.019577	0.906868	0.3659
C(21)	-4234.928	1906.107	-2.221769	0.0278
C(22)	-1250.911	2012.704	-0.621508	0.5352
C(23)	-0.157807	0.127679	-1.235964	0.2184
C(24)	-0.111955	0.119207	-0.939163	0.3492
C(25)	13027.89	16315.02	0.798521	0.4258
C(26)	38533.68	16771.91	2.297514	0.0230
C(27)	-844468.8	512422.8	-1.647992	0.1015
C(28)	835941.8	442984.4	1.887068	0.0611
C(29)	26324219	30226241	0.870906	0.3852
C(30)	-30143569	30195655	-0.998275	0.3198
C(31)	366122.8	333365.7	1.098262	0.2739
C(32)	287250.9	316937.2	0.906334	0.3662
C(33)	53099.71	77582.08	0.684433	0.4948

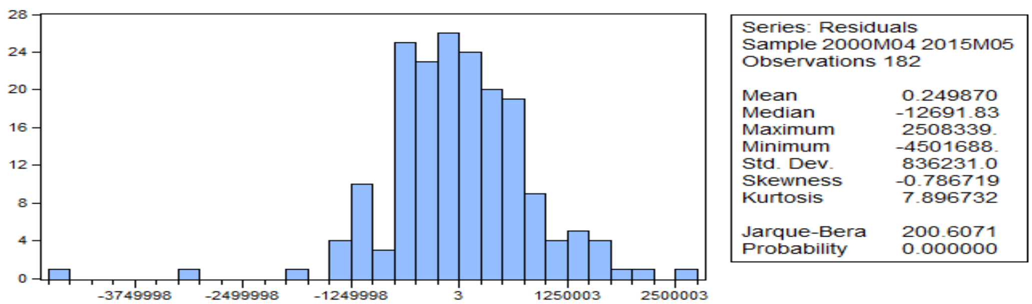
R-squared	0.600457	Mean dependent var	93406.59
Adjusted R-squared	0.514649	S.D. dependent var	1322953.
S.E. of regression	921663.6	Akaike info criterion	30.46833
Sum squared resid	1.27E+14	Schwarz criterion	31.04927
Log likelihood	-2739.618	Hannan-Quinn criter.	30.70383
F-statistic	6.997687	Durbin-Watson stat	2.007718
Prob(F-statistic)	0.000000		

ARCH Test

Heteroskedasticity Test: ARCH

F-statistic	0.211909	Prob. F(2,177)	0.8092
Obs*R-squared	0.429972	Prob. Chi-Square(2)	0.8066

Histogram – Normality Test



Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.069752	Prob. F(2,147)	0.9327
Obs*R-squared	0.172555	Prob. Chi-Square(2)	0.9173

Model 5 Second-hand Market Suezmax category

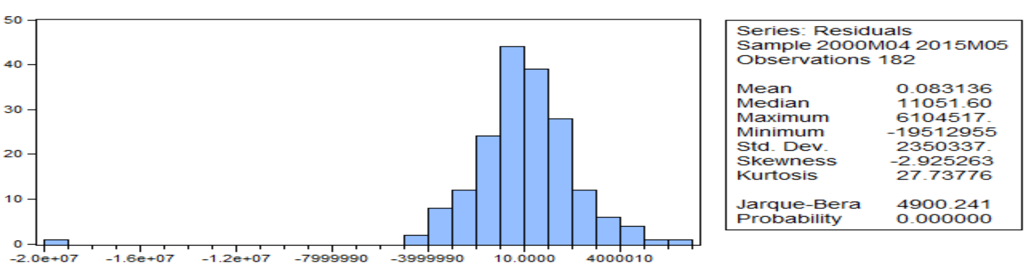
The regression analysis is presented in the next page.

ARCH Test

Heteroskedasticity Test: ARCH

F-statistic	0.009978	Prob. F(2,177)	0.9901
Obs*R-squared	0.020291	Prob. Chi-Square(2)	0.9899

Histogram – Normality Test



Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	3.491662	Prob. F(2,154)	0.0329
Obs*R-squared	7.895009	Prob. Chi-Square(2)	0.0193

Regression Analysis

Dependent Variable: D(SECOND_PRICES)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 07/30/15 Time: 18:09
Sample (adjusted): 2000M04 2015M05
Included observations: 182 after adjustments
D(SECOND_PRICES) = C(1)*(SECOND_PRICES(-1) + 7775.78633477
*TIMECHARTER1(-1) - 2449241.79572*ORDERBOOK(-1) -
3493.93814882*EARNINGS(-1) - 10.1037381649*OIL_PROD(-1) +
1070265.28394*OIL_PRICE(-1) - 10078473.8924*LIBOR(-1) -
575411721.614*INFLATION(-1) - 51647890.2194*GDP(-1) +
758604453.819) + C(2)*(NEWBUILD_PRICES(-1) + 4966.39102833
*TIMECHARTER1(-1) - 1540970.76357*ORDERBOOK(-1) -
2278.35887969*EARNINGS(-1) - 6.39732330463*OIL_PROD(-1) +
550817.327737*OIL_PRICE(-1) - 6999749.32255*LIBOR(-1) -
234890272.23*INFLATION(-1) - 24369638.2322*GDP(-1) +
457399918.141) + C(3)*(SPOT(-1) - 0.00786306714732
*TIMECHARTER1(-1) + 1.83848569677*ORDERBOOK(-1) +
0.000600065508137*EARNINGS(-1) + 1.33499889591E-05
*OIL_PROD(-1) - 1.73700943562*OIL_PRICE(-1) + 10.0046152992
*LIBOR(-1) + 483.517183398*INFLATION(-1) + 12.2602084201*GDP(
-1) - 1015.25873106) + C(4)*D(SECOND_PRICES(-1)) + C(5)
*D(SECOND_PRICES(-2)) + C(6)*D(NEWBUILD_PRICES(-1)) + C(7)
*D(NEWBUILD_PRICES(-2)) + C(8)*D(SPOT(-1)) + C(9)*D(SPOT(-2)) +
C(10)*D(TIMECHARTER1(-1)) + C(11)*D(TIMECHARTER1(-2)) + C(12)
*D(ORDERBOOK(-1)) + C(13)*D(ORDERBOOK(-2)) + C(14)
*D(EARNINGS(-1)) + C(15)*D(EARNINGS(-2)) + C(16)*D(OIL_PROD(
-1)) + C(17)*D(OIL_PROD(-2)) + C(18)*D(OIL_PRICE(-1)) + C(19)
*D(OIL_PRICE(-2)) + C(20)*D(LIBOR(-1)) + C(21)*D(LIBOR(-2)) +
C(22)*D(INFLATION(-1)) + C(23)*D(INFLATION(-2)) + C(24)*D(GDP(
-1)) + C(25)*D(GDP(-2)) + C(26)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.184090	0.039842	-4.620542	0.0000
C(2)	0.286292	0.065462	4.373392	0.0000
C(3)	18236.11	18273.17	0.997972	0.3198
C(4)	-0.060632	0.087898	-0.689801	0.4913
C(5)	0.112238	0.097659	1.149288	0.2522
C(6)	-0.035353	0.186617	-0.189439	0.8500
C(7)	-0.105413	0.184349	-0.571814	0.5683
C(8)	10858.22	26063.93	0.416600	0.6775
C(9)	-4617.679	25478.43	-0.181239	0.8564
C(10)	136.9015	124.1121	1.103048	0.2717
C(11)	53.03834	126.5239	0.419196	0.6756
C(12)	-41307.17	160012.2	-0.258150	0.7966
C(13)	-144360.9	155691.5	-0.927224	0.3552
C(14)	-26.13275	49.95742	-0.523100	0.6016
C(15)	33.76942	46.69808	0.723144	0.4707
C(16)	-0.633450	0.322798	-1.962372	0.0515
C(17)	-0.231385	0.312817	-0.739681	0.4606
C(18)	88226.06	40507.60	2.178013	0.0309
C(19)	144200.0	42461.06	3.396053	0.0009
C(20)	-2396081.	1351597.	-1.772779	0.0782
C(21)	957217.6	1260134.	0.759616	0.4486
C(22)	-11225482	82576261	-0.135941	0.8920
C(23)	-59756210	79744471	-0.749346	0.4548
C(24)	-2992548.	874921.9	-3.420360	0.0008
C(25)	-2217916.	882318.8	-2.513736	0.0130
C(26)	81709.11	204067.2	0.400403	0.6894

R-squared	0.369975	Mean dependent var	104395.6
Adjusted R-squared	0.269010	S.D. dependent var	2961089.
S.E. of regression	2531671.	Akaike info criterion	32.45822
Sum squared resid	1.00E+15	Schwarz criterion	32.91594
Log likelihood	-2927.698	Hannan-Quinn criter.	32.64377
F-statistic	3.664375	Durbin-Watson stat	1.983782
Prob(F-statistic)	0.000000		

Model 6 Second-hand Market Aframax category

Regression Analysis

Dependent Variable: D(NEWBUILD_PRICES)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 07/30/15 Time: 18:36
Sample (adjusted): 2000M04 2015M05
Included observations: 182 after adjustments
D(NEWBUILD_PRICES) = C(1)*(NEWBUILD_PRICES(-1) + 2.4037316825
*OIL_PROD(-1) - 213815.541574*OIL_PRICE(-1) - 3304960.36875
*LIBOR(-1) + 1432140120.08*INFLATION(-1) + 136888194.154*GDP(
-1) - 328537799.489) + C(2)*(SECOND_PRICES(-1) +
3.52592591449*OIL_PROD(-1) - 104156.624979*OIL_PRICE(-1) -
4546629.52231*LIBOR(-1) + 1946285919.17*INFLATION(-1) +
196065671.872*GDP(-1) - 458009261.851) + C(3)*(SPOT(-1) -
7.42785058927E-06*OIL_PROD(-1) + 1.69406019861*OIL_PRICE(-1)
- 12.0399619834*LIBOR(-1) - 2515.1543159*INFLATION(-1) -
30.4605830248*GDP(-1) + 477.185109691) + C(4)*(
TIMECHARTER1(-1) + 2.55134995624E-06*OIL_PROD(-1) +
178.673163822*OIL_PRICE(-1) - 1723.94353021*LIBOR(-1) +
265964.729508*INFLATION(-1) + 49762.3072306*GDP(-1) -
57712.1286773) + C(5)*(ORDERBOOK(-1) + 7.45733970033E-06
*OIL_PROD(-1) - 0.4639402076*OIL_PRICE(-1) - 1.02961175089
*LIBOR(-1) + 2935.11587665*INFLATION(-1) + 216.496991661*GDP(
-1) - 784.54103322) + C(6)*(EARNINGS(-1) - 0.000780633748606
*OIL_PROD(-1) + 439.415349301*OIL_PRICE(-1) - 3108.41675698
*LIBOR(-1) + 269250.866119*INFLATION(-1) + 71814.3875902*GDP(
-1) - 22088.1325547) + C(7)*D(NEWBUILD_PRICES(-1)) + C(8)
*D(NEWBUILD_PRICES(-2)) + C(9)*D(SECOND_PRICES(-1)) + C(10)
*D(SECOND_PRICES(-2)) + C(11)*D(SPOT(-1)) + C(12)*D(SPOT(-2))
+ C(13)*D(TIMECHARTER1(-1)) + C(14)*D(TIMECHARTER1(-2)) +
C(15)*D(ORDERBOOK(-1)) + C(16)*D(ORDERBOOK(-2)) + C(17)
*D(EARNINGS(-1)) + C(18)*D(EARNINGS(-2)) + C(19)*D(OIL_PROD(
-1)) + C(20)*D(OIL_PROD(-2)) + C(21)*D(OIL_PRICE(-1)) + C(22)
*D(OIL_PRICE(-2)) + C(23)*D(LIBOR(-1)) + C(24)*D(LIBOR(-2)) +
C(25)*D(INFLATION(-1)) + C(26)*D(INFLATION(-2)) + C(27)*D(GDP(
-1)) + C(28)*D(GDP(-2)) + C(29)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.141313	0.035389	-3.993150	0.0001
C(2)	0.094331	0.039363	2.396435	0.0178
C(3)	20689.44	6551.426	3.158005	0.0019
C(4)	-113.1972	59.24799	-1.910566	0.0579
C(5)	49208.94	20011.28	2.459060	0.0150
C(6)	-54.08699	21.87910	-2.472085	0.0145
C(7)	0.232388	0.080715	2.879134	0.0046
C(8)	0.110971	0.076405	1.452408	0.1484
C(9)	0.053133	0.048610	1.093047	0.2761
C(10)	0.017724	0.043972	0.403068	0.6875
C(11)	-7899.750	8787.090	-0.899018	0.3701
C(12)	-20276.18	8446.173	-2.400636	0.0176
C(13)	52.65854	83.20563	0.632872	0.5278
C(14)	226.0124	84.11183	2.687046	0.0080
C(15)	-57205.18	95810.48	-0.597066	0.5513
C(16)	-80945.59	99294.19	-0.815210	0.4162
C(17)	10.42487	25.69981	0.405640	0.6856
C(18)	41.50721	23.39541	1.774160	0.0780
C(19)	-0.201508	0.118962	-1.693890	0.0923
C(20)	-0.133625	0.114829	-1.163683	0.2464
C(21)	11865.46	15197.91	0.780730	0.4362
C(22)	32436.03	15725.06	2.062697	0.0408
C(23)	-409136.3	465742.9	-0.878460	0.3811
C(24)	788479.6	442352.1	1.782471	0.0767
C(25)	25231852	30059050	0.839409	0.4025
C(26)	-25539791	30164866	-0.846673	0.3985
C(27)	479255.1	316111.2	1.516097	0.1316
C(28)	212490.9	312993.9	0.678898	0.4982
C(29)	80500.84	75348.38	1.068382	0.2870

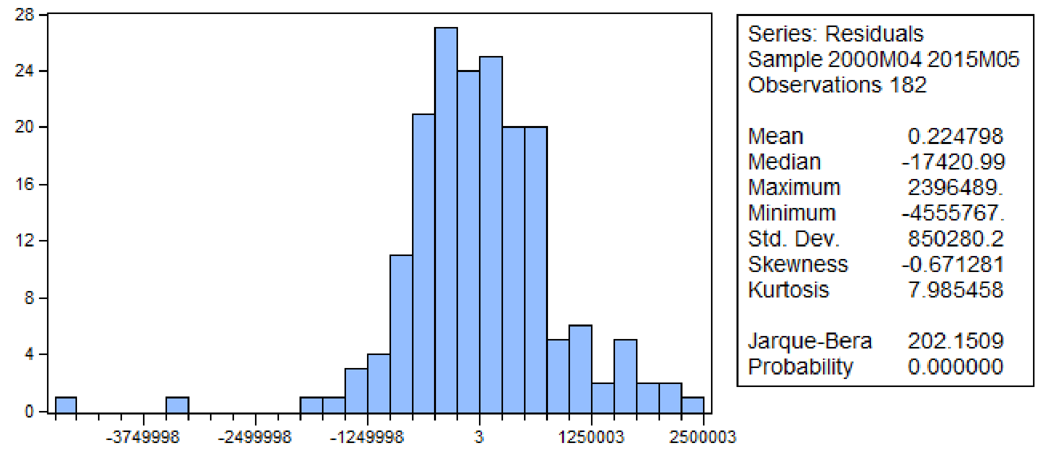
R-squared	0.586919	Mean dependent var	93406.59
Adjusted R-squared	0.511323	S.D. dependent var	1322953.
S.E. of regression	924816.6	Akaike info criterion	30.45769
Sum squared resid	1.31E+14	Schwarz criterion	30.96822
Log likelihood	-2742.650	Hannan-Quinn criter.	30.66465
F-statistic	7.763837	Durbin-Watson stat	1.980681
Prob(F-statistic)	0.000000		

ARCH Test

Heteroskedasticity Test: ARCH

F-statistic	0.417885	Prob. F(2,177)	0.6591
Obs*R-squared	0.845940	Prob. Chi-Square(2)	0.6551

Histogram – Normality Test



Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.140081	Prob. F(2,151)	0.3225
Obs*R-squared	2.707391	Prob. Chi-Square(2)	0.2583