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# The VLCC Tanker Market: the present, past and future

## *A historical fleet analysis followed by a stochastic partial equilibrium model of the spot freight market*

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## Abstract

This thesis analyzes the development of the VLLC fleet over the last two decades. On the basis of collected data, the supply curves of the current and historical fleets are calculated under three distinguished speed regimes; speed optimized regime, fixed speed at maximum speed and fixed speed at 12 knots. We then proceed with the current fleet and construct a partial equilibrium model of the spot freight market. Our model incorporates a stochastic process surrounding bunker price, demand, scrapping and new building. The model is applied to simulate the probability distribution of the future spot rates under the different speed regimes. Finally we find the short-term distribution of the spot rate when demand is high and low.

## Preface

First and foremost we would like to thank our supervisor, Roar Adland. His enthusiasm and overwhelming knowledge of the topic is truly inspiring. We would also like to thank Siri Pettersen Strandenes, who had valuable input regarding literature and the optimizing problem.

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# Contents

# List of figures

# 1. Introduction

Ever since the commercial production of crude oil started in the 1850s, it has been transported around the globe by sea. In the early days, the oil was filled in wooden barrels and loaded on ships. The barrels were however soon replaced by tanker vessels, and only the notion of a barrel as a measure in the oil trade persists. As demand for oil increased, along with the discovery of large oil reserves in the Middle East, the crude oil tanker ships grew considerably larger. The largest, most common tanker today is a Very Large Crude Carrier (VLCC), typically measuring around 300,000 dwt[1].

The shipping market is a cyclical one, where freight rates can go from sky high in one period, giving ship owners massive profits, and plummet in the next, causing them to barely cover voyage costs. The concept of reducing speed in order to save fuel costs has therefore been in focus during many periods of the shipping industry. Traditionally, this has been done in times when freight rates are low in comparison to fuel prices. In addition of saving fuel costs, the reduced speed of the vessel has another effect; it increases total time used on a single voyage, thus reducing the vessels transportation capacity in a given time frame. The reduction of supply of one vessel will, of course, only change the market situation marginally. However, looking at the effect on the market as whole where each ship adjust their speed in response to freight rates and fuel prices, would be of great interest to say the least.

Although the VLCC fleet has been regarded as fairly homogenous, clear differences exist. The most substantial difference in economic terms is due to different levels of fuel consumption. Fuel is the main cost of operating a tanker vessel, and gets very evident in a market such of today. The individual consumption of the vessel will therefore determine whether or not it will trade in the market.

In this thesis, we will focus on two main aspects of research; first we will look at the development of the fleet, by selecting fleet data from three years with five years intervals,

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[1] Dwt (deadweight tonnage) is a measure of the cargo capacity of a vessel.

making a comparison to the fleet of today. Second, we will perform a complete simulation of the fleet with a stochastic determination of oil price and with different speed regimes.

We will first present a walkthrough of selected previous work related to the topic. In the third chapter we find it useful to give an introduction to the shipping industry for readers unfamiliar to the subject. The development of the VLCC market as well as the fleet will then be studied, followed by a comparison of today's fleet with the fleet at three different years. The outstanding database of Clarksons SIN has provided the data basis for that analysis.

An introduction of the concept of slow steaming and speed optimization is given before introducing the Nortank model (Norman & Wergeland, 1981). The Nortank model, in addition to the collected data, creates the basis for our calculation of the present and previous supply curves. We discuss the impact the changes in fleet constellation have had on the shape of the supply curve, and how it changes under different speed regimes.

In the following chapter the parameters needed to perform the simulation of the VLCC market is estimated. A discussion around the development of bunker prices is given, and the data is tested. The same procedure is done with the demand function. The scrapping and new building process is estimated by using a method inspired by Adland & Strandenes (2007). We then discuss the results of the simulation and the implication it has.

# 2. Literature review

The volatile world of the freight market has been subject of modeling in many studies, primarily through a traditional supply and demand equilibrium setting. Koopmans (1939) was one of first publications modeling the supply and demand in the tanker segment. In 1981, Norman & Wergeland published “Nortank”, which is a simulation model of the tanker market. Their main focus is related to the supply side where they calculate the individual supply curves of four different vessels, and create an aggregate market supply curve. Their modeling of the supply curve will form the basis of supply curve calculations in this thesis.

In the same series, “Norbulk” (Wergeland, 1981) was published, a simulation model focusing on the dry bulk marked. The model is also tested empirically by estimating elasticities of historical data from 1964-74. Using the estimates in accordance with year-specific exogenous variables for the period 1974-75, a theoretical equilibrium freight rate is found. Comparing the calculated equilibrium freight rate with the actual, they find that their model is fairly accurate.

The model “Ecotank” (Strandenes & Wergeland, 1981) asses the influence of the spot freight rates on time charter rates, new building prices and second hand values are modeled. The “Norship” model (Strandenes, 1986), is another publication in the series, and looks at the interdependence between the tanker market and the dry-bulk market. The constructed model computes equilibrium prices and volumes in the freight market, new building market and scrapping market in accordance with spot freight prices. Looking at the tanker market, Beenstock & Vergottis (1989) estimates an aggregate econometric model, applying a theoretical model where freight markets and ship markets are interdependent. They create a model where freight rates, lay-up, new and secondhand prices and the total size of the fleet is jointly and dynamically determined. Chen et al (2013) studies the relationship between freight rates, new building prices, second hand prices and scrapping prices in the tanker market empirically. They examine the relationships between developments in these markets, and find a positive correlation in line with the classical literature. In addition, they find that that indirect effects between some of the markets are more statistical significant than comparing the direct effects.

The bunker price and the freight rates are the main determinants of the supply curve in the models. Devanney (2010) illustrates slow steaming supply curves of a VLCC vessel under different levels of bunker costs, i.e. which speed the vessel should sail in response to freight rates and bunker prices. He also demonstrates how the elasticity of the curve decreases as bunker price increase. Norman & Wergeland (1981) discuss how changes in freight rates would affect utilization of the fleet. With low freight rates, they argue that off-hire for repair and general maintenance would increase due to lower opportunity costs. Queuing in load areas would also decrease, as the cost of waiting for potentially higher yielding freight are less substantial. Moreover, they argue that the utilization with regard to loaded cargo would also decrease, simply because the “lost” cost of extra cargo is lower.

The demand curve of tanker marked has been assumed to be completely inelastic with respect to freight rates in most classical maritime economic literature (Koopmans, 1939; Stopford, 2009). The reason behind this assumption has commonly been the lack of alternative ways of transport, thus making the demand independent of the freight rate. Adland and Strandenes (2007) points out that this assumption is fair under normal freight conditions. However, in situations where freight rates rises substantially relative to cargo value, it has been argued that demand of transport becomes gradually more elastic. Studies suggesting elasticity in the demand function is such as Strandenes and Wergeland (1982). By analyzing variation in routes in response of freight rates, they find that trade patterns are less efficient in terms of minimizing distance when freight rates are low. Price elasticity of the commodity traded could also affect demand for transport if the commodity is substitutable (Wergeland, 1981; Adland & Strandenes, 2007). Moreover, a cross substitution of vessels operating in different bulk segments in response to high segment specific freight rates, as well as other ways of transport, suggest elasticity in the demand curve. As stated by Adland & Strandenes (2007), the arguments would imply the existence of a theoretical freight where any profit from sea transport of a specific commodity would be eliminated, and where transportation costs would no longer be possible to transfer to the commodity buyer.

Mossin (1968) was one of the first to discuss the lay-up problem. By assuming that earnings followed a random walk with a lower and upper bound, he showed that when there are cost involved in taking a ship out and in of service the ship owner will take a ship out of service if earnings fall below x. It is further shown that x is lower than operational costs, which are assumed not to be fixed. For it to be profitable to set the ship back in operation, earnings would need to reach a level y, which is shown to be higher than operational costs. Lastly it is shown that the values of x and y are independent of the upper and lower bound of the earnings.

As all time-horizons are by definition a sequence of momentary equilibriums, Adland (2012) presented a hypothesis that the voyage cost of the marginal vessel will always set the spot freight rate, and thus the lower bound of the freight rate would be the most efficient vessel. By empirically recreating the daily supply curve of a specific route in the Capesize market over more than a decade, it was found that the spot freight rate never went below the marginal cost of the most efficient ship. Moreover, results revealed that the freight rate could frequently fall and remain below levels normally associated with lay-up for longer periods. It was also found that freight rates were above marginal costs of the least efficient ships for about 50% of the time in focus, not explainable by traditional economic theory.

Ronen (1982) looks at the tradeoffs between bunker fuel savings through speed reductions, accounting for the loss of profit due to the extra sailing with reduced speed. He creates different speed optimization models for three different decision environments, namely: the income generating leg (laden[2]), the positioning leg (ballast[3]), and a speed related leg that includes penalties if the trip time deviates from the charter-party. In Ronen (2011) approach the container segment and rise in bunker prices, analyzing the tradeoff between slow steaming and vessels additions needed to minimize annual operating cost for a specific route. He presents numerical examples, illustrating costs savings in accordance with different bunker prices. Looking from the environmental perspective, several papers have been published in recent times regarding the reduced CO2 emissions caused by slow steaming (see Cariou, 2010; Corbett et al., 2009; Devanney, 2010 amongst others).

Empirical observation of speed optimizations have mainly been conducted in the container segment. Notteboom & Vernimmen (2009) investigates how container vessels have adapted to factors such as speed in reaction to higher bunker costs. They find that speed has been reduced, as well as more and significant larger vessels have been added to the fleet. Jonkeren et. al. (2012) analyzed the dry bulk trips made by inland waterway transport carries in North-west Europe. Measuring elasticity, their results indicate that freight prices have a positive

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[2] A vessel is said to be laden when carrying cargo

[3] A vessel that is not carrying cargo pumps sea water into its ballast tanks to lower the ship in the water. This is done to increase propeller efficiency and increase vessel stability

effect and fuel prices a negative effect on navigation speed. More specific, they found that a 10 percent increase in freight prices per day increased the navigation speed by 1.7 percent, and 10 percent increase in fuel prices reduced the speed by 1.1 percent. They also found that there was an inverse effect between an increase in the freight rates and the increase in fuel prices, i.e. that fuel is the key factor regarding speed choice in line with classical maritime theory. Assman (2012) study if the well-established relationship between speed, freight rates and bunker prices can actually be observed empirically by looking at the VLCC market. Using AIS data on a route from the Middle East to Japan, she finds no statistical evidence of the relationship between variables. Wahl & Kristoffersen (2012) compares the actual sailing speeds of VLCCs to a theoretical optimal speed, derived by using a model developed by Petter Haugen (2012). In an even more recent study, Adland (2013) investigate if ship owners actually adjust speed according to classic maritime economic theory, looking at 18,000 voyages in the Capesize drybulk sector since July 2011. He finds evidence of speed reductions, but states that the speed adjustments are not as dynamic as they should be.

This thesis will try to determine if the VLCC fleet is a homogenous one, and assess how homogeneity will affect the supply curve of the fleet. Moreover, we estimate the supply curve under 3 different speed regimes; speed optimized fleet, fixed speed fleet at maximum speed and fixed speed at 12 knots. We further create a partial equilibrium model with a stochastic process surrounding bunker price, demand, scrapping and new building in order to simulate the distribution of the future spot rates as well as the VLCC fleet.

# 3. The Shipping Industry

## 3.1 Segments

The international seaborne trade can roughly be divided into three main segments bases on the characteristics of the goods transported, namely: bulk shipping, specialized shipping and liner shipping. The following definitions are from Stopford (2009).

### Bulk

The bulk shipping segment is characterized by a transportation of homogenous goods in large quantities, often raw materials. The segment can be subcategorized into dry-bulk and liquid bulk transport. Currently, dry-bulk constitutes about 42 % of the total world shipping fleet in terms of capacity (Clarksons, 2013). The main commodities transported by dry-bulk vessel are iron-ore, coal, grain, phosphates and bauxite. The most common liquid goods needing tanker transport are: crude-oil, oil products, chemicals, vegetable oils and wine. The world tanker fleet constitutes about 32 % of the world fleet, making the bulk shipping segment account for almost three quarters of the world merchant fleet. In this thesis, we will focus on Very Large Crude Carriers (VLCCs), a tanker vessel that is typically around 300,000 dwt[4].

### Liner

The liner segment consists of transportation of less homogenous goods. The goods are often shipped in standardized containers, on pallets or simply just loose. Since there is no generalized form of goods, and due to the amount of different costumers shipping different goods, the level of organization needed in the liner segment is substantial. Goods transported can be of great value, and security of goods can thus be equally important in service level as transport price.

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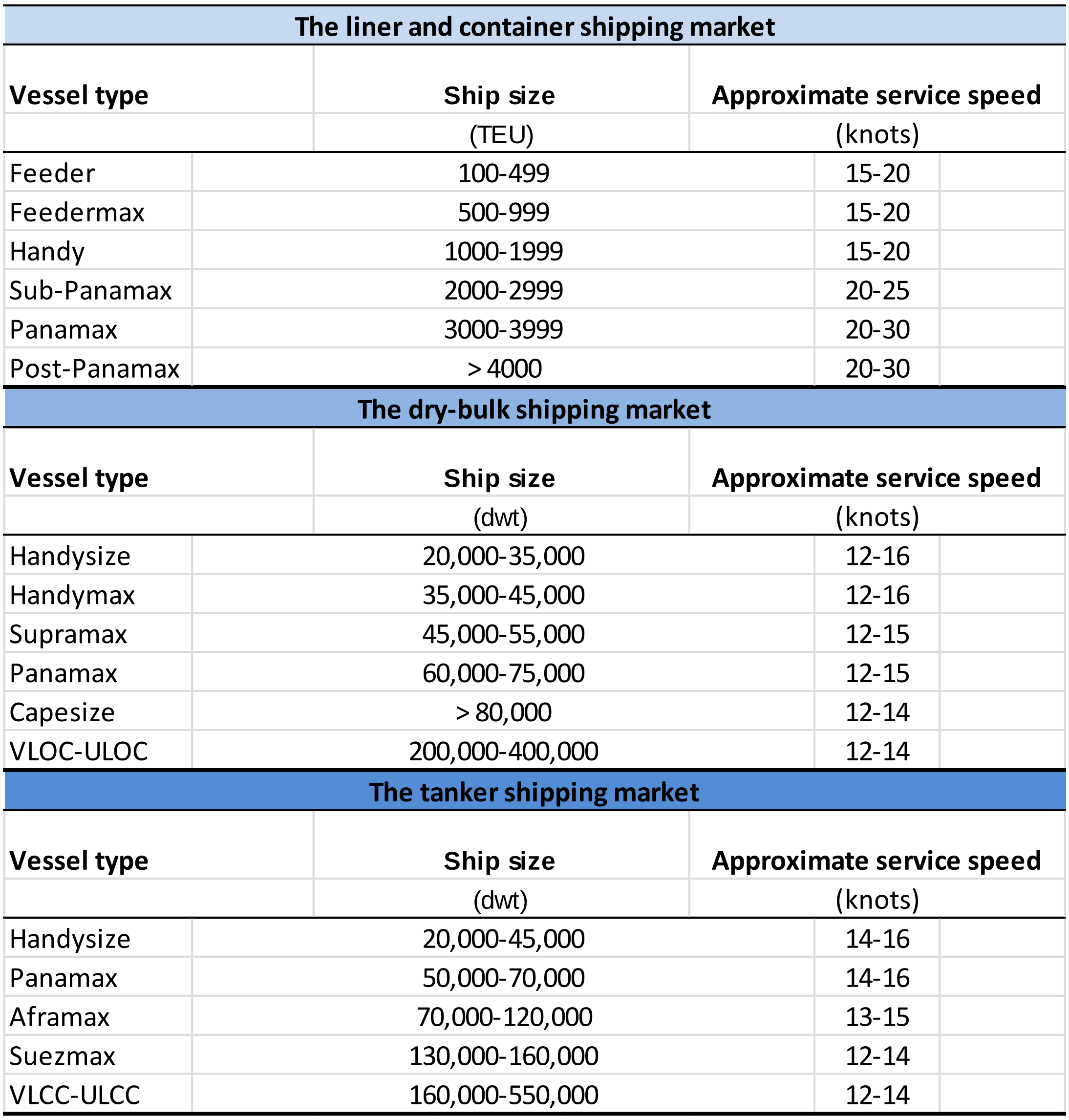
[4] The VLCC classification span from 160,000 dwt to 320,000 dwt. Vessels larger than this classifies as Ultra Large Crude Carrier (ULCC). There are only two vessels in the current tanker fleet that classifies as ULCC, and these are included in the analysis of this thesis.



**The liner and container shipping market**

| Vessel type | Ship size | Approximate service speed |
|---|---|---|
| | (TEU) | (knots) |
| Feeder | 100-499 | 15-20 |
| Feedermax | 500-999 | 15-20 |
| Handy | 1000-1999 | 15-20 |
| Sub-Panamax | 2000-2999 | 20-25 |
| Panamax | 3000-3999 | 20-30 |
| Post-Panamax | > 4000 | 20-30 |

**The dry-bulk shipping market**

| Vessel type | Ship size | Approximate service speed |
|---|---|---|
| | (dwt) | (knots) |
| Handysize | 20,000-35,000 | 12-16 |
| Handymax | 35,000-45,000 | 12-16 |
| Supramax | 45,000-55,000 | 12-15 |
| Panamax | 60,000-75,000 | 12-15 |
| Capesize | > 80,000 | 12-14 |
| VLOC-ULOC | 200,000-400,000 | 12-14 |

**The tanker shipping market**

| Vessel type | Ship size | Approximate service speed |
|---|---|---|
| | (dwt) | (knots) |
| Handysize | 20,000-45,000 | 14-16 |
| Panamax | 50,000-70,000 | 14-16 |
| Aframax | 70,000-120,000 | 13-15 |
| Suezmax | 130,000-160,000 | 12-14 |
| VLCC-ULCC | 160,000-550,000 | 12-14 |

*Figure 1: Vessel classifications and normal service speeds (Alizadeh & Nomikos, 2009; UNCTAD, 2000)*

### Specialized shipping

The specialized shipping services transport special cargo that is difficult to transport any other way. The segment sits somewhere between liner and bulk as it contains characteristics of both (Stopford, 2009). Goods transported in specialized vessels could be cars (Ro-Ro), refrigerated cargo (Reefer), chemicals and liquefied gas (LNG/LPG).

## 3.2 Markets

There are four different but highly related markets within the supply of shipping services: the freight market and the market for ships, with the underlying segments of the new building market, the second-hand market and the scrap market. These four markets can be divided into two categories, the auxiliary markets and the real markets (Strandenes, 2002; Adland & Cullinane, 2006). The real market consists of the new building and scrapping market as these markets have real impact of the fleet capacity. The auxiliary market is the freight and second-hand market, where ship owners offer transport and trade ships.

**The freight market**

The freight market is where sellers and buyers meet to trade sea transport services. The supply and demand for those services determine the freight rate. The determination of ship prices will depend on current and expected operational earnings, which is well documented in the shipping-economic literature. The current and expected freight rates are therefore key factors in variation of ship-prices (Nomikos & Alizadeh, 2009). Freight rates are very volatile, and can change significantly in a short period of time. The return on investments by ship owners, as well as the transport cost of cargo for shippers is therefore hard to predict.

The freight rate mechanism will be discussed more thoroughly later in the thesis.

**The new building market**

The new building market is where orders are placed to shipyards for new vessels. The positive relationship between freight rates and the new building market causes heavy ordering when freight rates are high. As shipyards order books starts to fill up, prices can rise considerably. Delivery of a vessel can take at least 2-3 years from the contract is signed, depending on demand (Stopford, 2009). Timing and expectations of the future market are therefore essential due to the time lag of delivery.

## The second hand market

The second hand market, also known as the S&P market, is the marketplace for the vessels ready to trade in the freight market. It’s an extremely competitive market where prices are directly determined by the operational profitability of the vessels, given by the general market. The relative value between vessel-sizes can change significantly with market conditions (Nomikos & Alizadeh, 2009). In a cycle of expansion, larger vessel would generate more revenue and operating profit due to the economics of scale. However, in a recession with lack of demand of transported cargo, the larger vessels with operational inflexibility would bear a higher risk of unemployment. Smaller vessels would be more likely to be employed, making the larger vessels relatively less valuable.

## The scrap- and demolition market

When a vessel is no longer economical viable for freight trading due to market conditions, it gets sold to a ship-breaker for demolition or scrapping. The ship-breaker buys the ship for the scrap metal on a $ /ldt[5][6] (light displacement tonnes) basis, in order to reuse the steel and other parts. The freight market, as well as the S&P and the new building marked, heavily affects the scrapping market. For example:  inefficient vessels that have been put in lay-up due to low freight rates and lack of expectations of market improvement, could be sold for scrap to cut losses. As supply of scrap vessels increases, the scrap values declines. Conversely, when freight rates are high, it may be profitable to keep trading in the market with old and less efficient vessel, thus decreasing supply of scrap vessels and increasing scrap values (Nomikos & Alizadeh, 2009).

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[5] Ltd (Light displacement tonnes) is the weight of a ship without anything onboard (i.e. without cargo, bunkers and fresh water)

[6] The notion $ is US dollars in this thesis

### 3.2.1 The cycle of ship markets

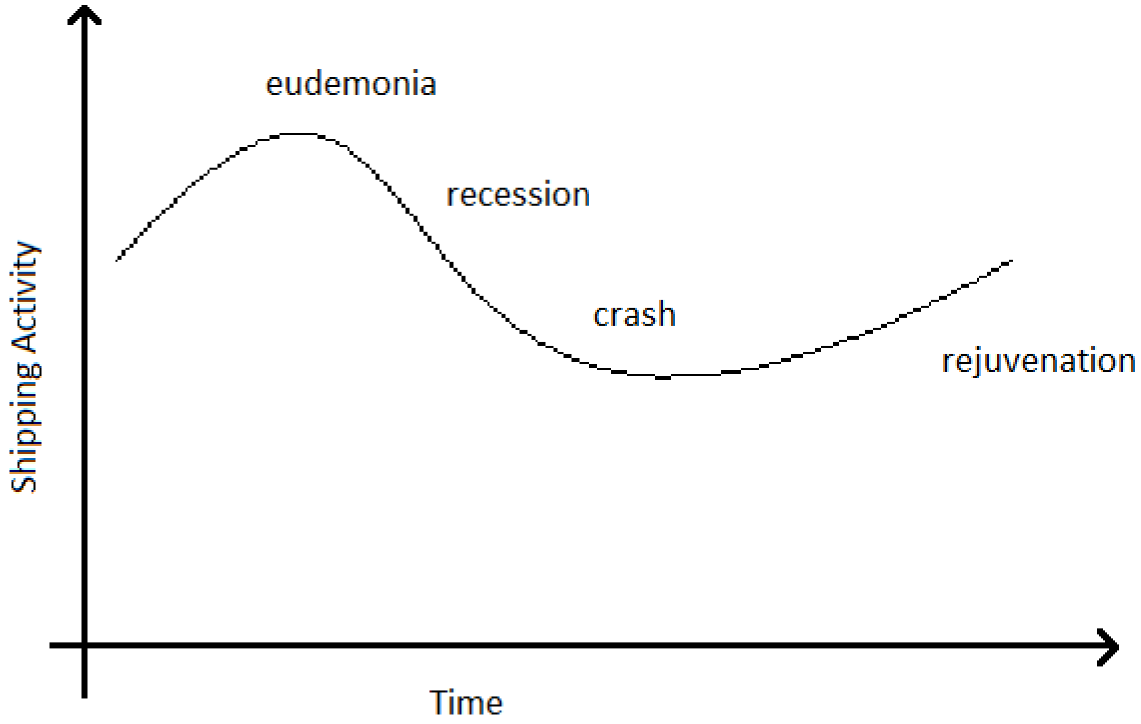

*Figure 2: The shipping cycle stages (Metaxas (1988) in Lyridis & Zacharioudakis (2012))*

The traditional shipping cycle (Metaxas (1988) in Lyridis & Zacharioudakis (2012) has the following stages:

*Rejuvenation*: Ship supply has dropped significantly, causing freight rats to increase just above operating costs. Laid-up vessels gradually return to the market resulting in a balance between supply and demand. Positive expectations of the future market rise, causing both second-hand prices and scrapping prices to increase.

*Eudemonia*: The shipping market is at its highest level, with freight rates far exceeding operating costs. The whole fleet operates at full speed, and only untradeable vessels are laid up. As ship values increase accordingly with the high freight rates, financing from banks ease. Second-hand prices increase to levels way over book value and modern vessels can even exceed the price of new-buildings. Heavy ordering causes capacity limitations in ship yards, increasing new-build prices as well as time-delay of delivery.

*Recession*: A surplus in ship capacity can be observed. As freight rates drop dramatically, ships decrease speed and the least efficient vessels are laid up. With freight rates causing negative cash flow for a longer period of time, some ship owners will sell ships at a low price. The prices in the second-hand market will therefore decrease, as well as prices in the scrapping market.

*Crash*: As ships ordered at the top of the market is being delivered causing more supply in a surplus capacity market, and freight rates drop. Orders and prices for new-building decrease, as well as second-hand and demolition prices.

The ship market is positively correlated with freight rates in short terms, the latter being the focus of this thesis.

## 3.3 The economics in Shipping

### 3.3.1 Structure and definition of costs

The costs associated with shipping consist of capital costs; operation costs; voyage costs; and cargo-handling costs. Type, size, age, speed and the financial structure of the vessel purchase determines the level of cost. The following definitions are from Alizadeh and Nomikos (2009):

*Capital cost* covers interest and capital repayments on a vessel. The current market situation, the financial structure of the purchase, and future market expectations affect the level of capital costs.

*Operating costs* consists of maintenance, insurance, inspections/renewal of certificates and crew wages. These costs are fixed, and incur whether or not the vessel is active.

*Voyage costs* are cost that incur for a particular voyage. Fuel costs, canal dues, pilotage and port charges are the main costs related to a specific voyage.

*Cargo-handling costs* involves loading, stowage, lightering, and discharging of the transported cargo.

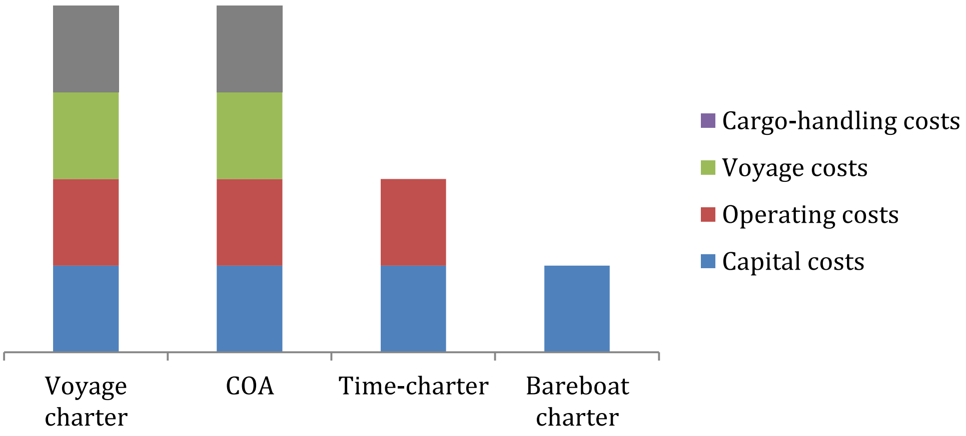

*Figure 3: Cost allocation from a ship owner perspective under different charter contracts (Nomikos & Alizadeh, 2009)*

## 3.3.2 **Arrangement for cargo shipment/chartering a vessel**

The shipper is an individual or a company that needs cargo shipped from port A to port B. The charterer is the individual or company that hires a ship to transport the cargo. The contract setting out the terms on which the shipper gets his cargo transported, or the terms on which the charterer hires a ship, is called the charter-party. A ship is said to be “fixed” when it’s chartered, or when an agreement of freight rate is made.

### 1. The voyage charter

A voyage charter is a contract to transport cargo between a load port and a discharge port for a single voyage. The ship owner is paid by the charterer by a pre-agreed route specific freight rate on a per-tonne or a lump-sum basis. As this form of contract covers only one voyage, it is known as a “spot contract”. The terms of the transport, such as freight rate, loading and discharging ports, type and quantity of cargo, speed, laytime[7], and demurrage[8], are specified in the charter-party. Deviation from the agreement could result in a claim. All costs related to the vessel are fully covered by the ship owner, with the occurring exception of cargo handling cost. For VLCCs, the voyage charter contract is the most common arrangement today.

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[7] Laytime is the time allowed to the charterer to load and discharge the cargo without incurring additional costs.

[8] Demurrage is the daily amount the charterer has to pay the ship owner if port day exceed the agreed laytime. Conversely, if port days used is less than the laytime agreement, a despatch is paid from the owner to the charterer.

### 2. Contract of affreightment (COA)

COA is an agreement on which the ship owner agrees to transport a series of cargoes on a fixed price per tonne within a specified period of time. The ship owner can utilize the vessel in any way within the restriction of the agreement.

### 3. The time charterer

A time charterer (TC) is an arrangement where the charterer is given operational control for the cargo-holding vessel, while leaving management in control of the ship owner. The vessel is paid a freight rate for a specific period of time, i.e. on a daily or monthly basis. The ship owner pays all operating costs of the vessel, while the charterer covers all the voyage-specific costs. There are two different types of time charter agreements; time and trip time charter. The trip time charter is for one voyage, or a very short period of time (Lansdale & Verreet, 2013). Trip charter rates are therefore also spot rates, but in contrast to the voyage charter the payment is made on a $/day basis, hence reducing risk for the ship owner in the occurrence of delay outside of port (Nomikos & Alizadeh, 2009).

### 4. The bare boat charter

An agreement where the charterer is given full control to the vessel for a specific long-term period, and where all operating- and voyage costs are covered by the charter. The vessel is often purchased as a pure financial investment, as the charterer bears all the risks and costs (Stopford, 2009).

## 3.3.3 Freight rate reporting.

Most tankers are traded under spot or time charter contracts.

The spot freight rate is the freight rate a vessel receives on a USD per tonne of cargo basis for a single voyage. For tankers, spot rates are reported in Worldscale.

*Worldscale* is a nominal worldwide tanker scale used to establish payment of freight services for a specific oil tanker’s cargo on a predefined voyage. The reference rate, also known as the flat rate, is reported as Worldscale 100 (WS100), and reflects the costs in USD of transporting a tonne of cargo for a standard vessel on a route-specific round voyage. The standard vessel is of 75.000 dwt, traveling at 14.5 knots with a consumption of 55 tonnes of

380cst fuel oil[9] a day. For each round voyage it's also added an extra 100 tonnes of fuel oil, as well as an extra 5 tonnes of fuel for each port involved. Port time is set to four days, and another 12 hours is added for each additional port used. The fixed rate for hire is set to a hypothetical $12.000 a day (Lansdale & Verreet, 2013). The calculations of the flat rate are based on last year's actual route specific costs, such as bunker costs and port costs. Due to changes in the voyage-cost, the Worldscale is adjusted every year by the World Scale Association. The freight rate negotiated for a specific vessel and voyage is normally quoted in a percentage of the flat rate, such as W35 or W200. An example could be that the flat rate for TD3[10] (Middle Eastern Gulf to Japan) is 22.5. If a voyage is traded at WS35, the price of the voyage in USD can be calculated as: 22.5*(35/100) = $7.875 /tonne. The Worldscale system simplifies comparison of earnings for ship owners and charterers in different routes (Fuglesang, 2011).

The *time charter rate* is the daily rate the ship owner receives for operating a vessel under a time charter agreement, and is denoted in USD/day.

To compare offers in the spot market, as well as to compare earnings between spot and time-charter operations, the *time charter equivalent* (TCE) can be calculated. The calculation of TCE is to firstly find the total freight payment, found by multiplying the spot rate ($/tonne) by the amount of cargo. The total voyage cost for the particular voyage is deducted from the total freight payment, finding the net freight payment. The net freight payment is then divided by number of days the vessel use for a round trip, resulting in the TCE or USD/day.

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[9] The most common bunker fuel used by tanker vessels is IFO 380cst (Intermediate Fuel Oil with a maximum viscosity of 380 Centistokes)

[10] Tanker Dirty 3 (TD3) is a common route for VLCCs, see section 4.1

# 4. VLCC specifications and market

In this section, we will first briefly look at different routes for VLCCs, followed by a historical development of the fleet.

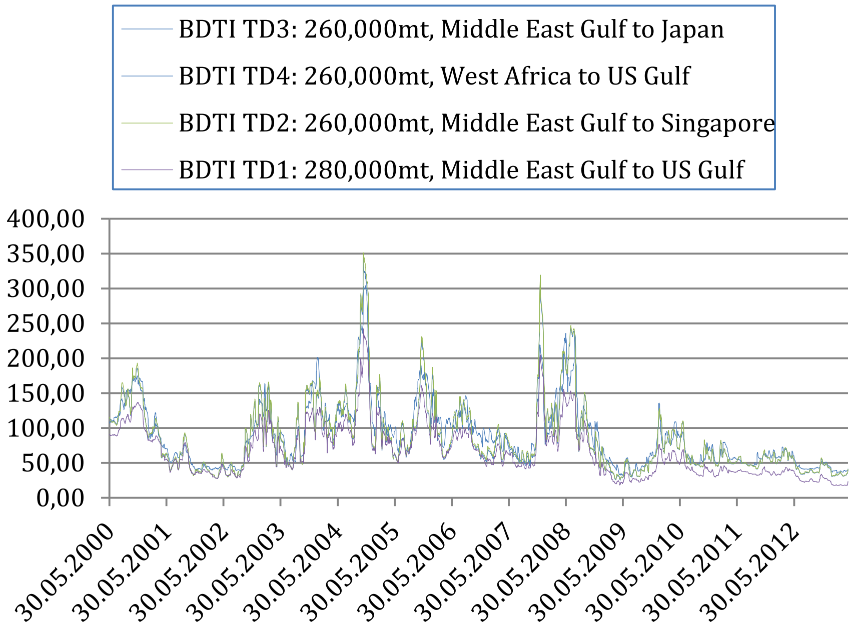
## 4.1 Indices and VLCC routes

The economies of scale related to VLCC reduces the per-tonne cost of transportation.

VLCC and Suezmax vessels are the main carriers of crude-oil. Due to draught and capacity restrictions in ports, oil terminals and canals, as well as the limitation of oil importing- and exporting regions, the VLCC only operate on a small amount of routes (Nomikos & Alizadeh, 2009). The market level for the crude-oil tankers are mainly described trough the BDTI index, published by the Baltic Exchange. Calculations are done one a daily basis, and are based upon reports from Baltic Exchange partners, shipbrokers and panelists (Lyridis & Zacharioudakis, 2012). The index is a weighted average of ten different routes, and four of the routes that are commonly operated by VLCCs are:

- TD1: Middle Eastern Gulf to US Gulf – 280,000 tonnes
- TD2: Middle Eastern Gulf to Singapore – 260,000 tonnes
- TD3: Middle Eastern Gulf to Japan – 250,000 tonnes
- TD4: West Africa to US Gulf – 250,000 tonnes

TD3 is the most traded route for VLCCs, and will therefore be used in this thesis. However, we would argue that it’s a fair assumption that the results will apply to all routes, due to the efficient characterization of the tanker market; the VLCCs are very homogenous, and operates within a near perfect market. If the development in freight prices should be remarkably higher on one route compared to another, the ship owner will simply allocate the vessel to the route with the higher rate. Thus, the hypothesis is that the trend in different VLCC indices should be highly correlated with each other (Steen, 2013). The indices measure level of freight service purchase on one particular route that, and if the hypothesis hold the trend in each index should be very stable Studying BTDI data of the four VLCC routes above, supports the hypothesis of trend correlation (figure 4).



| | TD3 | TD4 | TD2 | TD1 |
|---|---|---|---|---|
| TD3 | 1,00 | | | |
| TD4 | 0,94 | 1,00 | | |
| TD2 | 1,00 | 0,94 | 1,00 | |
| TD1 | 0,97 | 0,95 | 0,97 | 1,00 |

*Figure 4: BDTI comparison and correlation (Clarksons, 2013)*

# 4.2 VLCC fleet development

## 4.2.1 **Tonnage and prices**

The VLCC fleet as of May 2013 consists of 621 vessels, with a total of 187 million dwt. The supply of tonnage today has not been this extensive since the beginning of the 1980's. With the tonnage supply at its peak in 1980 at 193 million dwt, the Iranian revolution in 1979 caused oil-prices to rapidly increase. This led to an immediate negative reaction in oil demand, and consequently a decrease in demand for oil-transport. The fall in demand of transportation combined with the over-building of VLCC's in the 1970's caused the freight rates to plummet (Stopford, 2009). In the period 1980 to 1987, there was an extensive amount of VLCC demolitions as a response to the insufficient freight rates, ultimately resulting in a more balanced market (Stopford, 2009).

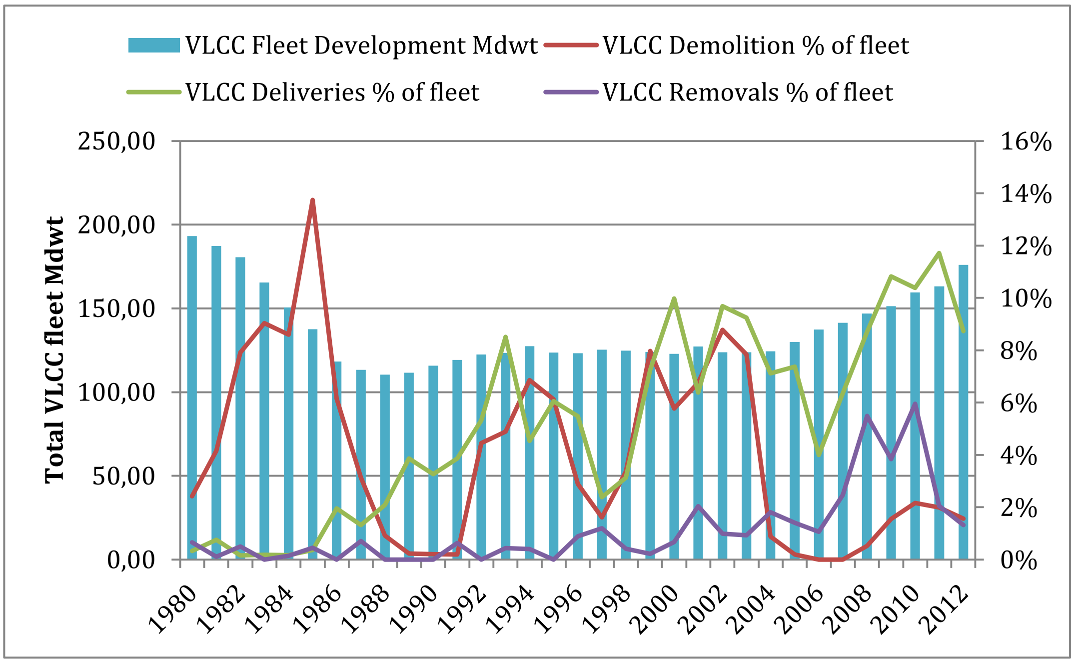


*Figure 5: VLCC fleet development 1980-2012 (Clarksons, 2013)*

Following improving rates, order-books were filled in the period 1988 to 1991. The new wave of orders was due to expectations of replacement of the VLCC's built in the 1970s, and an expected increase in demand of long-haul transport. However, most of the VLCCs from the 1970s continued trading in the market, and demand for long-haul transport did not increase as expected. When the deliveries of new VLCCs started, the market went into a recession lasting from 1992 to mid-1995 when freight rates started once again to improve (Stopford, 2009). High volatility in the rates in the late 1990s resulted in major scrapping of the 1970s VLCCs, and at the same time many new vessels were delivered.

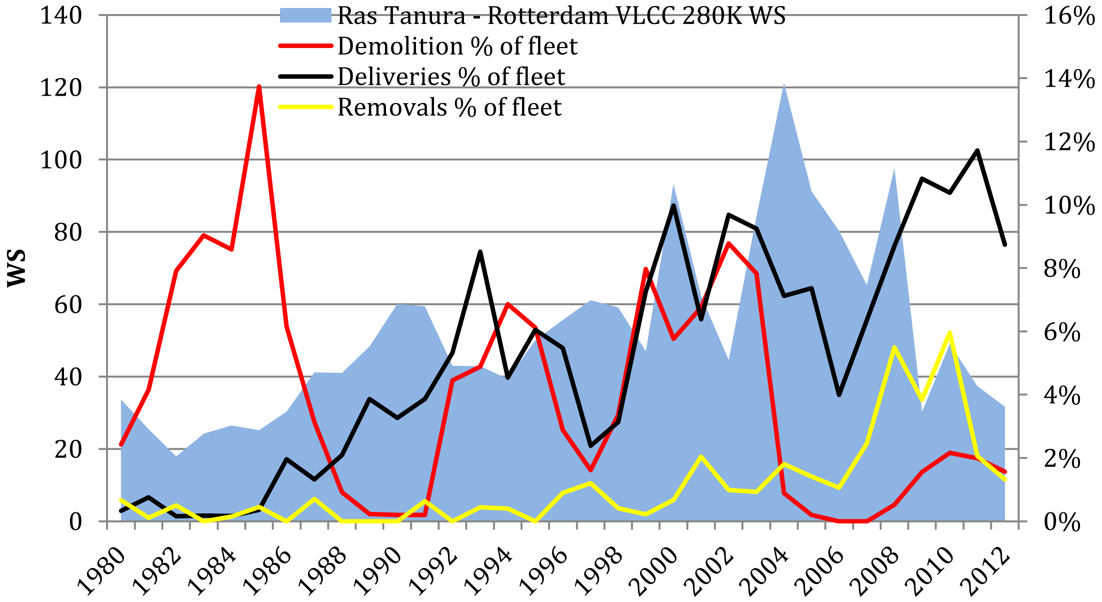


*Figure 6: Demolition & Deliveries in % of fleet vs. Ras Tanura - Rotterdam VLCC 280K WS (Clarksons, 2013)*

### 4.2.2 **Prices**

The prices of scrap value, second-hand vessels and new building is, as stated earlier, positively correlated with the freight rate, and thus with each other. A deviation of this can however be noted in the scrap value prices in the years following the market crash in 2008 (figure 7).

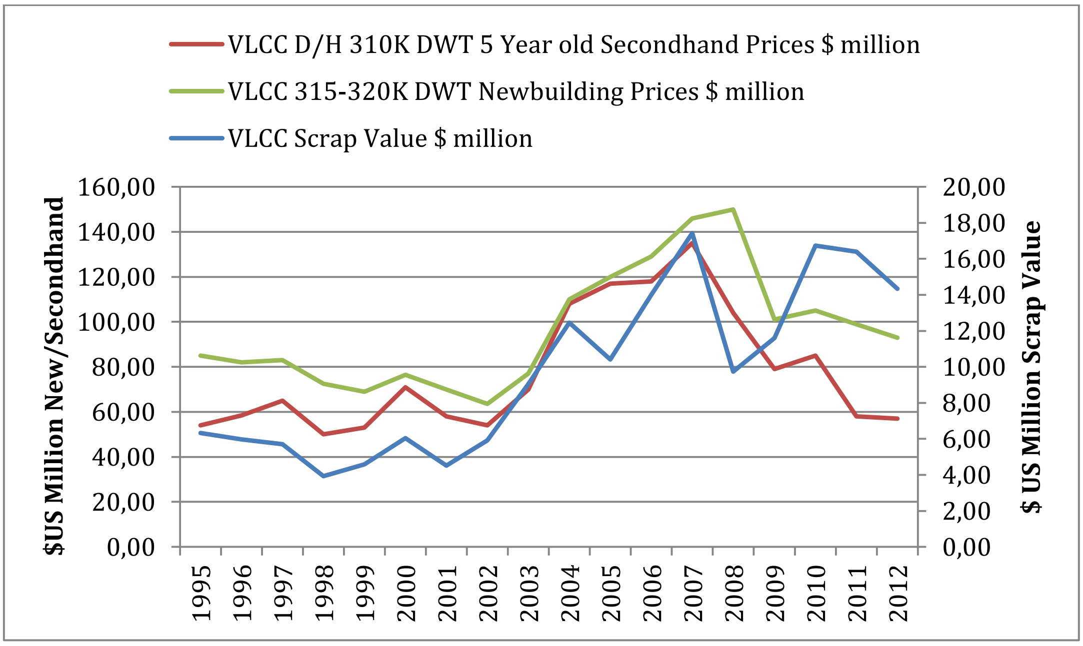


*Figure 7: New build, Secondhand, Scrap Value 1998-2012 (Clarksons, 2013)*

Due to increasing oil-import from fast growing economies like China, a great undersupply of crude-oil transport encountered, causing freight rates to increase rapidly in the autumn of 2003 (Stopford, 2009). The high rates caused a great demand for new vessels, creating a record high order backlog for shipping yards in 2007 (Bakkelund, 2008). The high freight rates and the recent heavy demolition of the oldest VLCCs resulted in near no demolition in the period from 2003 and 2007. In late 2008 the freight rates plummet due to the weakened economy and the following oversupply of tonnage strengthened by deliveries of the heavy ordering started in 2003.

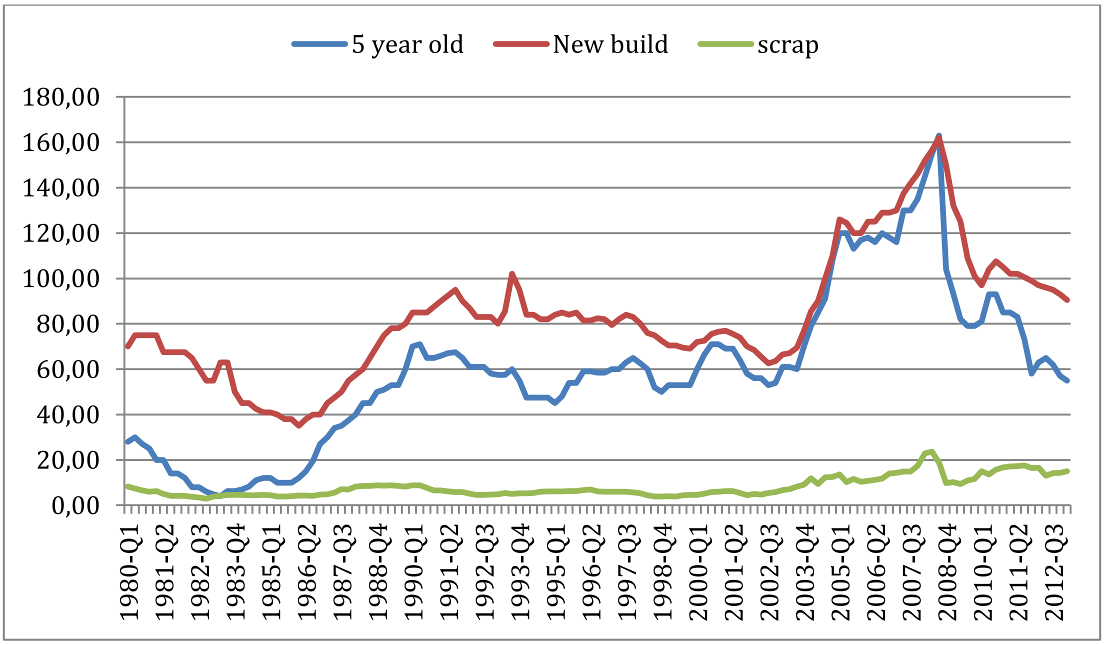


*Figure 8: New build prices, second hand prices and scrap prices 1980-2012 (Clarksons, 2013)*

Figure 8 shows that the scrap prices appears as a lower barrier to the VLCC second-hand prices. In the poor market between 1982 and 1987, the second hand prices were very close to scrap prices, followed by a steady development in relation to new build prices through the 1990s. In the good markets of 2002 to 2006, and 2006 to 2008, second hand prices were very close to new building prices, even exceeding them in the beginning of 2008. The surpassing of new building prices was caused by a large premium that would be paid to immediately benefit from the high freight rates (Nomikos & Alizadeh, 2009) . During the rapid fall in freight rates in late 2008, the prices in the ship market fell dramatically.

Looking at new building prices alone, the cyclical development has been argued to be caused by a combination of demand of seaborne trade (such as the world economic activity), and the investment ordering behavior driven by market expectations (Nomikos & Alizadeh, 2009; Stopford, 2009; Vergottis, 1988). Due to the time lag of building, new delivered vessels may enter a market that suffers from excessive tonnage due to new deliveries, a combination of new deliveries and a lack of scrapping, or a fall in demand for seaborne transport. The effect of oversupply of seaborne transport will then be reflected back to the new building market, causing prices to fall.

### 4.2.3 **Conversions**

In the weak market after 2008, the heavy demolition of the mid 1980s and 1990s as well as around year 2000 has not struck the VLCC fleet. Yet, there has been notable reduction of overall supply by VLCCs, looking apart from new deliveries. The reduction of supply is mainly caused by conversions of VLCCs to FPSOs/FSOs[11] (Floating (Production), Storage and Offloading vessels) VLOCs[12] (Very Large Ore Carriers).

There are at least two reasons for the rate of conversion. Firstly, from 2010 single hull[13] VLCCs were normally not allowed to trade due to regulations. This limited the options for the ship owner, either to send the vessel to demolition or conversion to a double hull vessel in order to keep trading. Secondly, the increasing demand and prices for FPSOs/FSOs and VLOCs, conversions would be quicker than new builds normally taking from 4 month to a year. The demand for FPSOs/FSOs is caused by the increasing number of deep water-production fields. In recent years a heavy demand for VLOC have grown mainly driven by the increasing demand for iron ore imports from Australia and Brazil to the steel mills in China (DNV, 2013).

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[11] FPSO is a floating production, storage and offloading vessel. Its purpose is to receive and process hydrocarbons produced from nearby platforms or subsea templates, and store the oil until it gets offloaded onto a tanker vessel or through pipeline. FSO (floating storage and offloading) is a vessel with the sole purpose of functioning as temporary oil storage.

[12] VLOC (Very Large Ore Carrier) is a vessel design to transport iron ore. The size range span from approximately 200,000 dwt to 400,000 dwt.

[13] Double hull (two watertight hulls) is todays standard. It’s required by the vast majority of flag states, and is applied for safety and environmental reasons, reducing risks of spilling oil. In addition, the sea water used on the ballast leg is pumped in to the double hull, rather than the tanks, thus eliminating contamination of the ballast water.

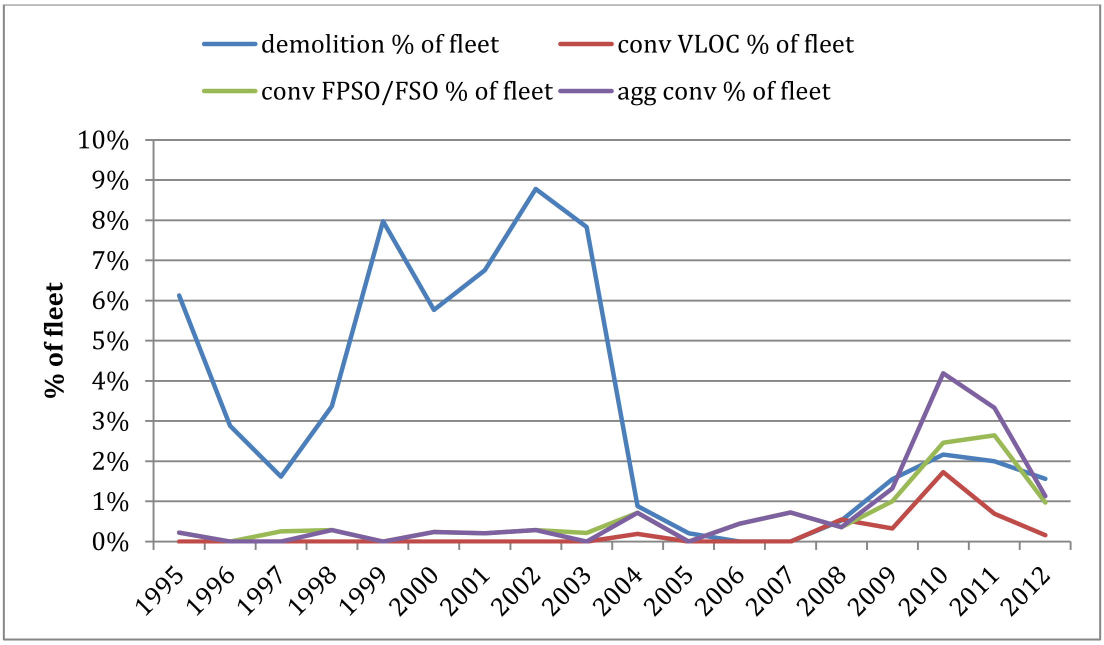

*Figure 9: Conversion and demolition (Clarksons (2013) and own calculations)*

### 4.2.4 **Cost of fuel**

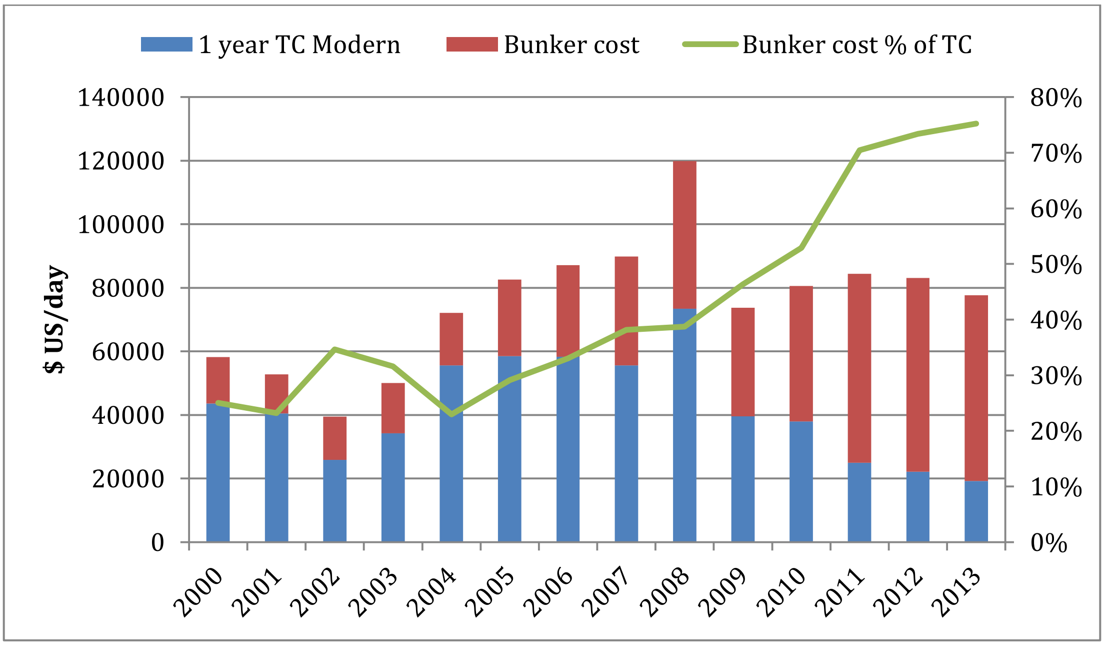

*Figure 10: Fuel cost vs. TC cost (Clarksons, 2013)*

The cost of bunker is the main cost operating a vessel. The figure above shows the development in bunker cost compared to an average 1 year time charter rate for a modern VLCC with data provided from Clarksons (2013). The price of bunker is the yearly average of 380cst in Singapore, expressed in $/tonne. The daily consumption is given by the average consumption at 91.9 tonnes/day for a vessel sailing at the average design speed of 15.9 knots.[14]

The development in bunker costs in in relation to TC cost has been significant since the early 2000s. Bunker cost constituted about 25% of hire cost in 2000. Today, it constitutes over 75% of the hire cost.

### 4.2.5 **Fleet comparison**

To further investigate the development in homogeneity of the VLCC fleet, fleet data of the existing fleet as of today is compared to the fleet of 2005, 2000 and 1995.

The VLCC fleet data is collected from Clarksons, 2013.  Of the existing fleet as of today, 529 of the 621 vessels have design speed given, and 317 of them also have data on fuel consumption of the vessel at the given speed. The vessels that lack data, have been applied this on basis of specifications to other vessels where data is given. The specifications used are build year, dwt, engine make and horsepower.

To estimate the VLCC fleet in the different time-periods we have used information on vessel demolition and vessel conversion[15]. On basis of the information on the current fleet, we removed all vessels that were not delivered at the time of the estimation. Using the demolition- and conversion data, we added all the vessels that were not demolished or converted at the time. As an example, the estimation of the 1995 fleet was done by first taking the list of all demolished vessels over time, and removing vessels that were demolished as of 31.12.1994. Then the same procedure was done with the vessel conversion list. Adding these vessels to the vessels built before 1995 that is still part of the current fleet, we found the VLCC fleet of 1995. Regarding data on speed and consumption, about 95% of the vessels derived from demolition and conversions had design speed given, and about 80%

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[14] This is the speed and consumption of the average VLCC today, according to Clarksons (2013)

[15] The total number of VLCC vessels derived from this data had some deviations in comparison to the number of vessels active in the respective years according to Clarksons SIN database. Therefore our estimations functions as a good *approximation* of the fleet in the respective years.

had consumption data for the design speed. Vessels that lacked such information were given estimates on the same basis described above.

### Age distribution

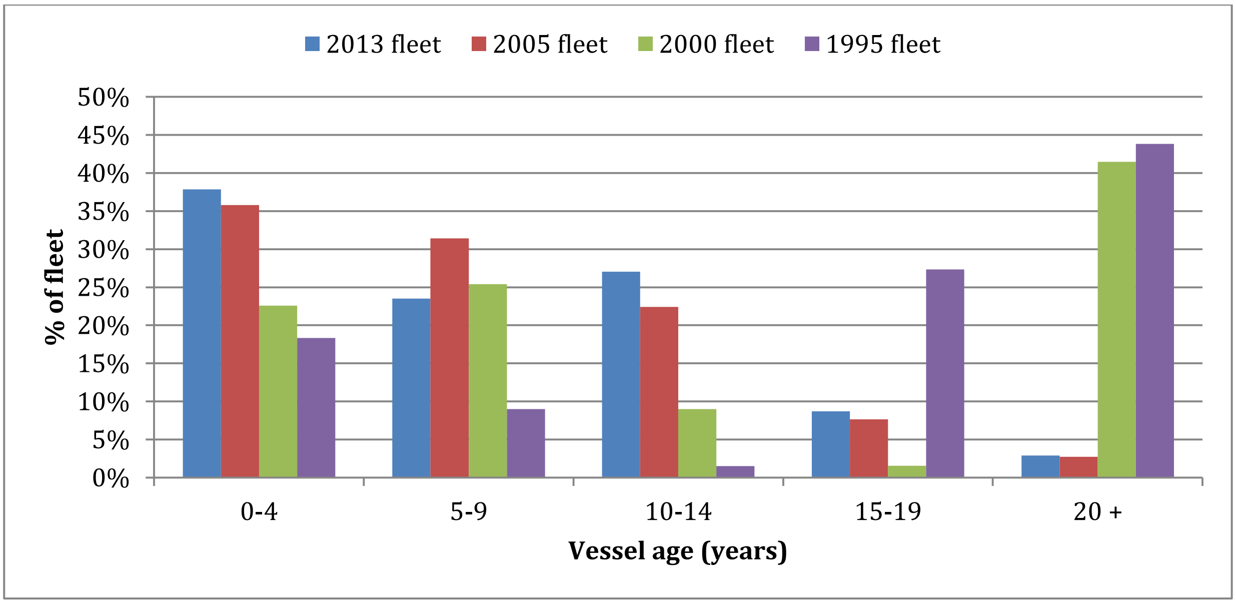

*Figure 11: Age distribution fleet (Clarksons (2013) and own estimations)*

Figure 11 shows the age distribution of the fleet at the respective year. The 1995 fleet consisted of almost 45 % vessels of 20 years or more, the average age being 15. In 2000, the average age had only declined to 14. The heavy demolition of 1970s tankers in the early 2000s in combination with new deliveries, brought the average age of the 2000 fleet down to 8 years, which is also the average age of todays fleet.

## Vessel Size

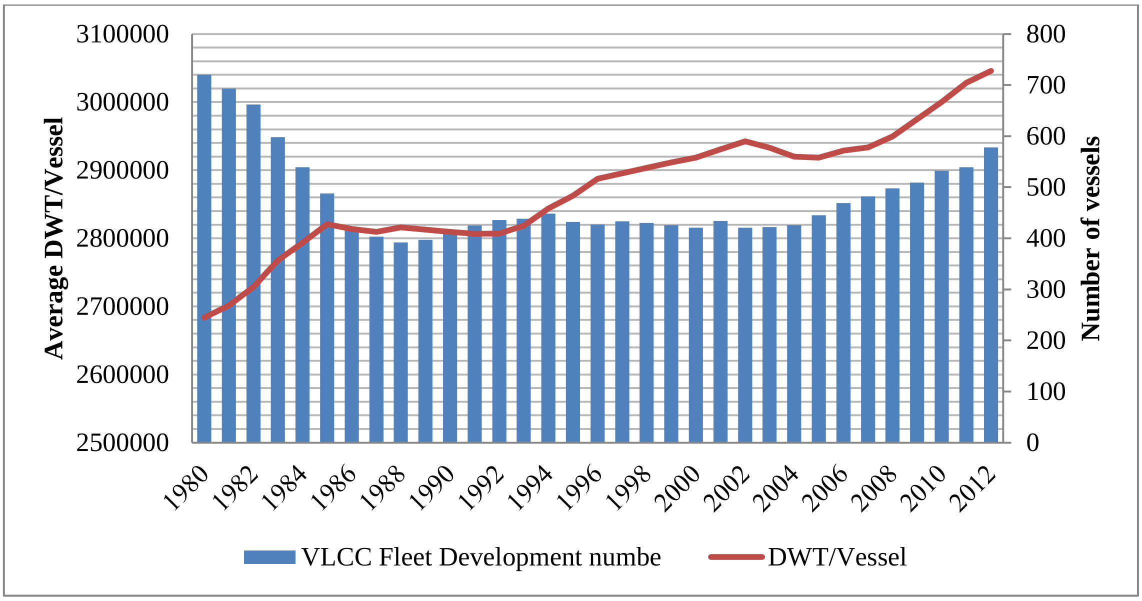

*Figure 12: Number of VLCCs and average size (Clarksons (2013) and own estimations)*

The number of VLCC vessels has declined since 1980 and was at a very stable level from 1986 all the way through the 1990s, before gradually starting to increase from 2005. The trend is quite clear; the average vessel has gradually become larger measured in dwt.

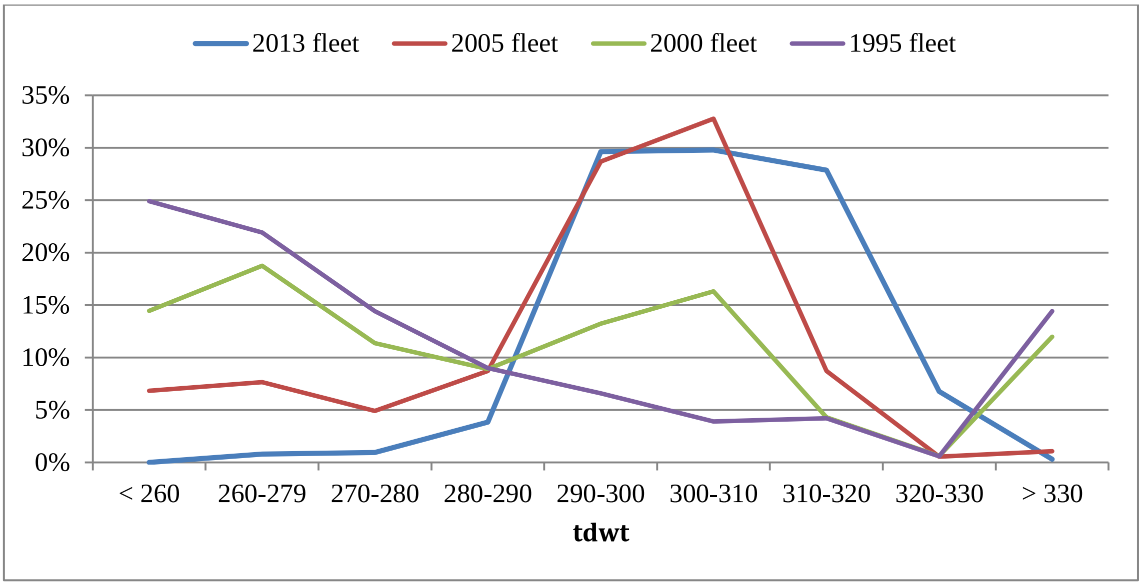

*Figure 13: Size distribution in fleet (Clarksons (2013) and own calculations)*

Looking at the year-specific comparison, the development in the fleet homogeneity regarding size is obvious. While the 1995 fleet is spread over various sizes, the size of the vessels become gradually more concentrated by the two fire year intervals, followed by a distinguished distribution curve of the current fleet with the vast majority of vessels spanning from between 290,000-300,000 dwt to 310,000-320,000 dwt. As the standard trade of oil today is around 2 million barrels, one should expect similarities regarding size of new built VLCCs.

### Engines makes and type[16]

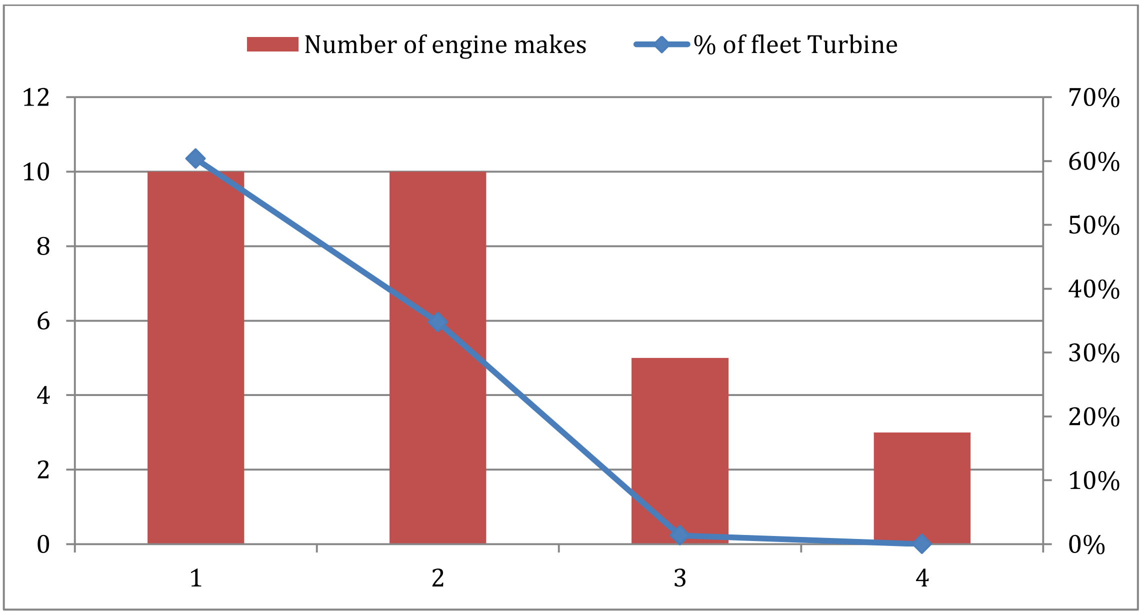

*Figure 14: Engine makes and % of fleet with turbine engines (Clarksons (2013) and own estimations)*

Most of the tankers built in the 1970s were turbine driven. The turbine driven tankers had very poor fuel efficiency, but a wide technical range of engine load. As bunker prices rose substantially compared to freight rates, the much more fuel efficient diesel engines were taken into use. The fleet as of 1995 consisted of about 60 % of the fleet being turbine driven. In 2005 those vessels were almost non-existing, and all the vessels of today's fleet have modern diesel engines.

The diesel engines have a lower technical range of load, limiting the choosing of speed. However, due to recent market conditions, modifications by engine manufacturers are offered to able a low engine load over a long period of time.

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[16] The amount of turbine powered vessels is derived from vessel data where given. Where data is lacking, assumptions based on specifications such consumption, engine make and age are used.

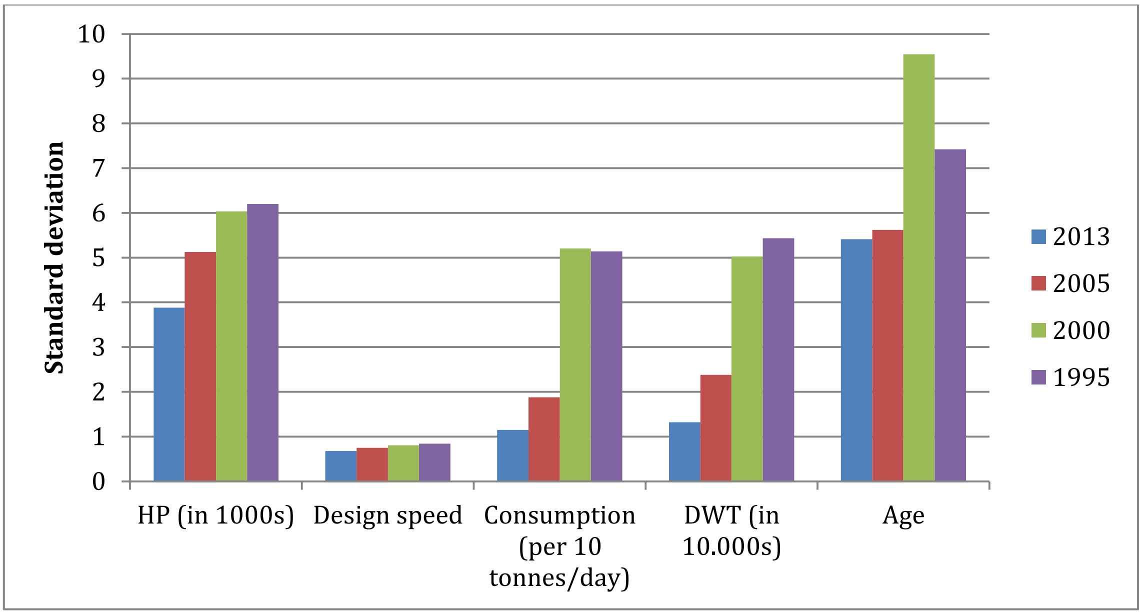


*Figure 15: Standard deviation of fleet characteristics (Clarksons, 2013)*

Measuring the standard deviation in horsepower, design speed, consumption, size and age, we can observe that the fleet has become truly more homogenous.

# 5. Theoretic basis of vessel supply

## 5.1 Slow steaming and speed optimization

**What is “slow steaming”, and what is optimal speed?**

Slow steaming has no official definition, but is used as a notion for vessels sailing below their design speed (Assman, 2012). The idea of slow steaming in order to save fuel costs is not a new phenomenon; the rapid increase in bunker prices along with the oversupply of tankers in the 1970s, caused ship owners to reduce speed in order to save costs.

As previously mentioned, in market situations characterized by high fuel prices and low freight rates, a reduction of vessel speed will have two direct consequences, namely; 1) Reduce the fuel consumption on the same haul, lowering overall transportation costs 2) Decrease individual vessel supply of transportation, increasing freight rates. The term “optimal speed” is the speed that maximizes profits for the ship owner in accordance with market conditions. As market conditions change, the optimal speed will change, i.e. the optimal speed is dynamically determined.

From a microeconomic perspective, the main reason behind the speed decision process is not the saved costs of fuel as a consequence of a speed reduction. The main reason is that a reduction in speed will reduce cost at a higher rate than it will reduce income. Laws of physics imply a convex function of fuel consumption in relation to speed. The income function is slightly concave, because port-time and anchoring is a constant and not linear with speed. Due to the fact that the cost function is convex and the income function is concave, we can deduce that the profit function (in relation to speed) is concave, hence a maximum will exist. In the following figures, the dynamics of this will be illustrated.

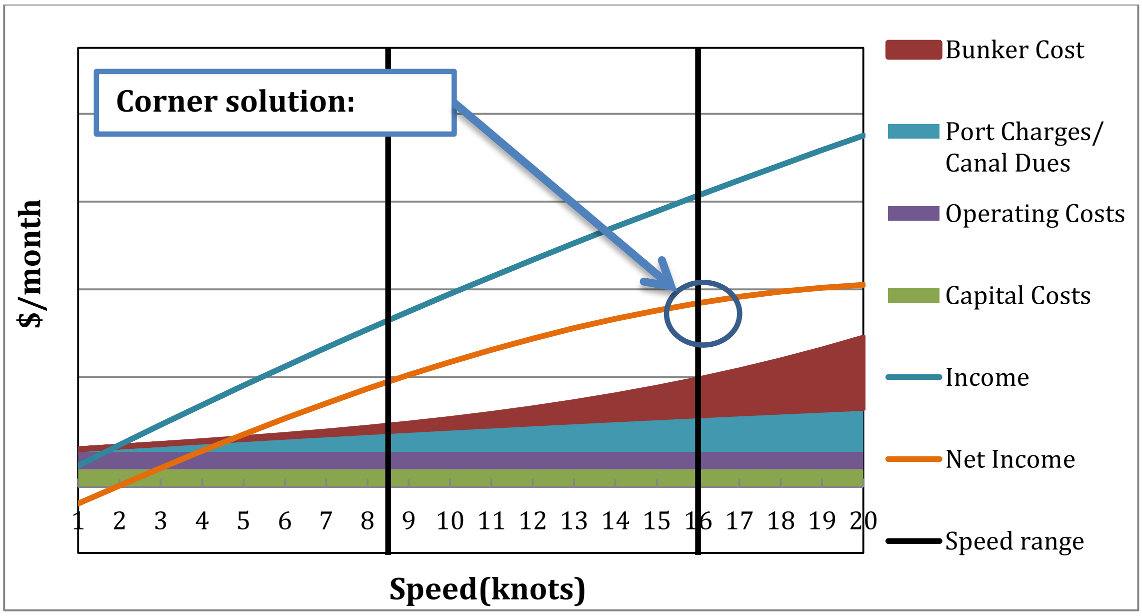


*Figure 16: Low bunker price relative to spot rate: maximum speed is optimal*

Figure 16 illustrates the optimal speed when bunker prices are low compared to the spot rate. In these market conditions, the maximum possible sailing speed will be optimal to maximize profits.

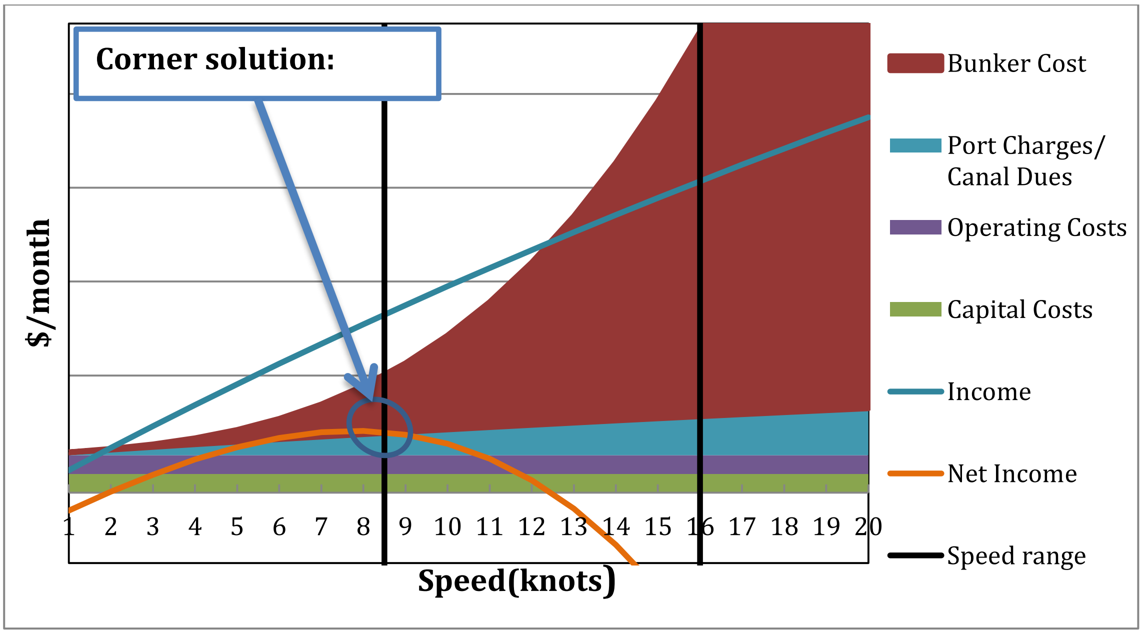


*Figure 17: High bunker price relative to spot rate: minimum speed is optimal*

Conversely, figure 17 shows how this dynamics change in response to high bunker prices relative to spot rate. The optimal speed of the vessel is now the technical minimum.

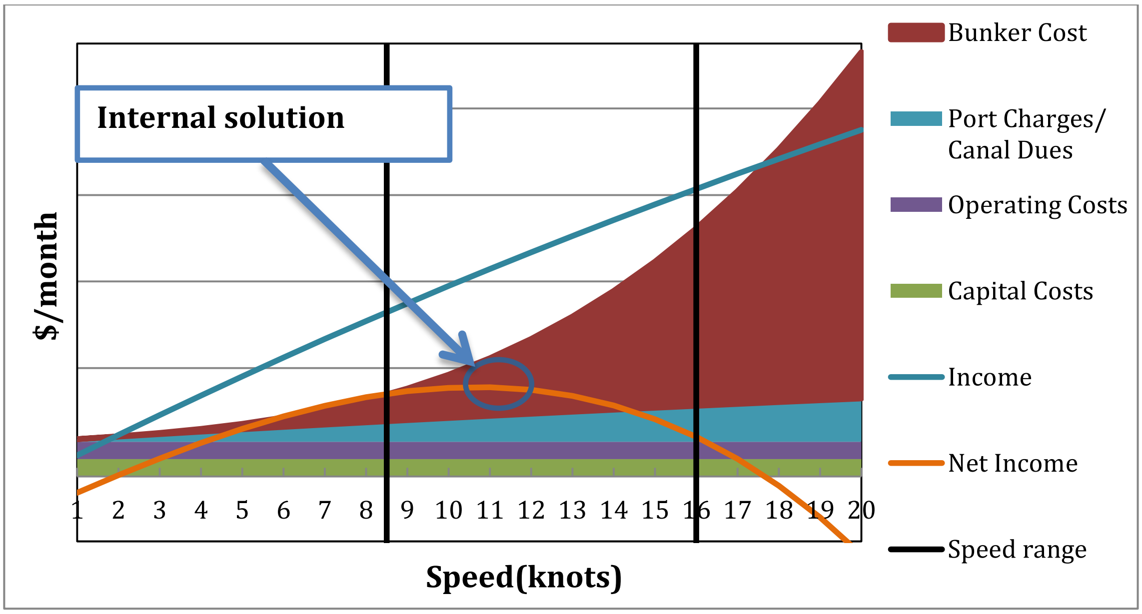


*Figure 18: Optimal speed is in the range between minimum and maximum*

Figure 18 demonstrates the optimal speed when profit is maximized within the range of possible speed.

**Why speed matters in today's market**

Publications like "Slow Trip Across Sea Aids Profit and Environment" (NY Times, 2010),"Fifty Shades of Fuel Savings" (McQuilling, 2012), and "Ultra low-speed engines for VLCCs make economic sense" (The Motorship, 2011) clearly states the interest and focus of slow steaming and reducing fuel costs in the current time.

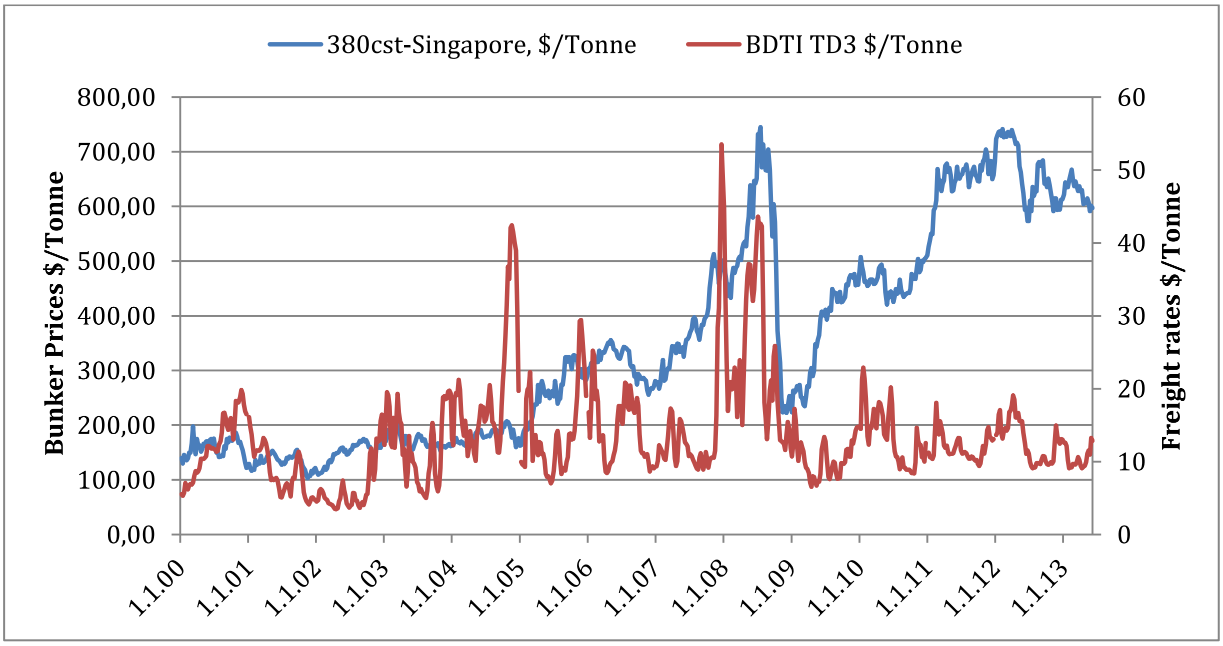


*Figure 19: Bunker costs & Freight costs $/tonne basis (Clarksons, 2013 & McQuilling, 2012)*

Figure 19 shows the development in bunker prices (Singapore) in and freight rates (TD3) on a $/tonne basis. The calculation is done by adjusting the Worldscale rate with the specific years' appropriate flat rate. The development between the two has changed dramatically since 2009, thus being the basis of the current wave of interest on slow steaming and speed optimization.

## 5.2 The spot freight-rate mechanism

The equilibrium freight rate is determined by constant interactions that affects the supply and demand for seaborne transport. According to Stopford (2009), ten key factors influence supply and demand in sea transport. Determination of demand relies on the world economy, the sea commodity trade, average haul, random shocks and cost of transportation. On the supply side factors key factors are the consistency of the world fleet and its productivity, deliveries of new vessels, scrapping and losses of vessels, and freight revenue.

### 5.2.1 **The market**

The bulk freight market is often described as a perfectly competitive marked. The following arguments for a perfect market are from Adland (2012) and Lyridis & Zacharioudakis (2012):

The *homogenous character* of the service provided and the goods transported makes similar sized vessels nearly perfect substitutable. An individual demand for higher freight rates would be nearly impossible.

The *lack of concentration* of ship owners allows for many buyers and sellers in the market of insignificant size. Co-operation between owners for a freight rate manipulation would therefore be difficult.

The *ease of entry in the market*: In economic terms, debt financing a vessel is relatively easy, and the market for new building is very liquid. The administrative operation of a tanker is not complex, and operation of the ship is almost exclusively done by the captain. In terms of economics of scale, there are few benefits regarding the number of vessels in the fleet of one owner. Large companies would not have a competitive advantage adding ships to the market.

The *ease of exit in the market*: Liquidity in the second-hand market and the demolition market ensures that ship owners do not suffer big sunk costs.  Transaction costs and a time-lag for entering and exiting does on another hand exist. The mobility of the vessel prevents a geographical limitation of the capital invested, assuring low exit cost for ship-owners from a non-profitable route. This also strengthens the equilibrium of supply and demand on geographical level.

*Full information* on prices and transportation services in the market is provided to all market participants due highly developed and active ship-brokers

### 5.2.2 An intuitive walkthrough of the equilibrium freight rate

#### The supply function

The supply of seaborne transport is measured in supply of tonnage, which is the total available carrying capacity of the existing fleet. All vessels that are suitable for trading, laid-up or not, constitute the overall tonnage supply (Lun, Lai, & Cheng, 2010). The supply of shipping services available is measured on a capacity-tonne-mile per time unit, derived from cargo capacity and voyage distance.

In the short run, the size of the fleet is given. Vessels will be laid-up or start trading in accordance with the given freight rates. In other words, each freight rate will have a given supply of tonne-miles available.

The theoretical shape of the supply curve will be explained trough an example from Stopford (2009). The ship used in the example is a 280,000 dwt VLCC, assumed to be loaded with cargo 137 days a year.

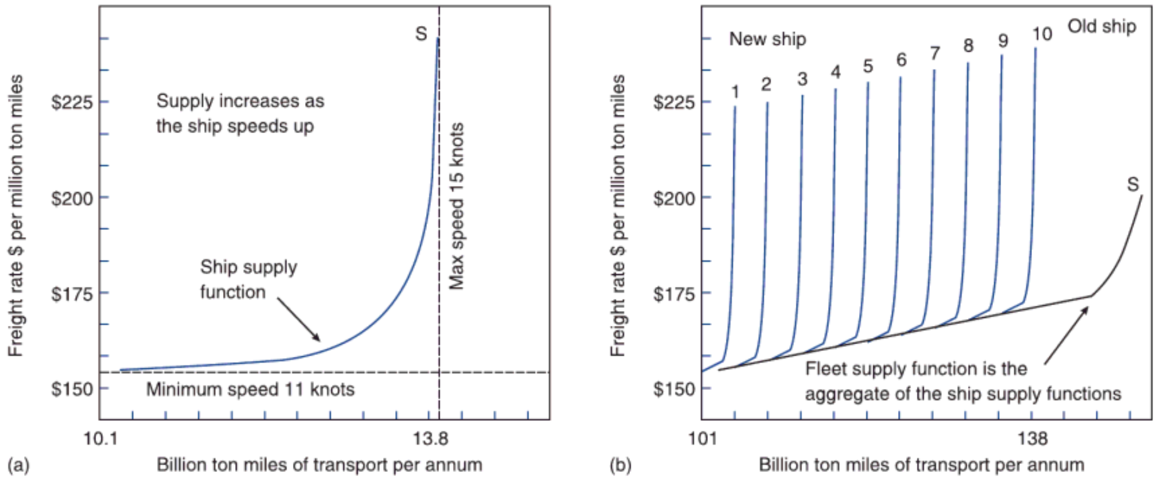


*Figure 20: Individual and aggregated supply (Stopford, 2009)*

Each ship has its own supply function that describe the amount of transport it will offer at a given freight rate. The supply of a ship is restricted by a specific operational and technical speed interval, as well as the freight rate, illustrated in figure 20 a). The ship at hand will start trading when freight rates rise slightly above $155 per million tonne-miles (mtm). If the freight rate falls below this, the ship will put into lay-up, offering no transportation. At $155 per mtm, the ship will sail at the lowest possible speed of 11 knots to save fuel, offering a transportation of 10,1 billion tonne-miles (btm) a year. If freight rates increase, the ship will speed up accordingly until the maximum speed of 15 knots is reached with a freight rate at $220 per mtm. The supply of the ship will then be 13.8 btm a year, a supply increase of 36 % compared with minimum speed.

Figure 20 b) displays the principle of aggregating individual supply functions to create a supply function for the whole fleet. The 10 individual vessels have different operating costs, here assumed to be higher in relation to age. If for instance freight rates fall below operating costs of vessel number 10, it will be laid-up, reducing the overall supply. Ship 9 will then break even, and the other eight ships will have a margin over operating costs.

### The demand function

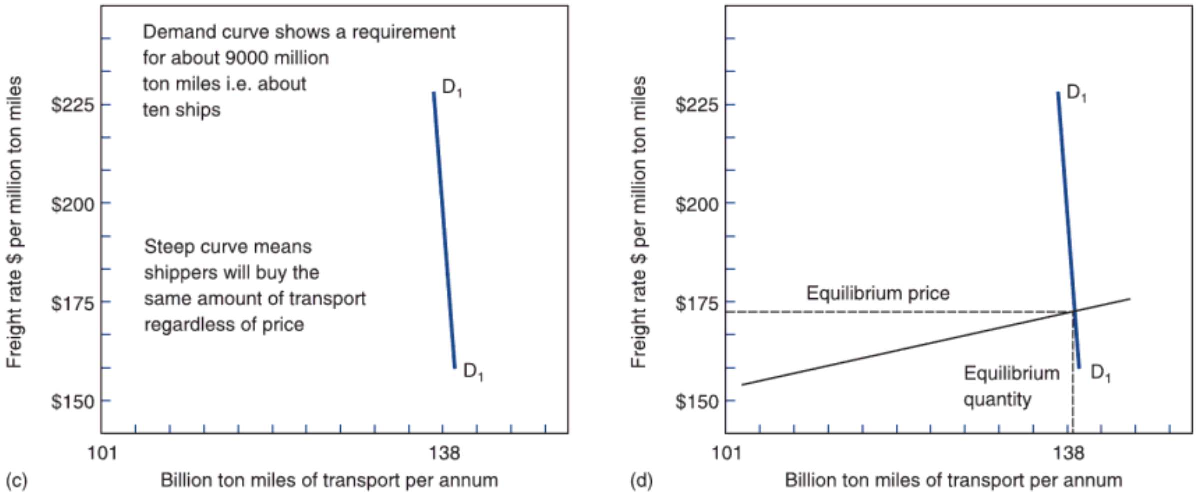


*Figure 21: The demand function (Stopford, 2009)*

The demand function in figure 21 shows how ship owners respond to changes in price and the equilibrium freight price. The supply function $D_1$ in the figure is very inelastic, as shippers have limited options of alternative ways of transportation in a short-term perspective (Stopford, 2009).

## 5.2.3 **Importance of time**

### Momentary equilibrium

As ships move slowly, the momentary equilibrium would be created within a geographical region by vessel ready to load within a short-time frame. Geographical shortages and surpluses of supply and demand will therefore determine the freight rates in the very short run. With low demand within a very short time frame economic theory implies that a vessel should accept an additional voyage at the marginal cost (voyage cost) of the vessel (Adland, 2012). This is because operational costs such as insurance and crew are fixed in a very short-term perspective.

### Short-term equilibrium

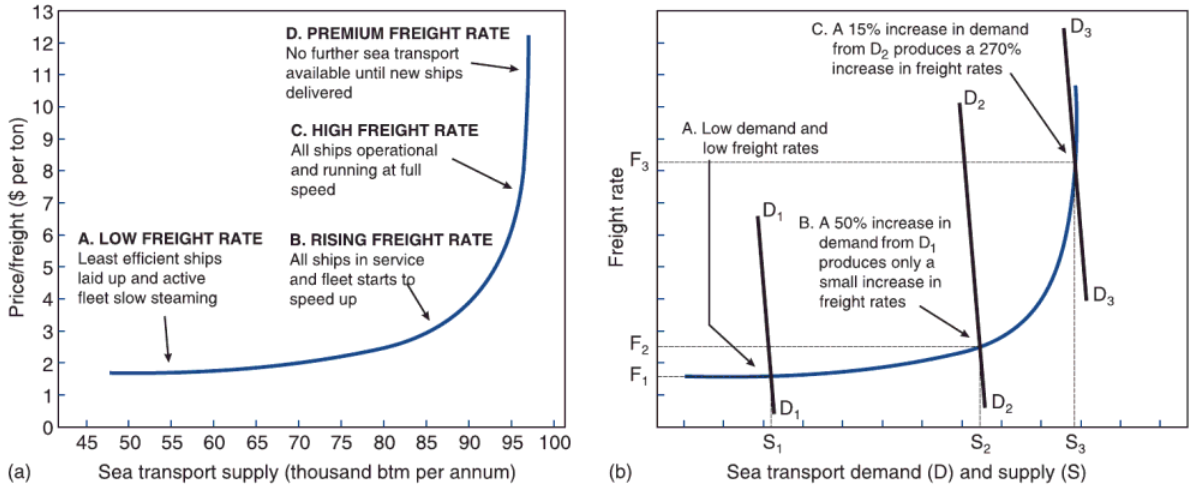


*Figure 22: Short-term equilibrium (Stopford, 2009)*

In figure 22, points A, B, and C shows how the freight rate will develop in accordance with demand (D). At point A with D1, demand is low and only the most efficient vessels are trading. If demand increases with 50% from D1 to D2, the freight rate will not be much affected, as vessel will go from lay-up to trading to meet the increase in demand. However, a change in demand in 15% from D2 to D3 in point C will cause an increase in freight rates of 270%. This is because the whole fleet, including the most inefficient vessels with high operating costs, would be utilized at full speed. As the whole fleet is utilized, a movement towards greater demand would cause a bidding war between shippers, making freight rates capable of going to any height.

As illustrated above, the short-term supply curve has a distinctive characterization, often described as a “J-shape”. When there is available capacity, the supply function is very elastic. However, when the fleet is fully utilized, the curve becomes very inelastic. The special characterization of this curve was first described by Koopmans (1939), and later been confirmed empirically (see for instance: Zannetos (1964), Norman & Wergeland (1981), Adland and Strandenes (2007), Adland (2012).

On a short-term basis, with the fleet close to full employment the only possibility to increase supply of tonnage is by increasing vessel productivity. The productivity level can increase through an increase of speed, shorter port-times and ballast legs, maximizing load, and by postponing maintenance. This will on another hand increase the cost related to the operation of the vessel due to higher fuel costs and increased wear and tear (Adland, 2012). On the contrary with low fleet employment, a large positive change in demand would be absorbed by the available capacity, not affecting the freight rate much.

The previous example stated that the lay-up point of the vessel was when operating costs were no longer covered by the freight rate. The classical view of a vessel taken to lay-up is when the TCE spot rate makes the ship-owner indifferent between trading and lay-up (Adland, 2012). However, due to cost related to lay-up, the decisive rate for lay-up would have to be slightly less than operating costs subtracted of lay-up costs (Mossin, 1968).

### The long-run

In the long run there are no fixed costs. The total fleet can be adjusted trough scrapping and new building of vessels.  As discussed earlier, recessions could cause the oldest ship to become unprofitable consequently being sent for demolition or conversion, permanently reducing the supply of the fleet.  With low freight rates, demand for new vessels will be low. On the other hand, when freight rates are booming, the second hand market as well as the new building market will flourish. Due to the time-lag of delivery, the supply adjustment of new builds will arrive when demand might have been reduced. These actions will therefore amplify the long shipping cycles (Stopford, 2009).

### 5.2.4 **Higher bunker prices**

**The supply curve effect**

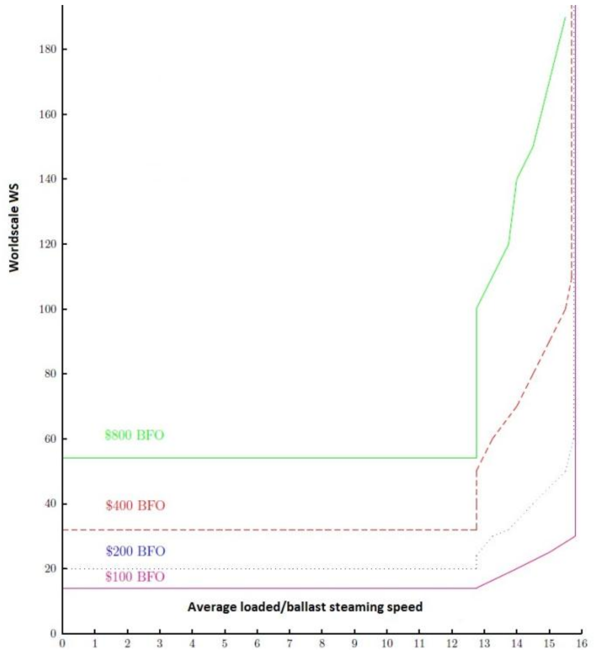


*Figure 23: The effect of increased bunker price on the supply curve (Devanney, 2010)*

An increase in bunker prices will shift the supply curve upwards, thus raising the trigger level for a vessel to start offering transport. Due to the increased impact of bunker costs in the total operating costs, the least efficient vessels will also become more pronounced in the aggregated supply curve, making it less elastic. Looking at the supply curves at different bunker prices from Devanney (2010), with a bunker price of $100/tonne the ship will come out of lay-up sailing at minimum speed (here set to 12,75 knots) at WS15. It will then increase to maximum speed at WS22. If bunker prices rise to $400/tonne, a WS100 is required in order for the ship to sail at maximum speed. To maximize profit (minimize costs), ship owners must adjust speed in response to bunker prices and spot rates.

**The freight rate effect – are ship owners fully compensated?**

In the market condition today, a common opinion among ship owners is that the spot prices does not fully compensate for the higher bunker prices (Andersen, 2012). Norman & Wergeland (1979) looked further into this issue, and the following example is from their argumentation. In their reasoning, they assume that there will be no changes in lay-up, and that demand is inelastic.

In the first scenario described, speed is considered constant. Looking at figure 23, each step on the supply curve indicates the transport capacity of vessels with specific operating costs. Using the vessel with a unit operating cost of ***$b_1$***, it will start to trade when freight rate is sufficient to cover the cost. It will offer ***$x_1$*** tonne-miles per time unit, here assumed to be one year. If fuel prices rise by 1 percent, the unit operating cost will rise by one percent times the share of fuel cost in the total operating cost. Denoting ***s*** to the cost share of fuel, the unit operating cost will rise by ***s*** percent. The supply for ships with unit costs of ***$b_1$*** will shifts to ***$b_1(1 + 0.01*s_1)$*.** Generalizing this, each "step" on the "latter" will shift upwards by ***$s_i$*** percent, ***$s_i$*** and ***$b_i$*** being the vessel specific fuel cost share and operating cost, respectively.

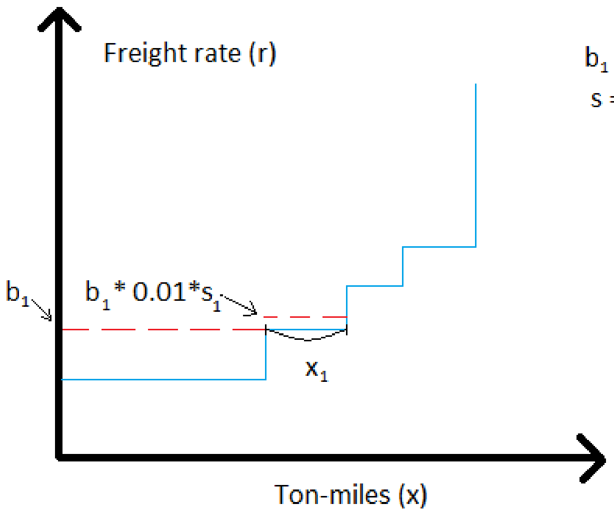


*Figure 24: Effect on supply of increasing oil price (Norman & Wergeland, 1979)*

Given that this was the only effect of fuel prices on supply (speed is constant), the net effect in earnings will vary between ships and their relative fuel cost shares. Assuming that the freight rates will be equal to the unit operating cost of the marginal ship, the freight rates would only increase in respect of the marginal ship cost share of fuel. Following that argument, vessels with a higher cost share of fuel will receive lower net earnings, and conversely the ones with a lower share will benefit. The economics of scale of large modern vessels will typically have a low operating cost than smaller and older vessels, thus making the cost share of fuel greater. This would imply that owners generally will lose from higher bunker prices.

However, allowing for adjustments in vessel speed, the ship owner will simple chose the speed that maximizes profit. Higher speeds will result in more cargo transported per year, hence a bigger income (the freight rate times the additional cargo transported per year), as well additional costs due to higher fuel consumption. The optimal speed (or min/ max speed) is the speed given by the equality of the two factors. This implies that it is only the ***ratio*** of the freight rate and the bunker cost that sets the optimal speed, i.e. if both freight rates and bunker prices rises with one percent, the optimal speed will remain unaltered. As an example, if a vessel sails at an optimal speed of 11 knots with a freight rate of WS50 and a bunker cost of $600/tonne, the same speed would be optimal if with a freight rate of WS100 and a bunker cost of $1200/tonne. This effect of fuel prices on freight rates and earnings would mean that a one percent increase in the bunker cost would shift the supply curve upwards by one percent, which is in fact greater than the compensation needed for ship owners to cover the additional fuel cost. Assuming no change in lay- up, and no response to price changes in demand, ship owners will actually gain from higher bunker costs.

The reasoning from Norman & Wergeland (1979) above has some very strong assumption, but it proves an important point. As discussed earlier in this thesis, although the sailing speed of VLCCs have been reduced in the last years, the limitations of speed adjusting from a ship owners perspective are among many implication for a theoretical optimal speed to be applied in the real world.

# 6. Simulation

## 6.1 The supply curve

### 6.1.1 Theoretical basis

To estimate the supply side, we base our model on Nortank (Norman &Wergeland, 1981). In this model we estimate the supply curve of each individual ship and aggregate them to create the market supply curve.  The supply of a single ship is given by the following equation:

$$S_{i=}F_i\ E_i\ L_i\ Y_i\ (12 - U_i\ )M_i$$

- F- dwt
- E- is the ship in operation (E is a Boolean variable; it is either 1 or 0)
- L- load factor
- Y- number of trips per month
- U- number of months of hire per year
- M- route distance

The supply of each ship is given in tonne-miles per year. This is calculated by multiplying the ship's deadweight tonnage with the loading factor, number of trips per month, distance of the route, and the number of months each year the ship is in traffic. Among these variables the load factor and route distance is assumed to be equal for all ships.

For simplicity reasons the length of each month is set to 30.5, and the number of trips is then given by:

$$Y_i\ = \frac{30.5}{W + \frac{2M}{24s_i}}$$

The part below the fraction bar constitutes the number of days it takes to make a roundtrip, i.e. number of days in port (and waiting) and the time it takes to sail back and forth.

- P- freight rate per tonne
- H- port charges per dwt

- Q- price per tonne of fuel
- W- port and waiting time per round trip
- M- transport distance
- $B_0$- fuel consumption while waiting per day
- $B(s)$- fuel consumption per day at sea
- $s$- vessel speed

The voyage result is given by subtracting the involved costs from the income:

$$Voyage\ Result = Income - Cost$$

The income is given by the spot rate, multiplied by the quantity carried. The quantity carried can be written as the ships dwt times the load factor. By dividing by dwt, we find that income per dwt equals the spot rate multiplied by the load factor:

$$Income = P * cargo\ carried = P * dwt * L \rightarrow {}^{Income}/_{dwt} = \mathrm{PL}$$

Potential costs involved include bunker cost, port- and canal fees. However, as our route is from Ras-Tanura to Chiba, there are no canal costs involved.

$$Cost = Port\ Cost\ and\ canal\ fees + bunker\ cost = H + bunker\ cost$$

The bunker cost can be divided into the cost of oil used while loading, discharging and anchoring, and the consumption while sailing between ports.

$$bunker\ cost = Q * waiting\ days * consumption\ while\ waitng + Q * duration * \frac{consumption}{day}$$

$$Bunker\ cost = QWB_0 + QB(s)\left(\frac{2M}{24s}\right)$$

The voyage result per trip per tonne is thus given by:

$$V = PL - H - QB_0W - QB(s)\left(\frac{2M}{24s}\right)$$

We want to calculate the earnings over a given period of time, because even if the voyage yields a high level of income, it will be less attractive if it lasts for a very long time. We therefore use the time charter equivalent (TCE) as a measure of earnings over a period of time, in this case one month. By multiplying by the number of trips per month, the TCE per month is derived:

$$R = V\left(\frac{30.5}{W + \frac{2M}{24S_i}}\right)$$

By using the formulas for V and R above, it is possible to calculate the speed and supply for different vessels and different routes. However, this is not feasible as there are enough tanker routes to fill a book the size of a phonebook with the corresponding Worldscale flat rates. This is avoided by assuming economic efficiency and a competitive equilibrium. Consequently, the maximum TCE will be the same for all routes (otherwise the market is not efficient) simply due to the fact that if the TCE was higher on one route, owners would move their ships to that route in order to increase earnings. This is not to say that no differences exist at any time for effective TCE on different routes, but it is a solid argument that those differences are only temporarily in existence and will be eradicated by the profit conscious ship-owner (or the efficient market). When TCE is equal for all routes, the optimal speed must be equal as well[17]. One argument against one global market, is the fact that it exists different regulations in different parts of the world (different jurisdiction). An example is the requirements regarding sulfur levels in the North Sea and the coast of North America. Such emission control areas will also probably be set up in the Mediterranean and in the port of Singapore (DNV, 2010). Regulations regarding the age of ships also vary in at different geographical locations. This may lead to a market where not all of the tankers can compete within the entirety of the market. Strandenes (1999) have simulated such a two-tier market.

In order to derive the expressions for the optimal speed, the functions for number of trips per month, as well as fuel consumption is assumed to be power functions. These are constructed using a log-log transformation. This is theoretically correct for fuel consumption and is also very accurate for number of trips per month.

---

[17] A formal proof of this is found in the appendix of Nortank (Norman & Wergeland, 1981)

$$B(s) \cong Ks^{\beta}$$

$$Y_i = \frac{30.5}{W + \frac{2M}{24s_i}} \cong A(W)s^{\alpha(W)}$$

It is now possible to rewrite the expression for the TCE to

$$R = A(W)\left\{(PL - H - QB_0W)s^{\alpha(W)} - QB(s)s^{\alpha(W)+\beta-1}\right\}$$

where

$$B = K\frac{M}{12 * dwt}$$

When maximizing R with respect to the speed, s, the optimal speed will be equal to:

$$s_i = \begin{cases} s_{min} \; for \; G(W)(\left(\frac{P^*}{Q}\right)^{\frac{1}{\beta-1}} < s_{min} \\ G(W)(\left(\frac{P^*}{Q}\right)^{\frac{1}{\beta-1}} \; for \; s_{min} < G(W)(\left(\frac{P^*}{Q}\right)^{\frac{1}{\beta-1}} < s_{max} \\ s_{max} \; for \; G(W)(\left(\frac{P^*}{Q}\right)^{\frac{1}{\beta-1}} > s_{max} \end{cases}$$

$$P^* = PL - H - QB_0W$$

$$G(W) = \left\{\left(\frac{\alpha(W)}{\alpha(W) + \beta - 1}\right)\frac{1}{B}\right\}^{\frac{1}{\beta-1}}$$

In order to calculate the aggregated market supply we summate the supply given by each individual ship at each spot rate:

$$S_{market}(P,Q) = \sum_{i=1}^{N} S_i(P,Q)$$

The calculations above are derived in Nortank (Norman, Wergeland 1981). A broker is usually used for a ship to get a contract to freight cargo. The broker charges a fee, which usually constitutes a percentage of the cost of the contract (gross income for transporter). The cost of the contract equals the spot rate multiplied by the quantity carried, equaling the ships dwt multiplied by the load factor:

$$Broker\ commision = gross\ income * bc = PL * dwt * bc$$

- bc- broker commission as percent of gross income

To get the net income, the broker commission is subtracted from the gross income:

$$Net\ income(NI) = Gross\ income(GI) - Broker\ Commision$$

$$NI = spot\ rate * cargo\ carried - bc * GI$$

$$NI = PL * dwt - bc * PL * dwt$$

$$NI = PL * dwt(1 - bc)$$

We are interested in net income per dwt, which is inferred by:

$$\frac{NI}{dwt} = PL(1 - bc)$$

From this we derive a new income after cost per dwt:

$$P^* = PL(1 - bc) - H - QB_0W$$

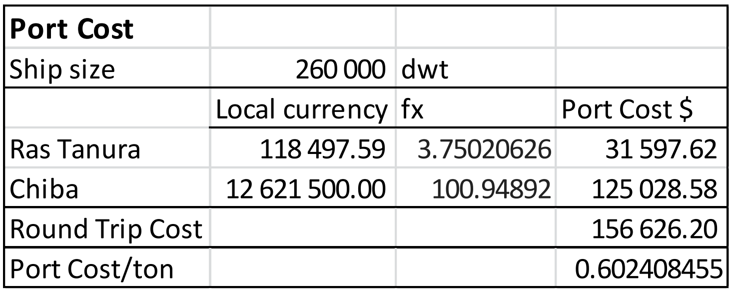
We also get an updated time charter equivalent:

$$R = A(W)\{(PL(1 - bc) - H - QB_0W)s^{\alpha(W)} - QB(s)s^{\alpha(W)+\beta-1}\}$$

### 6.1.2 **Setting values of variables**

In order to create the supply curve, the values of the variables must be estimated. Some of the variables are readily available such as the deadweight tonnage and freight distance. For the most part, reasonable data is also available for the remaining variables, and can be derived by logic estimations.

- H- Port charges per dwt: Port cost was retrieved from Clarkson for a ship of 260,000 dwt at Chiba and Ras-Tanura. The port costs were assumed to be linear in dwt and calculated the port cost per dwt for the trip.



| | | | |
|---|---|---|---|
| **Port Cost** | | | |
| Ship size | 260 000 | dwt | |
| | Local currency | fx | Port Cost $ |
| Ras Tanura | 118 497.59 | 3.75020626 | 31 597.62 |
| Chiba | 12 621 500.00 | 100.94892 | 125 028.58 |
| Round Trip Cost | | | 156 626.20 |
| Port Cost/ton | | | 0.602408455 |

W- port and waiting time per round trip: 2 days loading, 2 days discharging and 1,5 days waiting anchoring was assumed.

M- transport distance: In addition to the distance between Ras Tanura and Chiba (6655 miles), a 5% margin was added for weather.

$B_0$- Fuel consumption while waiting per day: Data regarding ships built in the time period between 2000 and today was included. As the consumption differs greatly between loading, waiting and discharging (which have a substantially higher consumption), a calculation including a weighted average of consumption while not sailing is calculated in accordance with assumptions described in W.

B(s)- Fuel consumption per day at sea: As previously described the relation: B(s) = Ks^β will be used to determine fuel consumption. Data was retrieved on ships built in the time period from 2000 to 2011. By using a log-log transformation we estimated the ships' beta value per year. Ship designs and fuel efficiency changes over time, where the focus can differ from one period to the next. Consequently, it was assumed that the build year of a ship is the deciding factor in estimating the beta value of a ship. To estimate the beta value of a ship built a given year, we set the beta value equal to the most recently built reference ship. For ships built before 2000, beta value for the ship built in 2000 is used. When working with older fleets, some ships are substantially older (built before 1990). These ships' beta is set to the beta used in Nortank for motor tankers, 2.87, and for turbine tankers 1.8. Because fuel consumption is available for ships at their design speed, we have used the beta value that is retrieved from the laden trip. Even if the fuel consumption is considerably different at laden trip compared to the ballast trip, this does not affect the beta value to a great extent; it does however affect the K-value. As previously noted, fuel consumption data is available for each ship at design speed.[18] By using the hereby proposed equation for fuel consumption, the K-value can be estimated for each ship in the fleet:

$$B(s) \cong Ks^{\beta} \rightarrow K = \frac{B(s)}{s^{\beta}}$$

| Estimations of β- values | |
|---|---|
| Motor Tankers | |
| 2011-2013 | 2.600 |
| 2008-2010 | 2.595 |
| 2007 | 2.598 |
| 2004-2006 | 2.590 |
| 1991-2003 | 2.314 |
| 1990> | 2.87 |
| Turbine Tankers | |
| All years | 1.600 |

*Figure 25: Beta values*

<u>s- Ships speed (min/max speed):</u> The maximum speed is assumed to be equal to the design speed for each ship. The minimum speed is set to 10 knots for motor tankers built before 2000. For motor tankers built later the minimum speed is set to 8.5 knots. Turbine tankers have a wider speed range than motor tankers and their minimum speed is therefore set at a lower rate 8 knots.

<u>F- dwt:</u> Given (Vessel specific)

<u>E- is the ship in operation:</u> (E is a Boolean variable; it is either 1 or 0) – This constitutes one of the most challenging factors in determining the supply curve. In Nortank, a ship is set to be in operation (E=1) if the time charter equivalent is greater than the operating cost (TCE>OC). This makes sense as it will not be viable for a ship to operate if the operating costs are not covered in the long term. In the short run however, it does seem fair to consider

---

[18] Vessels lacking data of speed and consumption, were given such information based on similarities to other vessels (see section 4)

the cost of operation to be fixed, such as the crew cost. It was therefore assumed that a ship is in operation if the time charter equivalent is positive (E=1 if TCE>0). A more sophisticated model could take into account the fact that taking ships out of, and into operation often involves additional expenses. Mossin (1968) demonstrated that if revenue followed a random walk, one would take a ship out of operation if revenue fell to a level y (which would be below cost of operation, which was not assumed to be fixed in the long term). It was further illustrated that by placing the ship back in operation the revenue should reach a higher level z, which was derived to be higher than operating cost.

<u>L- load factor:</u> is set to 95%

<u>U- Number of months of hire per year:</u> For a ship to stay in operation it is necessary to make time for inspection and maintenance, during which the ship obviously will not be able to serve the market. It appears reasonable to assume that U will increase with the age of the ship due to repairs becoming more expansive and difficult as the ship ages. This is however ignored, and U is set to 0, as it does not affect analysis when demand is set in accordance with the supply curves.

<u>bc- Broker commission</u>: The broker commission is set to 2.5%, i.e. equivalent to the rate used for calculations by the Baltic Exchange.

One can argue that the variables (which are constants in our model); months of hire, U, and waiting/port time, W, varies with demand. This is because when the fleet is operating at full capacity, the only way to increase capacity is reducing number of months off hire, time spent waiting and port time. This would however be difficult to incorporate into a model, as well as contribute minimal impact; and we have thus chosen to ignore this aspect.

### 6.1.3 **The aggregated supply curve**

The aggregate supply curve is as previously demonstrated, constructed based on the vessel specific supply curve. The following example illustrates the how real vessels trading in the fleet today affect the supply curve.

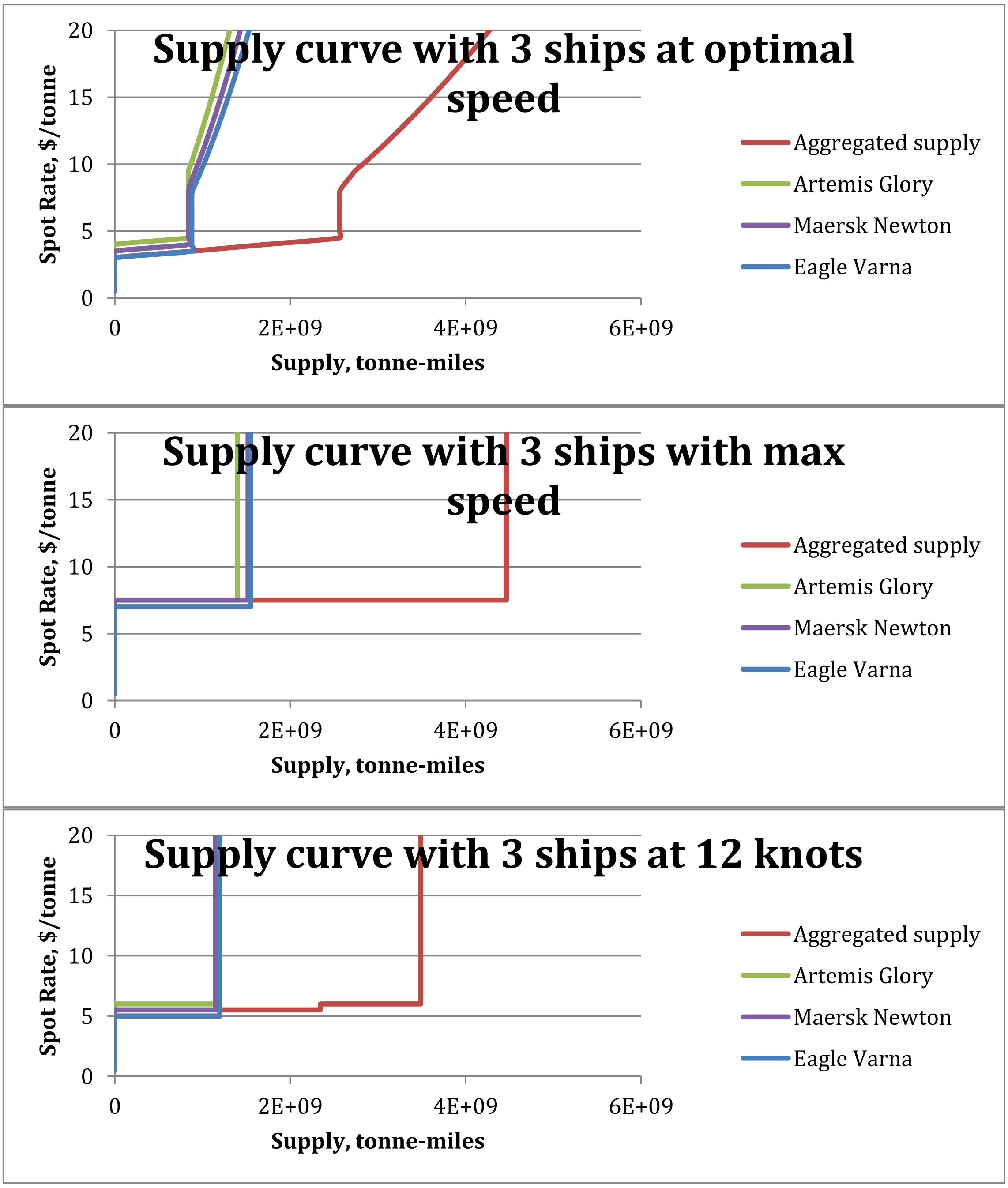


*Figure 26: Aggregating real supply curves under different speed regimes*

### 6.1.4 **The current fleet**

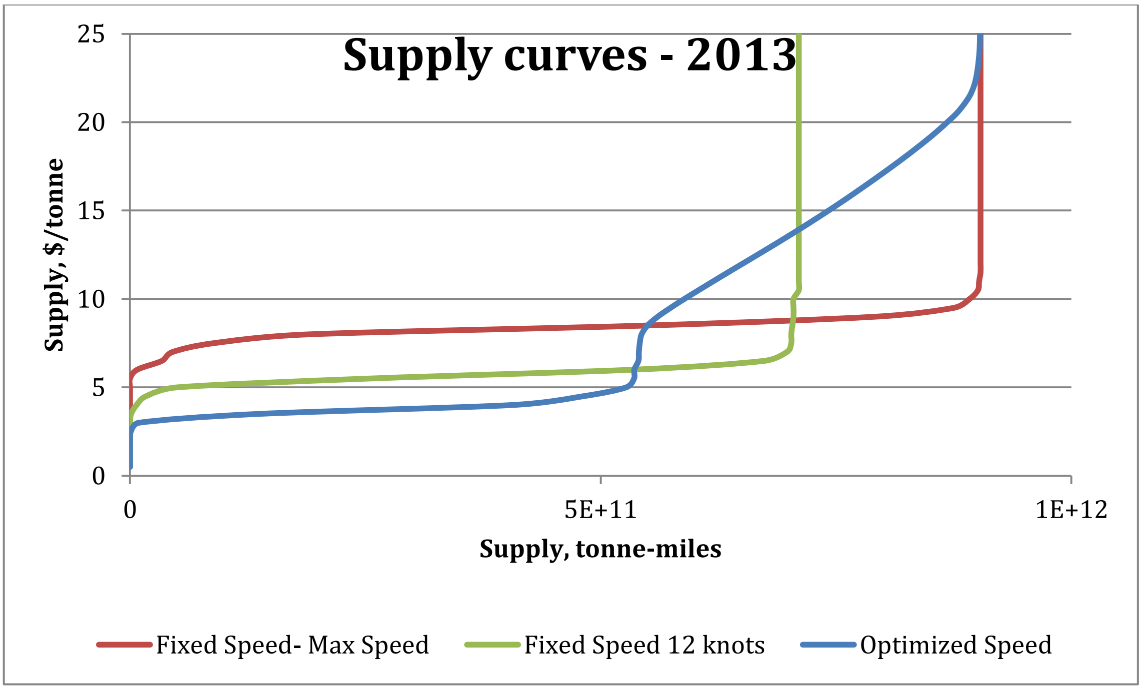
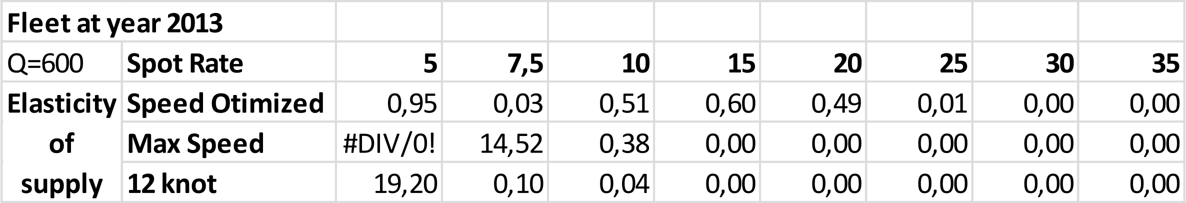


*Figure 27: The supply curve of the current fleet under different speed regimes*

If the bunker price is set at $600/tonne we get the supply curves shown above. We notice that when supply is given by a fleet that sails at a constant speed (either all ships at 12 knots or each ship sailing at its maximum speed) we get the characteristic J-formed supply curve known from standard literature. Here, the supply is initially very elastic until the capacity of the fleet is reached, upon which supply suddenly becomes extremely inelastic, and quickly perfectly inelastic. Further, it illustrates how the supply curve at 12 knots is able to supply tonne-miles at lower spot rates than at maximum speed, but with reduced maximum supply. When the fleet is sailing at optimal speed, it is able to deliver tonne-miles at even lower spot rates than the fleet sailing at 12 knots. This is not surprising, as the fleet would then be sailing at minimum speed (which is set to 8.5 or 10 knots, depending on age). The supply curve for the speed-optimized fleet then have a similar shape as the other two supply curves until it reaches a break point. The break point corresponds to the point where it becomes profitable for ships to sail above minimum speed in order to increase the TCE, partly by enabling more trips within a given time period (or more precise; because the marginal income of speeding up surpasses the marginal cost). We further notice that the fleet maintains supply at higher spot rates, compared to the other two regimes. Contrary to conditions with fixed speed (where if a ship sails, it yields the same amount of supply regardless of how much the spot rate surpasses the refusal rate), the ships will demand a higher spot rate to speed up to in a regime with speed optimization, in order to cover the increased bunker cost.



| **Fleet at year 2013** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q=600 | **Spot Rate** | **5** | **7,5** | **10** | **15** | **20** | **25** | **30** | **35** |
| **Elasticity of supply** | **Speed Otimized** | 0,95 | 0,03 | 0,51 | 0,60 | 0,49 | 0,01 | 0,00 | 0,00 |
| | **Max Speed** | #DIV/0! | 14,52 | 0,38 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| | **12 knot** | 19,20 | 0,10 | 0,04 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |

*Figure 28: Price elasticity - current fleet*

When looking at the price elasticity of supply this becomes yet more evident. The fleet reaches a perfectly inelastic supply at a much higher spot rate (between $30/tonne and $35/tonne) than with the other regimes. The supply reaches a point of perfect inelasticity at the lowest rates with the fleet sailing at a fixed speed of 12 knots, because it has lower bunker cost due to reduced speed. Hence the least efficient ship is able to cover its cost sooner, consequently achieving market supply.

The supply curves on the next page depict estimated supply curves at different speed regimes and different bunker prices. The supply curves presume oil prices of $100/tonne, $200/tonne (…) $1000/tonne. All of the curves represent spot rates as $/tonne and supply as tonne-miles. Note that the curves for the speed-optimized fleet become more similar to the supply curves of the other two regimes at lower oil prices, while it becomes increasingly different with higher oil prices.

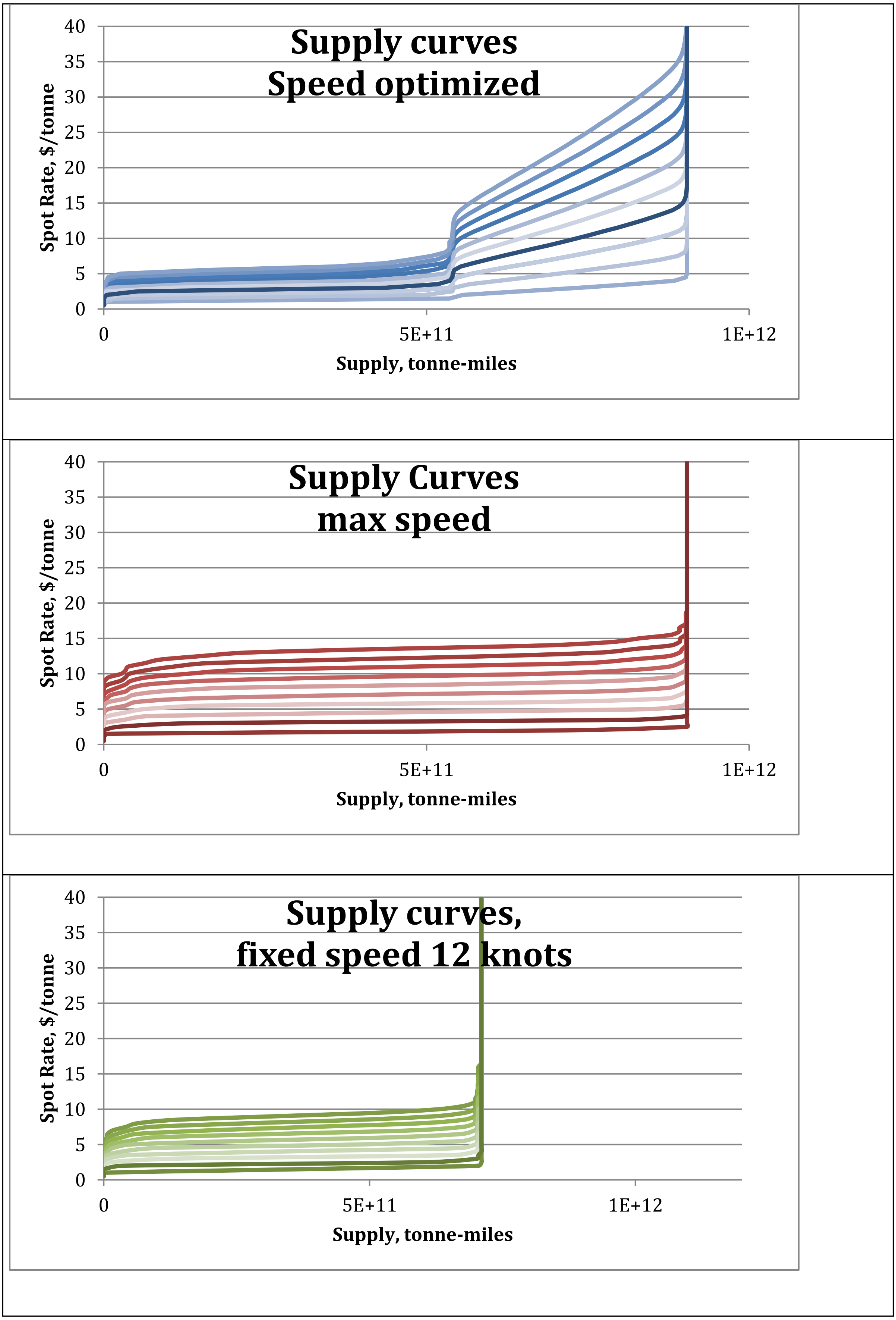


*Figure 29: Supply curves at different speed regimes at different bunker prices ($100 /tonne intervals)*

### 6.1.5 **Development in supply curves**

As a follow-up of the review of VLCC fleet development in section 4, we have created the supply curve of the fleet for the same years as used previously, i.e. 1995, 2000 and 2005, to illustrate how the development of the fleet homogeneity has altered the supply curve over time.

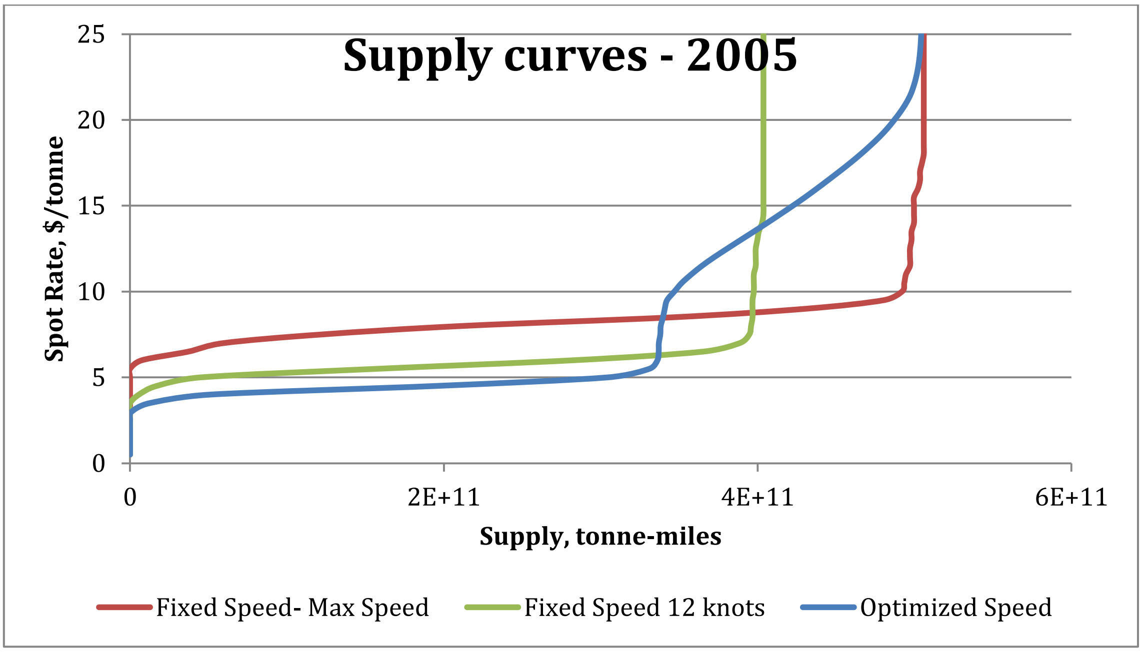


*Figure 30: The supply curve of the 2005 fleet under different speed regimes*

Starting with the supply curves of 2005, almost no turbine-powered vessels remain in the fleet. Except for a smaller fleet measured in dwt, we can see that the characteristics of the fleet are very similar to the fleet of today.

| **Fleet at year 2005** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q=600 | **Spot Rate** | **5** | **7,5** | **10** | **15** | **20** | **25** | **30** | **35** |
| **Elasticity** | **Speed Otimized** | 5,63 | 0,04 | 0,27 | 0,59 | 0,37 | 0,03 | 0,01 | 0,00 |
| **of** | **Max Speed** | #DIV/0! | 15,64 | 0,48 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| **supply** | **12 knot** | 16,59 | 0,23 | 0,04 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |

*Figure 31: Price elasticity - 2005 fleet*

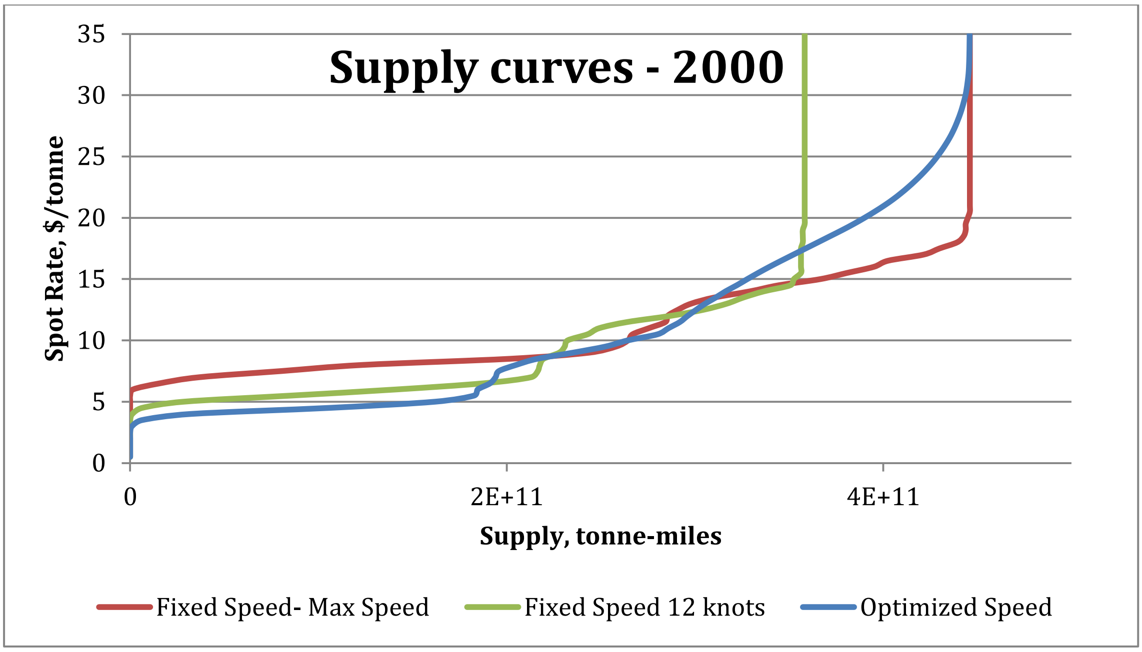
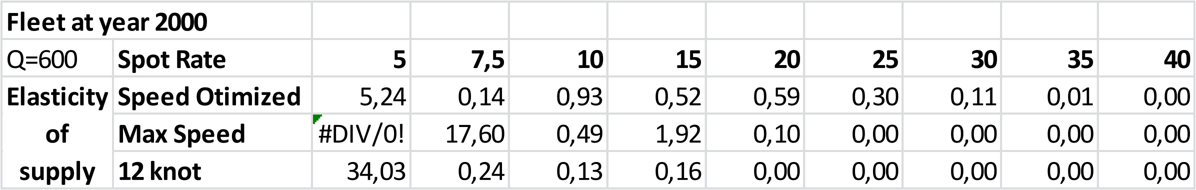


*Figure 32: The supply curve of the 2000 fleet under different speed regimes*

The fleet in year 2000 consisted of 37% turbine-powered tankers. This causes the supply curves to be substantially different from those of 2005, as well as from the supply curves of today. As we can see, the steps of elasticity are much clearer.



| **Fleet at year 2000** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Q=600 | **Spot Rate** | **5** | **7,5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
| **Elasticity** | **Speed Otimized** | 5,24 | 0,14 | 0,93 | 0,52 | 0,59 | 0,30 | 0,11 | 0,01 | 0,00 |
| **of** | **Max Speed** | #DIV/0! | 17,60 | 0,49 | 1,92 | 0,10 | 0,00 | 0,00 | 0,00 | 0,00 |
| **supply** | **12 knot** | 34,03 | 0,24 | 0,13 | 0,16 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |

*Figure 33: Price elasticity - 2000 fleet*

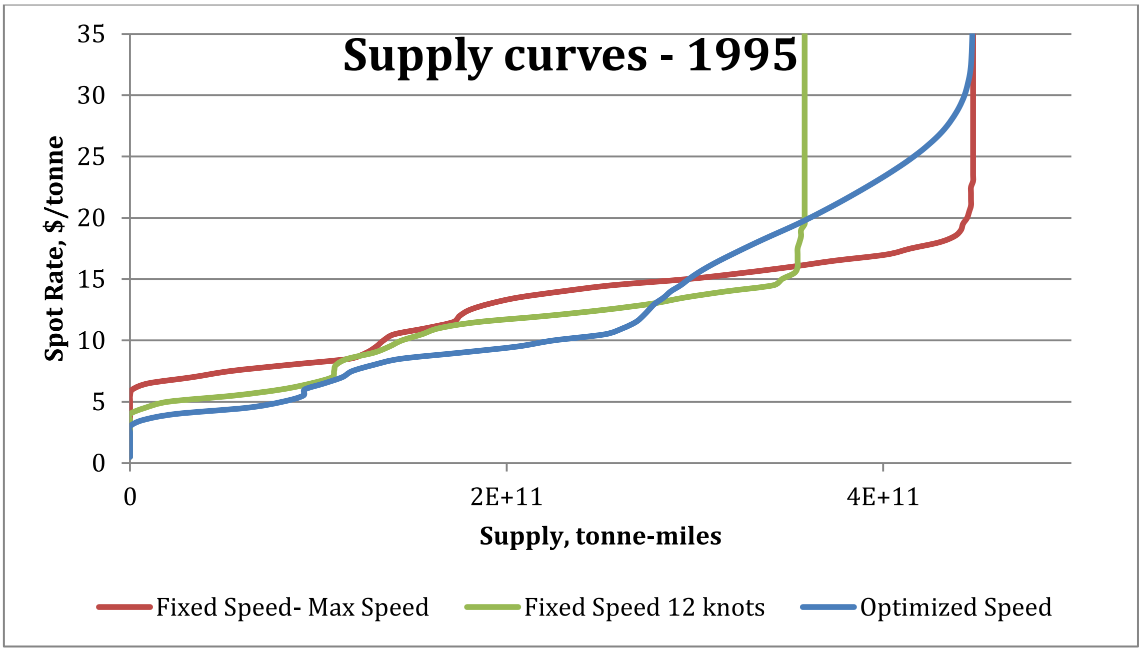
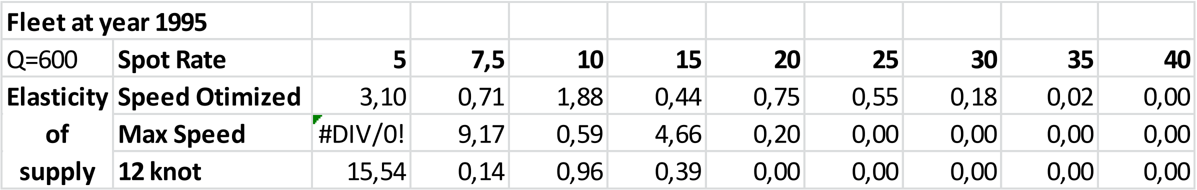


*Figure 34: The supply curve of the 1995 fleet under different speed regimes*

The fleet of 1995 was the least homogenous in our time sample, and the fleet of year 2000 shares great similarities with this. In 1995, an estimated 60 % of the fleet were turbine-powered.



| **Fleet at year 1995** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Q=600 | **Spot Rate** | **5** | **7,5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
| **Elasticity** | **Speed Otimized** | 3,10 | 0,71 | 1,88 | 0,44 | 0,75 | 0,55 | 0,18 | 0,02 | 0,00 |
| **of** | **Max Speed** | #DIV/0! | 9,17 | 0,59 | 4,66 | 0,20 | 0,00 | 0,00 | 0,00 | 0,00 |
| **supply** | **12 knot** | 15,54 | 0,14 | 0,96 | 0,39 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |

*Figure 35: Price elasticity - 1995 fleet*

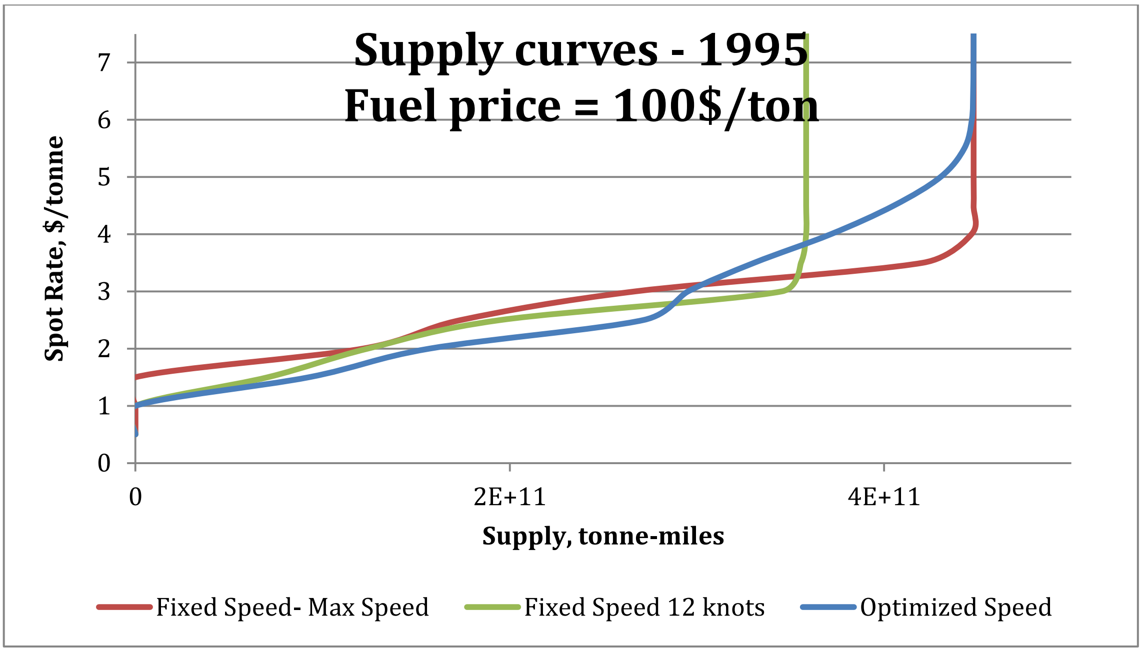


*Figure 36: Supply curve - 1995 fleet with fuel price set at $100 /tonne*

Looking at the supply curves for 1995 with a bunker cost of approximately $100/tonne at the time, the same distinguished steps in elasticity are evident as for current bunker prices.

| **Fleet at year 1995** | | | | | |
|---|---|---|---|---|---|
| Q=100 | **Spot Rate** | **2** | **4** | **6** | **8** |
| **Elasticity** | **Speed Otimized** | 2,78 | 1,00 | 0,11 | 0,00 |
| **of** | **Max Speed** | #DIV/0! | 0,49 | 0,00 | 0,00 |
| **supply** | **12 knot** | 3,02 | 0,06 | 0,00 | 0,00 |

*Figure 37: Price elasticity of the 1995 fleet with $100/tonne fuel price*

## 6.2 Estimation of parameters

### 6.2.1 **Estimation of the supply curve in simulation**

Due to the models complexity, the required data capacity to make merely one single aggregated supply curve at a one specific oil price is substantial. To be able to perform 1000 simulations of the development in the current VLCC market for the next 10 years with monthly time lags, would take several weeks. This necessitates a certain degree of simplification i.e. by omitting calculations for exact supply curve at each simulated oil price. A more thorough explanation is found in the appendix, section C).

### 6.2.2 **Stochastic process of the bunker price**

Before 2000 the observed price data of the crude oil price indicated a process with mean reversion. However, there is a clear break that the price process since then has followed a random walk process (Geman, 2007).

It is therefore interesting to test whether the bunker price follows a geometric Brownian motion.

The geometric Brownian motion has several features which make it well suited to replicate the price process of a commodity. Firstly the expected value at time t is the value today multiplied the exponential value of the expected growth multiplied with t:

$$E(S_t) = S_0 e^{t\mu}$$

Another feature is that a geometric Brownian motion cannot be negative and the standard deviation is given as a percentage of the value today as opposed to an absolute value.

For a more formal and comprehensive description please read Ross (1983).

In order to investigate whether oil prices are generated by a geometric Brownian motion OLS is used to estimate the following relation:

$$\frac{Q_t - Q_{t-1}}{Q_{t-1}} = \mu + \beta \frac{Q_{t-1} - Q_{t-2}}{Q_{t-2}} + \varepsilon_t$$

As the expected value of the next term in a geometric Brownian motion equals the last term (plus an eventual drift), this leads to our null hypothesis: that β=0

$$H_0: \beta = 0$$

$$H_A: \beta \neq 0$$

The data used is the monthly bunker price (380cst) at Singapore.

The result of the regression is as follows:[19]

## Regression Analysis: C4 versus C5

```
The regression equation is
C4 = 0,0196 + 0,0758 C5


173 cases used, 2 cases contain missing values


Predictor       Coef   SE Coef      T      P
Constant    0,019599  0,008727   2,25  0,026
C5           0,07580   0,07528   1,01  0,315


S = 0,113148   R-Sq = 0,6%   R-Sq(adj) = 0,0%



Durbin-Watson statistic = 1,90523
```

$$C4 = \frac{Q_t - Q_{t-1}}{Q_{t-1}}$$

$$C5 = \frac{Q_{t-1} - Q_{t-2}}{Q_{t-2}}$$

It is here apparent that β≠0 have a p-value of 0.315, i.e. β is not statically different from 0, and we can thus maintain the hypothesis that bunker price follows a geometric Brownian motion.

---

[19] To view complete regression, view Appendix A1

The regression yields a $R^2$ adjusted of 0% which is what we expect with geometric Brownian motion. The Durbin Watson statistic of 1.90 is close to 2 and we can therefore ignore the possibility of autocorrelation. The oil price have increased at a high rate the last decade and it is therefore not unexpected that $\mu$ is statistically different from 0. It is however difficult to determine if this increase will continue, thus an assumption of $\mu=0$ will be used during simulation. The residual seems to be normally distributed and the histogram of the residual plots is reasonably bell-shaped, enabling us to conclude that the residual appears to fulfill the requirements for homoscedasticity. A few extreme values are present in the normal probability plot which is not unexpected due to the occurrence of oil price shocks, and apart for these few extremes at the tail the standards for normality appears to be met. This leads to the conclusion that a geometric Brownian motion fits well. This yields a standard deviation of 11.3% monthly, assuming that there is no trend element.

### 6.2.3 **Demand**

It is often assumed that demand is perfectly inelastic to freight rates in the tanker market. The estimate provided by Tvedt (1995) is used here, setting $\varepsilon = 0.005$

To simulate demand we have used the following relation:

$$D_t = Y_t X_t^{-\varepsilon}$$

In order to simulate demand it is necessary to decide how $Y_t$ is to vary and set the elasticity of demand at a reasonable level.

It is common to assume that demand in the tanker market is perfectly inelastic (Koopmans, 1939; Adland & Cullinane, 2006). It has also been tried to estimate the value of the elasticity of demand. Strandenes and Wergeland (1982) made an estimation of $\varepsilon=0.005$ using deviation of tonne-miles actually supplied compared to a estimation that minimized the sailing pattern. As this implies an almost perfectly inelastic demand it fits well with previous theory. The theory surrounding demand has problems when spot rates are high and supply is scarce.

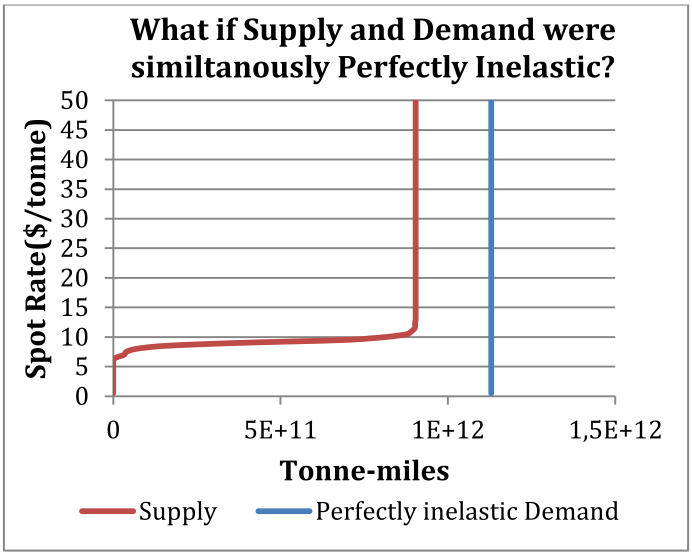


*Figure 38: Supply and demand when perfectly inelastic*

At high spot prices supply will be perfectly inelastic, and as it is obvious (as illustrated above) that demand and supply cannot both be perfectly inelastic at the same time it follows that one of the two must be modeled as somewhat elastic. Even when demand is not perfectly inelastic as with ε=0.005 it will lead to quite ridiculous spot rates if demand is to be slightly over supply. As we have modeled the supply of the current fleet based on data from each individual ship, and this is the most precise part of our model, we have decided to use a more elastic demand setting ε=0.1. This facilitates several needs: firstly demand will still be inelastic and at lower spot rates it will not yield dramatically different result than a perfectly inelastic demand. Secondly it facilitates the process that happens when demand is high, a rationing of supply trough higher spot rates. Even if we use less inelastic demand than what is often used it is still necessary to hinder the most extreme cases when demand surpasses supply, we have therefore set a roof of $250/tonne for the spot rate.

When it comes to $Y_t$ we use the same approach as Tvedt (1995) and assume it follows a geometric Brownian motion

Aggregated crude oil exports were used to estimate parameters related to demand.

## Regression with monthly data[20]

### Regression Analysis: C9 versus C10

```
The regression equation is
C9 = 0,00255 - 0,113 C10


266 cases used, 2 cases contain missing values


Predictor       Coef   SE Coef       T      P
Constant   0,002546  0,002150    1,18  0,237
C10        -0,11316   0,06097   -1,86  0,065


S = 0,0349962   R-Sq = 1,3%   R-Sq(adj) = 0,9%




Durbin-Watson statistic = 1,99783
```

We notice that the coefficient is almost significant with a p value of 6.5%. For a geometric Brownian motion to be true, the coefficient should be insignificant. It appears that changes in one period have some impact on development in the next period, and in this case one can argue that this likely constitutes seasonal variances. By making this assumption we can solve this issue by examining the annual data, adjusting the parameters later. Another benefit by ignoring seasonal variances is that this will simplify a potential model involving scrapping as well as building of new ships. Provided that a seasonal variation of demand does exist, it would be reasonable to assume that a seasonal variation in spot rate exists as well, as this in turn seems to be the most plausible reason for new building and scrapping.

---

[20] To view complete regression, view Appendix A2

## Regression with annual data[21]

Utilization of monthly data proved difficult due to seasonal variation. To eliminate the seasonal effect, yearly data is used instead, and the variance adjusted accordingly.

### Regression Analysis: C3 versus C4

```
The regression equation is
C3 = 0,0290 - 0,108 C4


21 cases used, 2 cases contain missing values


Predictor      Coef  SE Coef       T      P
Constant   0,02902  0,01875    1,55  0,138
C4         -0,1082   0,2267  -0,48  0,639


S = 0,0797511   R-Sq = 1,2%   R-Sq(adj) = 0,0%



Durbin-Watson statistic = 2,05465
```

Primarily we note that the p-value of the coefficient exceeds 60%, i.e. is not significant. This fits well with a geometric Brownian motion, as we want the coefficient to be 0. The regression yields a $R^2$ adjusted of 0% which is what we expect with geometric Brownian motion. The growth rate has been estimated to 2.9%, but is not deemed significant. The sign and size of the growth seem reasonable; however the growth may not be significant due to the limited number of observations. Accordingly, an annual growth rate of 2.9% will be maintained in our simulations, corresponding to a monthly growth rate of 0.24%. Calculations of annual standard deviation yields 7.98%, and dividing this by the square root of 12 we find a monthly standard deviation of 2.3%. As the Durbin-Watson statistic is around 2, no autocorrelation appears to be involved.

---

[21] To view complete regression, view Appendix A3

In order to estimate $Y_0$ we use the equilibrium spot rate in April of 2013 \$9.34/tonne[22], and use it to estimate supply at the three different speed regimes. We then estimate what the demand curve would be in order to demand that amount of tonne-miles at the April spot rate. We then use an average of the estimated values of $Y_0$ to set the $Y_0$ used in the simulations:

$$Y_0^{sim} = \frac{1}{n}\sum_{i=1}^{n} Y_0^i = \frac{1}{3}\left(Y_0^{optS} + Y_0^{mxS} + Y_0^{12k}\right)$$

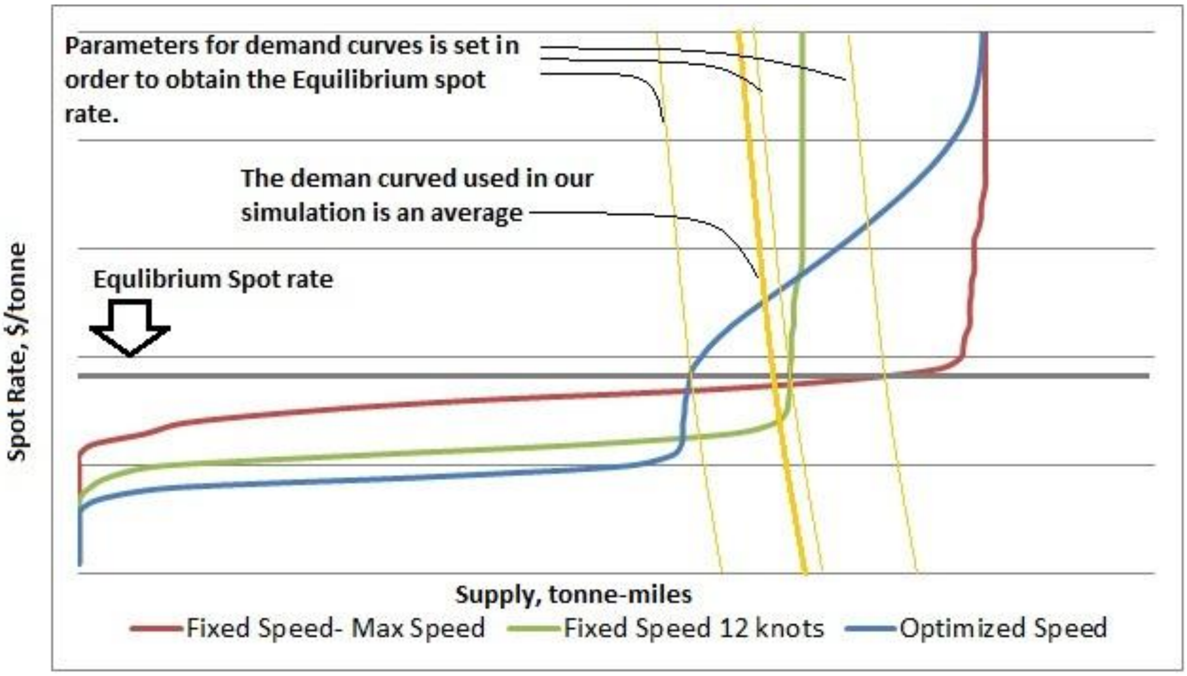


*Figure 39: Determination of demand curve*

## 6.2.4 **Scrapping**

To improve the analysis further, functions of ordering and scrapping can be incorporated. The method of Adland and Strandenes (2007) is used to make these estimations.

The scrapping process is presumed to follow a Poisson distribution. Lambda is estimated using former spot rates as well as demolition rates. Adland and Strandenes(2007) used

---

[22] WS spot in April was 31.75, while the Worldscale flat rate for 2013 is 29.40. The spot rate thus become 9.34=100*31.75/29.40 for the TD3 route

deliveries as an additional parameter; we however concluded that deliveries of new ships were insignificant and have therefore opted to disregard this.

The deliveries follow a geometric distribution. The expected value is determined by the spot rate as well as changes in the order book.

This enables us to estimate the number of ships entering and exiting the fleet, as well as adjusting the supply accordingly. In the case of scrapping, supply is adjusted by subtracting a value equivalent to the amount a reference ship would have supplied, whereas in the event of a new build, the value of a different reference ship is added to the supply[23]. It must be noted that the removal and addition of supply on the supply curve, occurs by adding supply at the same spot rate according to standard microeconomic theory.

As a first step, regression was performed according to the works of Adland and Strandenes (2007), results demonstrated below:[24]

### Regression Analysis: Scrapping t versus Scrapping t-; Scrapping t-; ...

```
The regression equation is
Scrapping t = 0,981 + 0,326 Scrapping t-1 + 0,248 Scrapping t-2
              - 0,0639 Deliveries t - 0,00447 WS t-1


302 cases used, 2 cases contain missing values


Predictor           Coef   SE Coef      T      P
Constant          0,9815    0,2368   4,15  0,000
Scrapping t-1    0,32577   0,05644   5,77  0,000
Scrapping t-2    0,24831   0,05604   4,43  0,000
Deliveries t    -0,06389   0,04508  -1,42  0,158
WS t-1         -0,004466  0,002301  -1,94  0,053


S = 1,50795   R-Sq = 27,9%   R-Sq(adj) = 27,0%
```

Neither values for deliveries nor spot rate yields significant values at a 5% level for number of ships being scrapped. It is certainly not significant regarding deliveries, but regarding the

---

[23] The reference ships used to add new ships to supply and subtract supply with respect to scrapping, is set to be an average of the ships built in 2013 for new building and the average of the ships built in 1993 and earlier for scrapping.

[24] To view complete regression, view Appendix A4

spot rate the margin is sparse. We therefore decide to do another regression without including deliveries as a variable.[25]

**Regression Analysis: Scrapping t versus Scrapping t-; Scrapping t-; ...**

```
The regression equation is
Scrapping t = 0,845 + 0,322 Scrapping t-1 + 0,243 Scrapping t-2 - 0,00466 WS t-1


302 cases used, 2 cases contain missing values


Predictor           Coef   SE Coef      T      P
Constant          0,8450    0,2167   3,90  0,000
Scrapping t-1    0,32180   0,05647   5,70  0,000
Scrapping t-2    0,24296   0,05601   4,34  0,000
WS t-1         -0,004656  0,002301  -2,02  0,044


S = 1,51050   R-Sq = 27,4%   R-Sq(adj) = 26,7%
```

It is evident from these new regression results that the spot rate now has become significant. Moreover the signs of the variables seem rational. The constant is positive, which is reasonable due to the fact that every ship must be scrapped at some point. The positive correlation between scrapping today and scrapping over previous time periods is also reasonable, because ships are often scrapped at the same time (during poor market conditions). At last, the fact that the spot rate correlates negatively with scrapping makes sense, as a higher spot rate leads to higher income and thus justifies maintenance cost, and it is in turn reasonable that maintenance costs will increase along with the age of the ship.

## 6.2.5 **Deliveries**

Unlike scrapping, new building does not have an acute impact on the supply curve. Building a ship is time-consuming, and at the time a ship-owner is in the greatest need of a new ship,

---

[25] To view complete regression, view Appendix A5

the waiting-time is most likely the longest, simply because other ship-owners also will want new ships and global shipbuilding capacity is a limited resource. It would therefore be rational to assume a correlation between delivery time and the size of the order book. For simplicity, this is ignored in our model and delivery is set to 2 year (24 months) regardless of the order book. The rationale behind new building is not very different from that of scrapping; if ship earnings are up, people will want to 'join the party' and earn money by ordering ships of their own – and ship-owners who wishes to earn more money will order more ships as well. We have chosen to use a similar model as Adland and Strandenes (2007), i.e. use a stochastic process to determine the number of orders for new ships at time t. The process is determined by two factors:

- The spot rate ($X_{t-1}$ ) for the previous period. The rationale behind this factor is evident, as the best indication of future spot rates (and thus the future earnings of the ship to be ordered) is the current spot rate.
- Changes in the order book ($\Delta OB_{j-1}$)

The expected number of contracts at time t is estimated by:

$$\mu_t = \alpha + \beta_1 \ln(X_{t-1}) + \beta_2 \Delta OB_{j-1}$$

The results of the regression analysis follows:[26]

## Regression Analysis: Contracting versus ln(WS); delta O

```
The regression equation is
Contracting = - 5,12 + 1,97 ln(WS) + 0,282 delta O


Predictor      Coef  SE Coef      T      P
Constant     -5,118    2,656  -1,93  0,055
ln(WS)       1,9741   0,6196   3,19  0,002
delta O     0,28198  0,05587   5,05  0,000


S = 3,88610   R-Sq = 21,1%   R-Sq(adj) = 20,3%
```

---

[26] To view complete regression, view Appendix A6

At first inspection, the signs appear as predicted in accordance with our previous discussion; expecting increasing numbers of contracts correlating with higher spot rates as well as increasing number of orders. In accordance with Adland and Strandenes (2007) we assume the number of contracts follow the geometric distribution.

**Drawbacks of scrapping and new building process**

The expected number of scrapping's and new contracts was estimated based on the spot rate. However, a high spot rate does not necessarily mean high earnings; if the bunker price is high, the spot rate will have to increase to cover the bunker cost even if demand is low.

| **Parameters used in the simulation** | |
|---|---|
| $Y_0$ | 765593142052.471 |
| Monthly growth of $Y_0$ | 0.2418% |
| Elasticity of demand $\varepsilon$ | 0.1 |
| Monthly standard deviation of demand | 2.3% |
| Initial Bunker Price | 661.29 |
| Standard deviation of Bunker Price | 11.3% |
| Expected value of monthly Scrapping's and Contracts for New building | In accordance with regressions |

*Figure 40: Summary of variables used in the simulation*

## 6.3 Results

### 6.3.1 **Demand elasticity = 0.1**

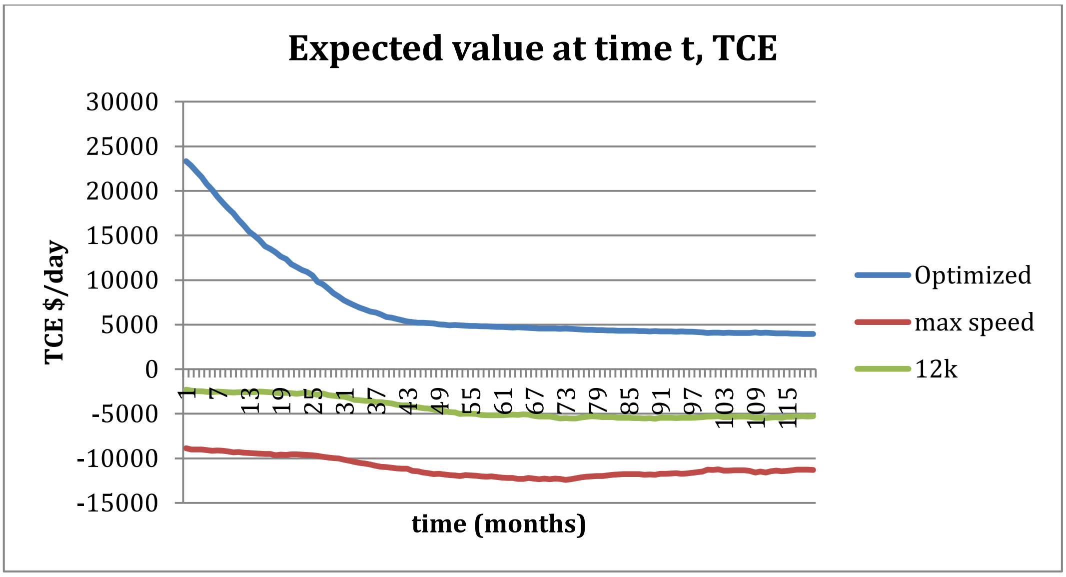


*Figure 41: E (TCE) at time t, Ɛ = 0.1*

We here see that values for TCE[27] in all speed regimes converge towards their respective equilibriums. Additionally, the vessel operating within the speed-optimized regime has the highest expected value at all times. We also notice that the TCE has a negative expected value for the fixed speed regimes. This may seem strange but it's important to remember this is only a reference ship, that it has a negative value does not mean the rest of the fleet has a negative TCE. It must also be noted that the TD3 time charter equivalent rate from the Baltic Exchange, which is the basis for our TCE calculation, was negative for several months in 2012 in addition to April of this year (Clarksons, 2013).

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[27] To see the calculation of the TCE of the reference ship, view appendix section E)

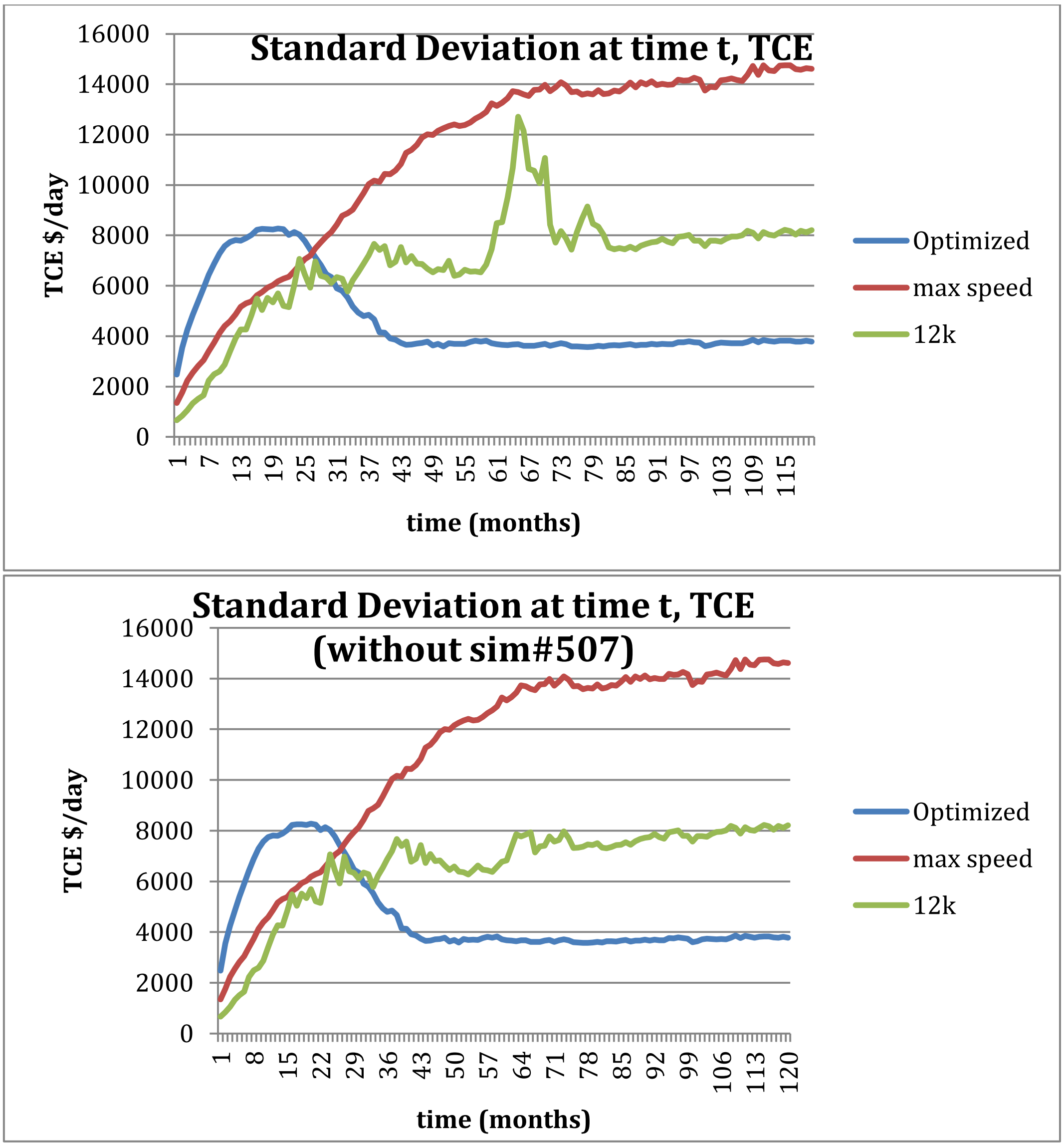

*Figure 42: Standard deviation TCE at time t, $\mathcal{E} = 0.1$*

We see that the ship in the speed-optimized fleet has the highest standard deviation in the initial phase, whereas it has the lowest standard deviation throughout the remaining time period. This is an important feature because low variance in earnings is desirable as it facilitates future planning, makes estimates of future earnings more accurate and in turn eases the investment process. It is also interesting to see that the standard deviation for the ship sailing at 12 knots have a major spike at around 60 months. This was somewhat unexpected, and by reviewing the data it became evident that this is caused by one specific simulation (#507); an increase in demand at a time when supply is already inelastic - combined with reduced oil price - leads to a big spike in the TCE.[28]

For analytical purposes it is useful to examine the graph without the extreme value caused by simulation #507. We see that the depicted standard deviation for the optimized fleet and the fleet sailing at maximum speed appear smoother than the fleet sailing at 12 knots. This implies that conditions surrounding the fleet running at 12 knots are more unstable and prone to extreme values. While kurtosis is usually a measure of the shape of the peak of a distribution, it can also be used as a measure for the occurrence of infrequent extreme values. If the occurrence of extraordinary high spot rates is higher for the fleet sailing at 12 knots, the kurtosis of the distribution would be larger. This is evidently the case here, as illustrated by the graph below, and is also confirmed by looking through the data[29]. When using kurtosis as a measure for extreme values of the TCE, it is apparent that this occurs increasingly rare towards the end of the time series, which implies that it takes longer time for the TCE to be stabilized within a speed regime of 12 knots.

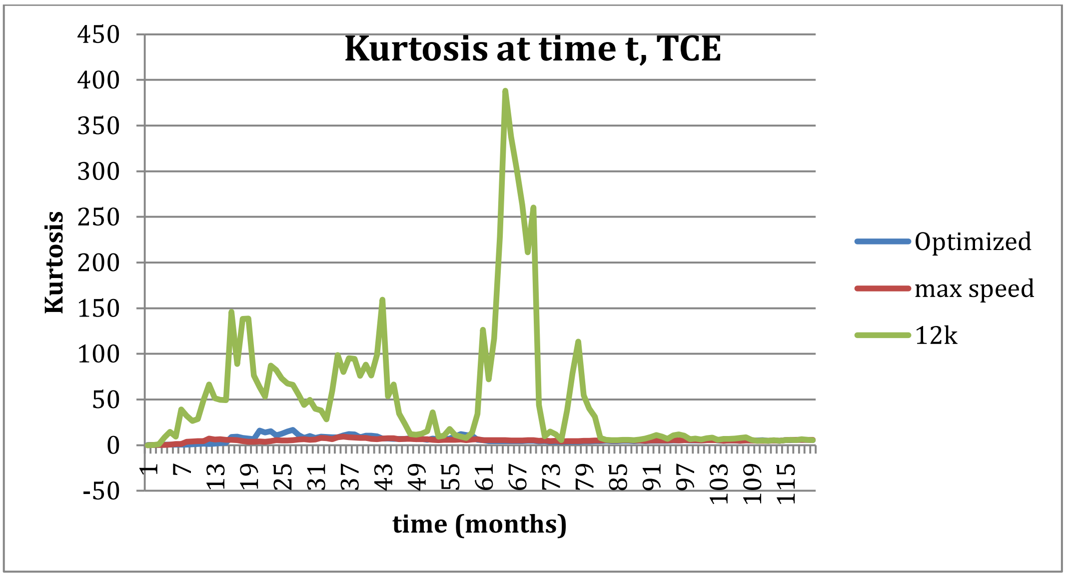

*Figure 43: Kurtosis TCE at time t, $\mathcal{E} = 0.1$*

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[28] Simultion#507 peaks with a TCE at 311.040 in month 65, this is 3.1 times larger than the largest observed TCE at the speed optimized fleet and 4.3 times larger than the largest observed value at the fleet sailing at max speed

[29] In 7 simulations the TCE on at least one occasion exceeds 75.000 for the fleet sailing at 12 knots, compared to twice and none in the speed optimized fleet and the fleet sailing at maximum speed respectively.

**An unexpected result:**

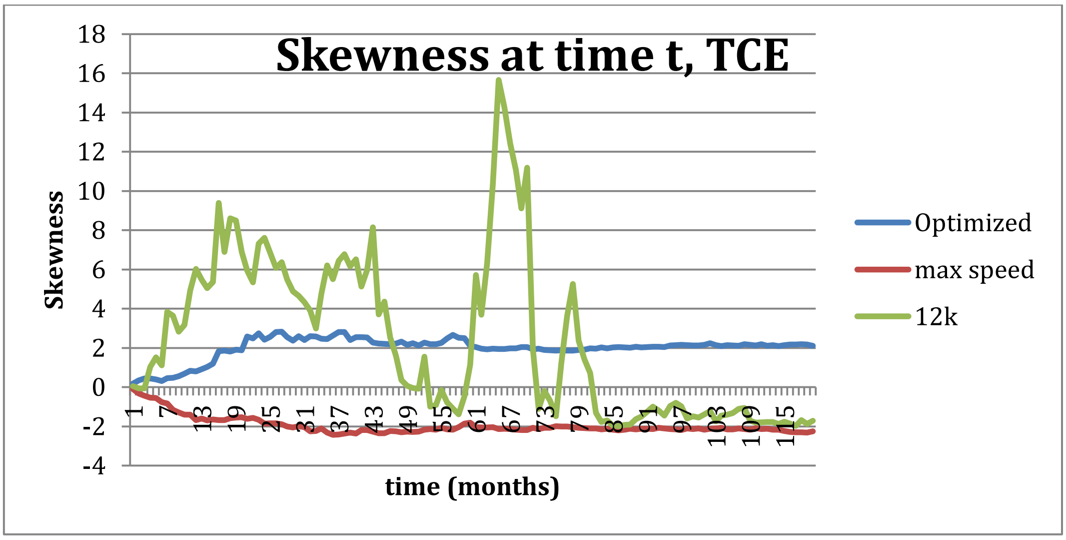


*Figure 44: Skewness TCE at time t, Ɛ = 0.1*

Interestingly, we observe a positive skewness of the TCE for the optimized speed regime. Moreover, the skewness remains positive throughout the entire time period for this regime, as opposed to the two regimes of fixed speed. Contrarily, the skewness remains constantly negative for the ship complying with the maximum speed regime. TCE for the 12 knot regime starts out by being instable and predominantly positively skewed for the first ⅔ of the time period simulated, but eventually stabilizes at a negative level. The initial instability in the latter regime is caused by a few extremely high TCE values in a short period of time.

If we consider the TCE to be the return on investment (in this case the ship), financial theory can be applied to analyze an individual's perspective on asset value (i.e. the ship). When using a standard utility function, an individual will usually prefer higher returns and lower variance. We already established that the ship in the speed-optimized fleet has the highest return (TCE) and the lowest variance (except during the first few months). For most common utility functions (with the exception of quadratic utility), individuals will also most often prefer a distribution of returns that is positively skewed. An intuitive explanation for this is that a negatively skewed distribution involves a higher probability of negative returns (a formal proof explaining how positive skewness is preferable is presented in the appendix).

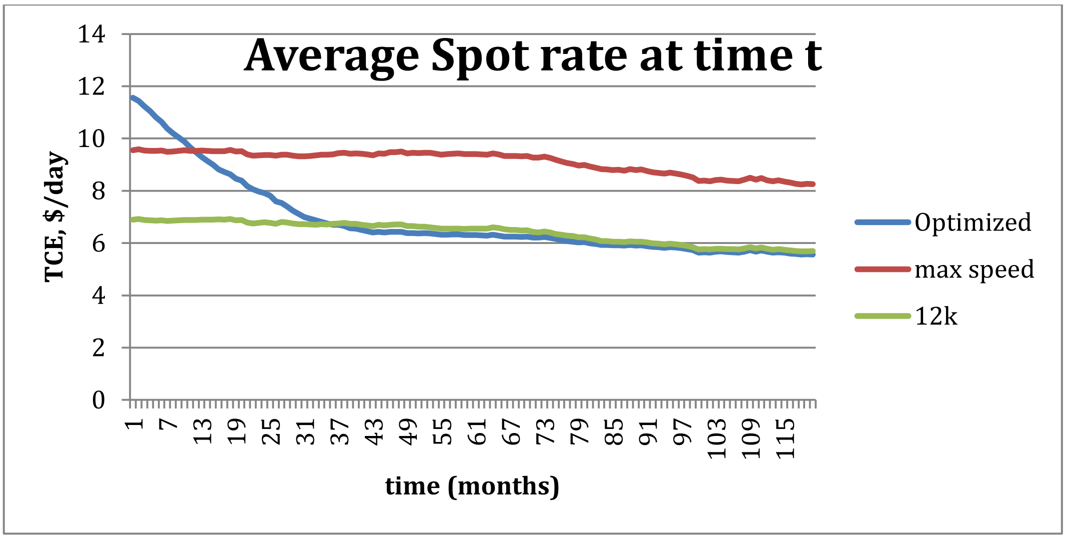


*Figure 45: Average spot rate at time t, Ɛ = 0.1*

There is a similarity between the development of spot rate and evolving TCE, in the way that all the spot rates are stable within a narrow range, except the rate for the speed optimized fleet which display an initial decline before stabilizing around $6/tonne. There is a minor decline in spot rate for all the fleets, which we postulate is because a large part of the fleet has been replaced after 10 years. The least cost-efficient ships have been taken out of service and replaced with new and more cost-efficient ships; thus making the fleet increasingly cost-efficient and enabling the supply of larger quanta at lower rates. Another perspective on the development is that the least cost-efficient ship in the fleet has become more cost-efficient. It is a logical extension to assume that the marginal vessel becomes more cost efficient. In this context our results fits perfectly with the hypothesis introduced by Adland (2012):"Because all time horizons are by definition a sequence of momentary equilibria it is *always* the voyage cost of the marginal vessel that sets the spot rate." The spot rate for the fleet sailing at optimal speed, is almost identical to the spot rate of the fleet sailing at 12 knots. One could argue that the spot rate appears low, and this is likely because - in addition to the evolvement of a more cost-efficient fleet over the 10 years as previously stipulated - this is due to the assumption that a ship will continue to supply the market as long as TCE>0. This is a reasonable assumption in a shorter perspective, but in the long run operational costs must be covered for a ship to be profitable and remain in operation.

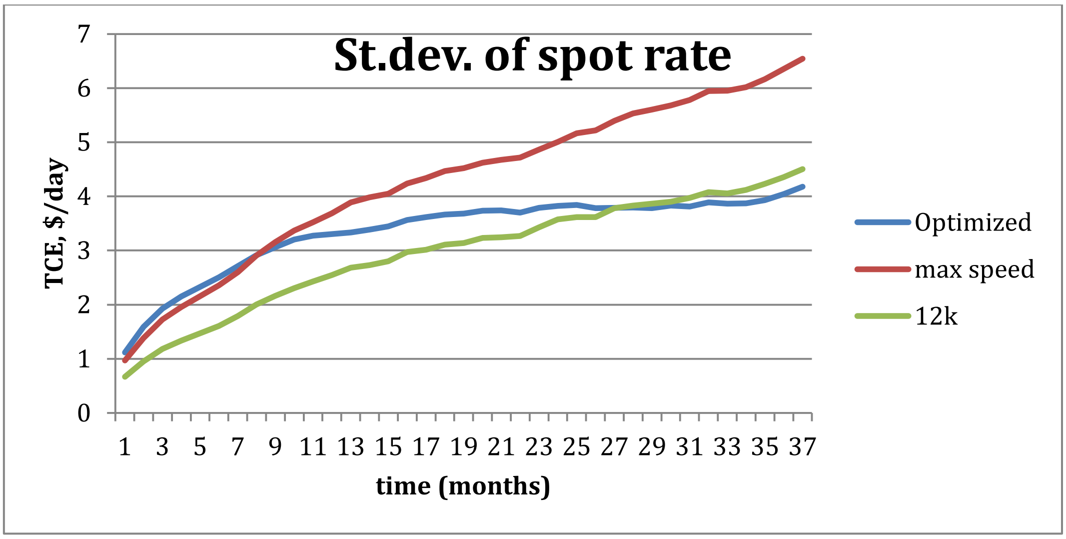


*Figure 46: Standard deviation of spot rates at time t, Ɛ = 0.1*

By examining the development of the standard deviation, we notice that the fleet sailing at maximum speed is associated with the largest standard deviation. Developments in standard deviation for the fleet sailing at 12 knots and the fleet with optimized speed are very similar. It is interesting that these speed regimes display the lowest standard deviation, and it must be specified that this is partly because the spot rates are simply lower for these regimes.

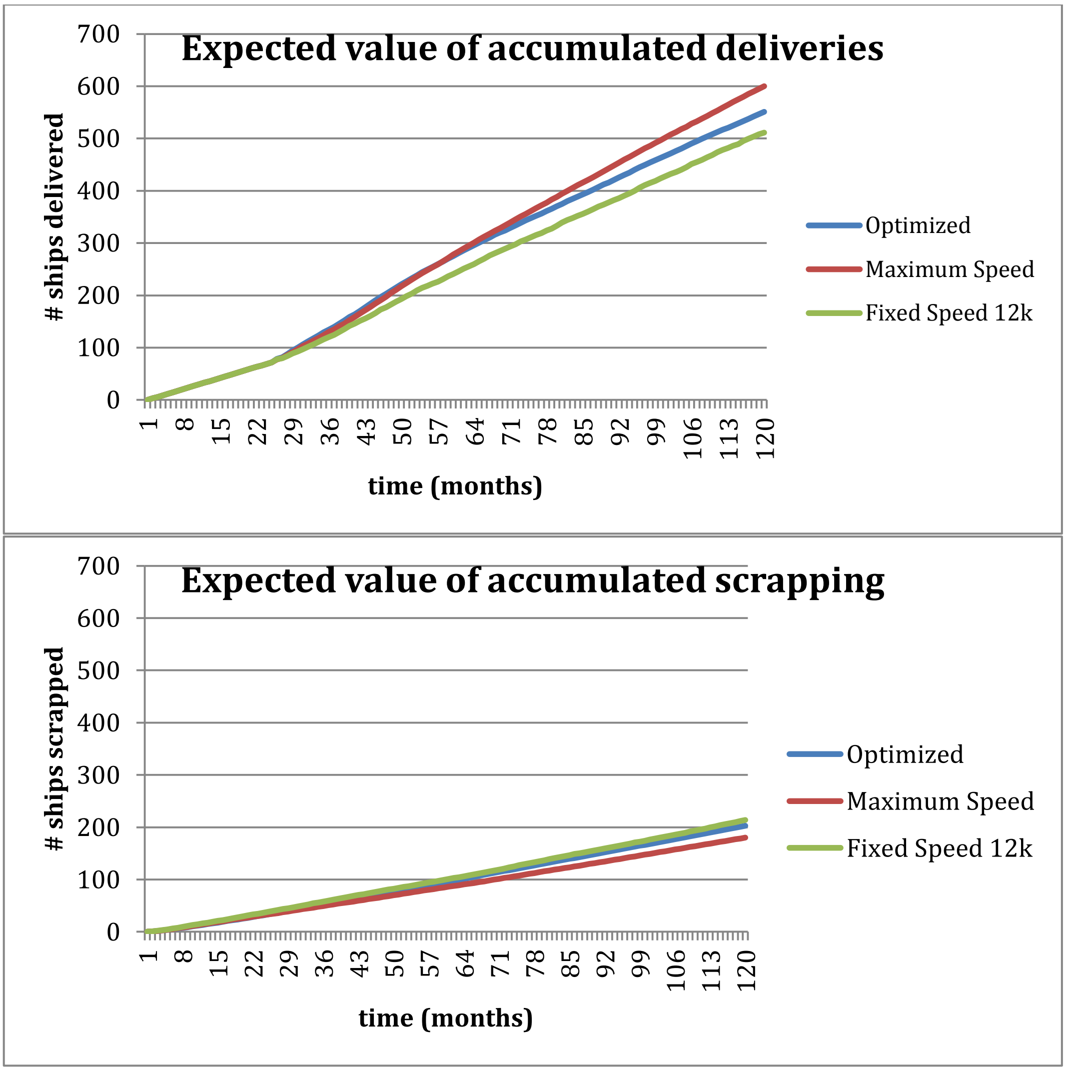


*Figure 47: Expected accumulated deliveries/scrapping at time t, Ɛ = 0.1*

When we approach the numbers for accumulated scrapping and new builds, we see that the number of ships delivered, outnumber ships scrapped. This is not surprising as we previously made an assumption of a 2.9% increase in the demand of tonne-miles per year. The fleet itself must increase to be able to keep up the supply to meet a growing demand in the long-term perspective.

### 6.3.2 **Demand of elasticity = 0.05**

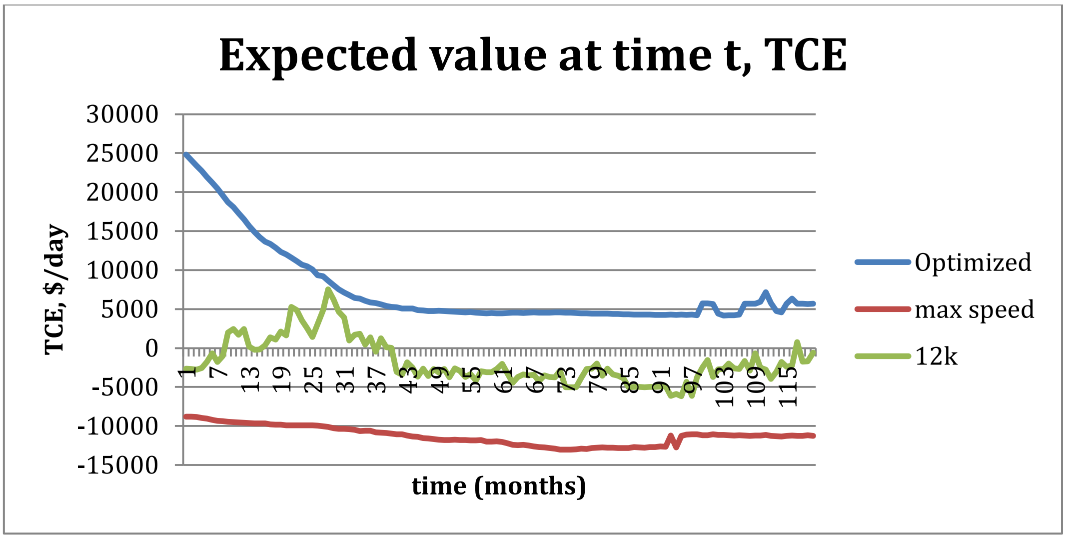


*Figure 48: Expected TCE time t, Ɛ = 0.05*

The main reason for setting the elasticity of demand at 0.1 was to avoid extreme spot rates more efficiently than with an elasticity of 0.005. The latter would correspond to a situation of nearly perfect inelasticity - and consequently under conditions where demand is high -, the supply would be perfectly inelastic along with a near perfect inelasticity for demand; which obviously is not a realistic situation. It is however interesting to explore the properties of a simulation with an elasticity of 0.005.

The development of the average TCE follows the same pattern as we observed with higher elasticity of demand, but the TCE values stabilize at slightly higher values. Another difference is that TCE is less stable; this is particularly true for the fleet sailing at 12 knots. Both these differences are easy to relate to the new demand curve. The higher expected values for the TCE can be explained by higher spot rates when demand exceeds supply, this will also lead to a more volatile market as the spot rate will to a greater extent be either high or low.

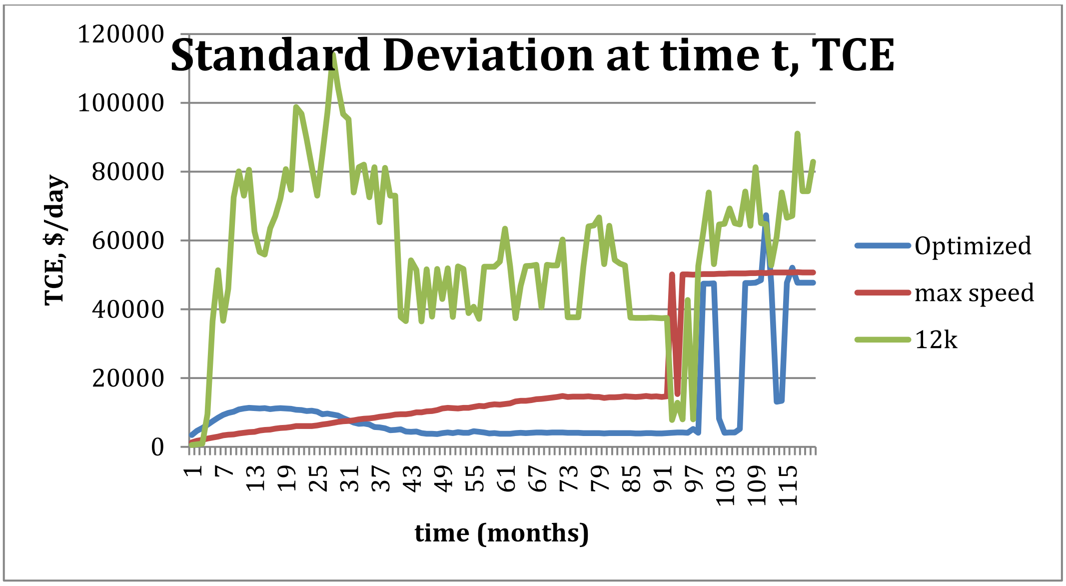


*Figure 49: Standard deviation time t, Ɛ = 0.05*

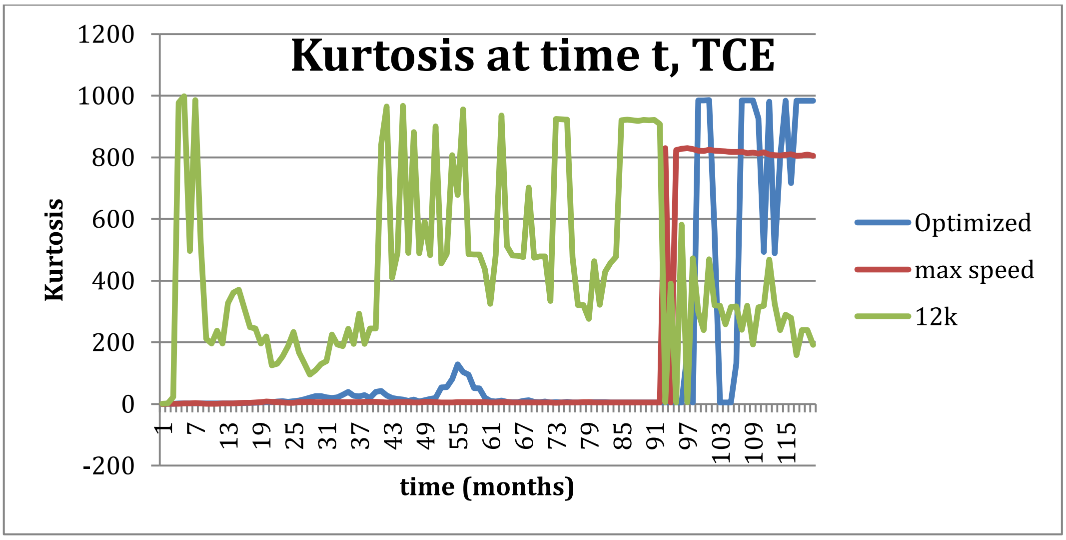


*Figure 50: Kurtosis TCE time t, Ɛ = 0.05*

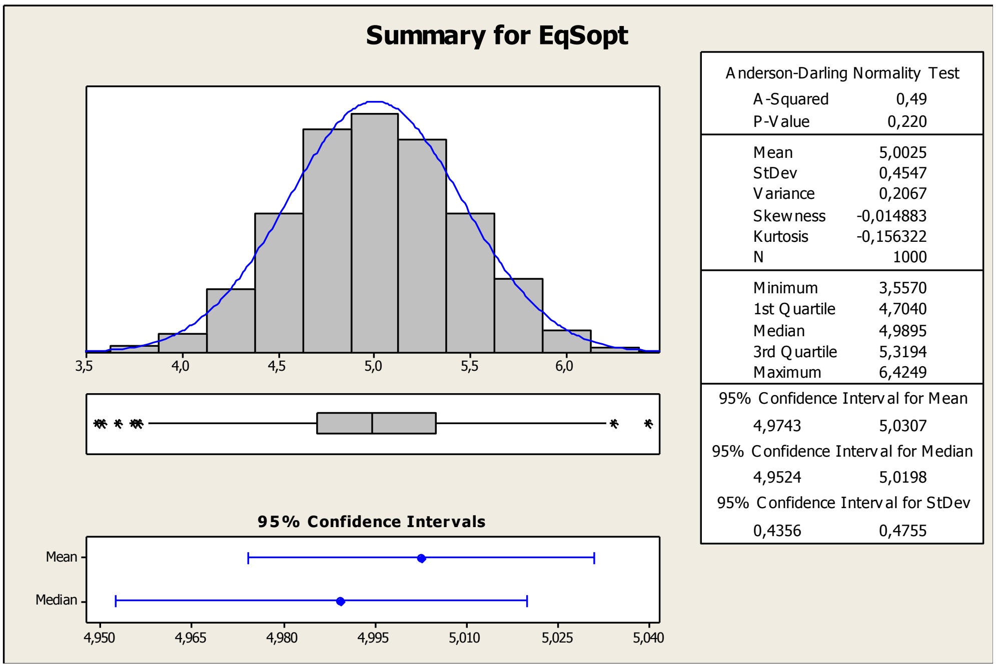
With an elasticity of 0.1 we observed a sudden spike in the standard deviation of the fleet sailing at 12 knots due to an increase in demand when supply already was perfectly inelastic. By inspecting the standard deviation along with the kurtosis, it is evident that this occurs to an even larger extent with a more inelastic demand. Standard deviation remains predominantly very high for the majority of the time-period for the fleet sailing at 12 knots. By comparison with the kurtosis it becomes clear this is caused by the fat tail possibility of very high spot rates (whose standard deviation naturally correlates strongly with the standard deviation of the TCE). This is no surprise because with a perfectly inelastic supply, a more inelastic demand will evoke further increase in the spot rate as demand increase. Thus, a near perfectly inelastic demand often creates an unstable situation with a fluctuating spot rate and consequently an increasingly fluctuating TCE.

### 6.3.3 **What happens with the spot rate in the short term?**

We are further intrigued to explore potential short-term alterations in spot rate, depending on where we are situated on the supply curve.

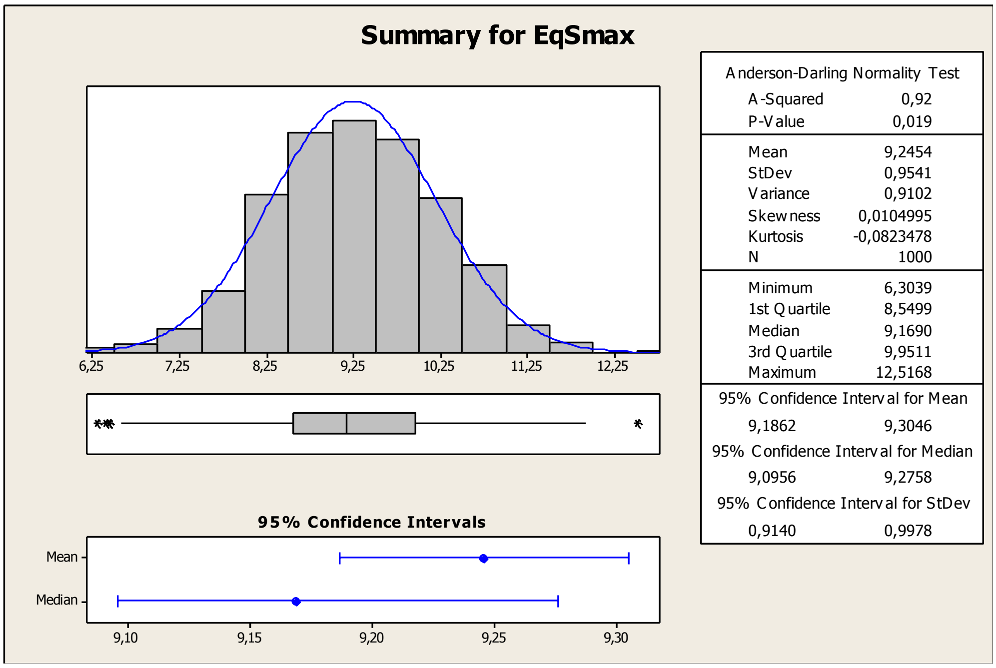
**Low demand:**

In the short term, spot rate displays a well-fitted normal distribution when demand is low. The standard deviation is relatively small for all speed regimes, and as we would expect; the standard deviation is lower when the expected value is lower. Expressed as a percentage, the standard deviations range from 8.9% to 10.1%.



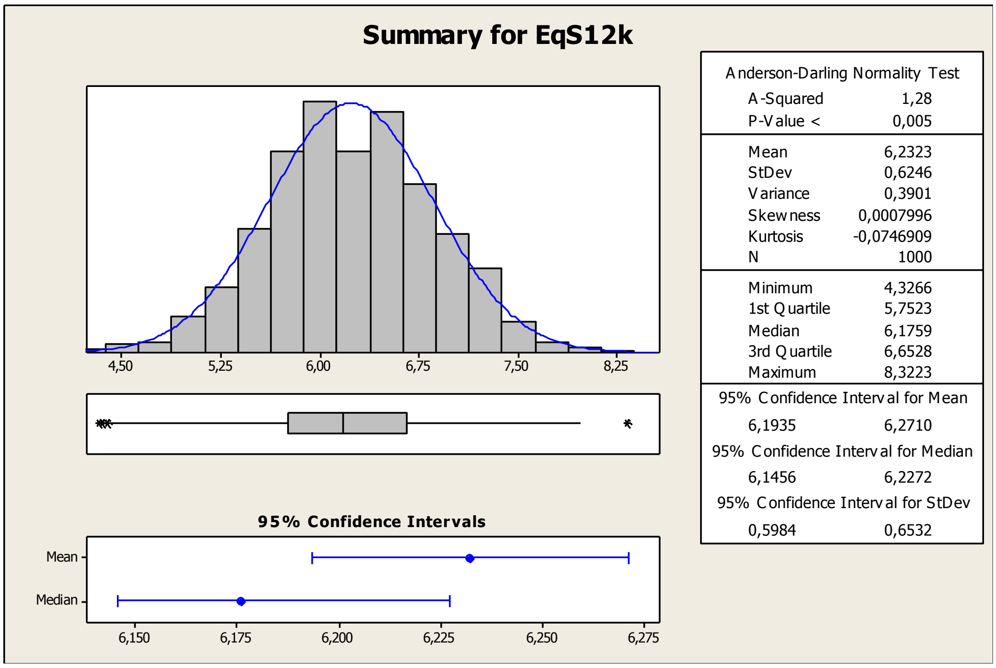
| Anderson-Darling Normality Test | |
|---|---|
| A-Squared | 0,49 |
| P-Value | 0,220 |
| Mean | 5,0025 |
| StDev | 0,4547 |
| Variance | 0,2067 |
| Skewness | -0,014883 |
| Kurtosis | -0,156322 |
| N | 1000 |
| Minimum | 3,5570 |
| 1st Quartile | 4,7040 |
| Median | 4,9895 |
| 3rd Quartile | 5,3194 |
| Maximum | 6,4249 |
| 95% Confidence Interval for Mean | |
| 4,9743 | 5,0307 |
| 95% Confidence Interval for Median | |
| 4,9524 | 5,0198 |
| 95% Confidence Interval for StDev | |
| 0,4356 | 0,4755 |

*Figure 51: Short term: speed-optimized fleet (low demand)*



```
Anderson-Darling Normality Test
   A-Squared            0,92
   P-Value             0,019

   Mean               9,2454
   StDev              0,9541
   Variance           0,9102
   Skewness        0,0104995
   Kurtosis       -0,0823478
   N                    1000

   Minimum            6,3039
   1st Quartile       8,5499
   Median             9,1690
   3rd Quartile       9,9511
   Maximum           12,5168
95% Confidence Interval for Mean
   9,1862             9,3046
95% Confidence Interval for Median
   9,0956             9,2758
95% Confidence Interval for StDev
   0,9140             0,9978
```

*Figure 52: Short term: fleet sailing at max speed (low demand)*

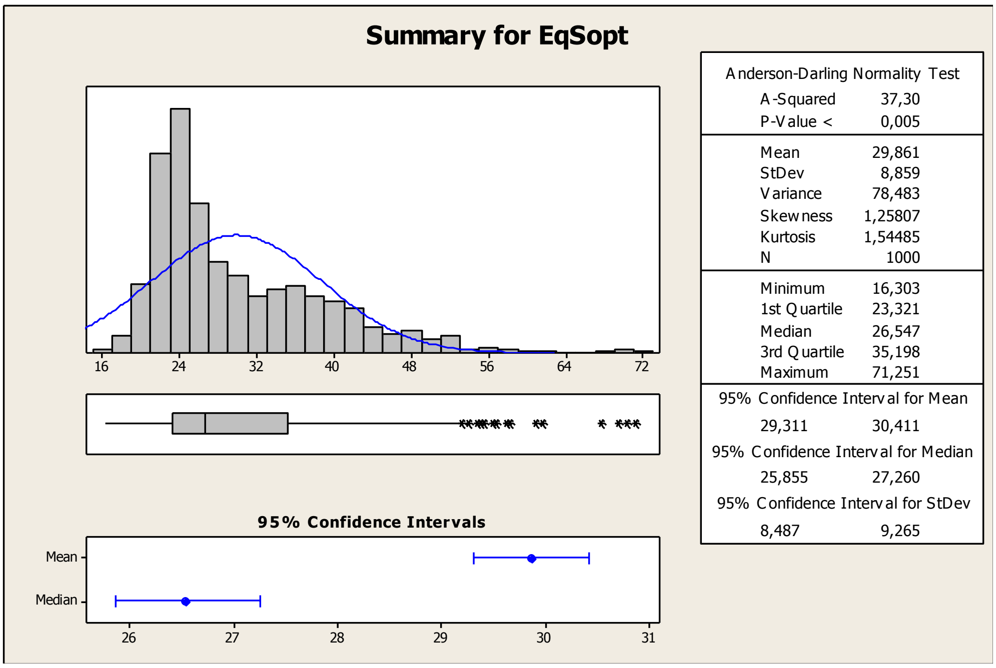


```
Anderson-Darling Normality Test
   A-Squared            1,28
   P-Value <           0,005

   Mean               6,2323
   StDev              0,6246
   Variance           0,3901
   Skewness        0,0007996
   Kurtosis       -0,0746909
   N                    1000

   Minimum            4,3266
   1st Quartile       5,7523
   Median             6,1759
   3rd Quartile       6,6528
   Maximum            8,3223
95% Confidence Interval for Mean
   6,1935             6,2710
95% Confidence Interval for Median
   6,1456             6,2272
95% Confidence Interval for StDev
   0,5984             0,6532
```

*Figure 53: Short term: fleet sailing at 12 knots (low demand)*

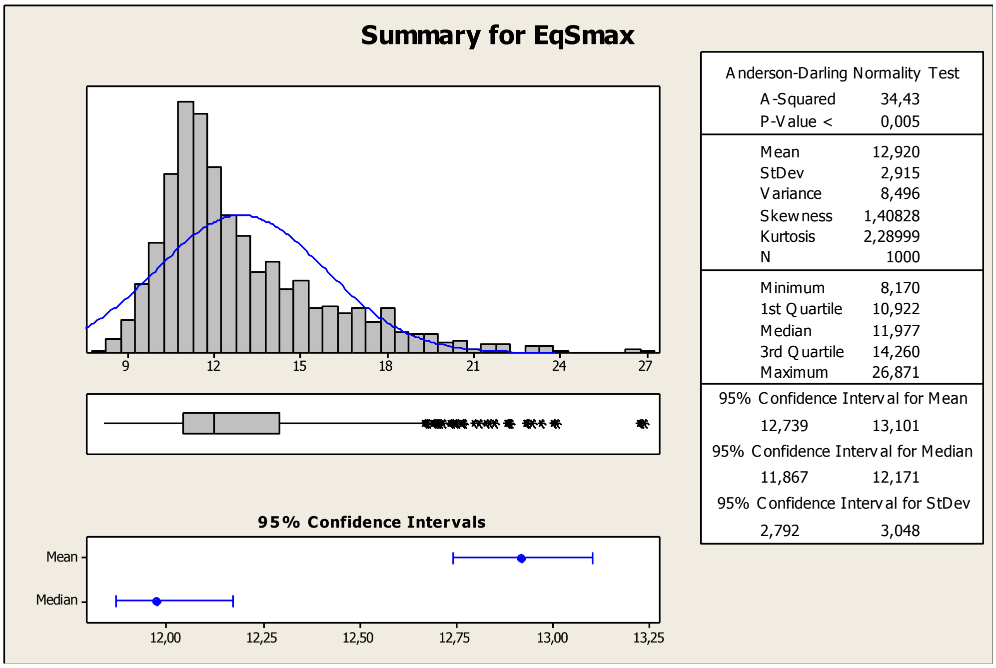
## High demand:

The spot rate distribution for the next time-period is substantially different when demand is high, compared to when demand is low. As displayed below, all of the distributions are characterized by a positive skewness. This agrees with the fact that supply is perfectly inelastic. If demand were to increase, it would be rationed by increasing spot rates due to the limited supply. Another observation is that the standard deviation is larger in this situation than with a low demand - not only in absolute values (as expected) - but also as a percentage which ranges from 17.9% to 21%.



| Anderson-Darling Normality Test | |
|---|---|
| A-Squared | 37,30 |
| P-Value < | 0,005 |
| Mean | 29,861 |
| StDev | 8,859 |
| Variance | 78,483 |
| Skewness | 1,25807 |
| Kurtosis | 1,54485 |
| N | 1000 |
| Minimum | 16,303 |
| 1st Quartile | 23,321 |
| Median | 26,547 |
| 3rd Quartile | 35,198 |
| Maximum | 71,251 |
| 95% Confidence Interval for Mean | |
| 29,311 | 30,411 |
| 95% Confidence Interval for Median | |
| 25,855 | 27,260 |
| 95% Confidence Interval for StDev | |
| 8,487 | 9,265 |

*Figure 54: Short term; speed-optimized fleet (high demand)*



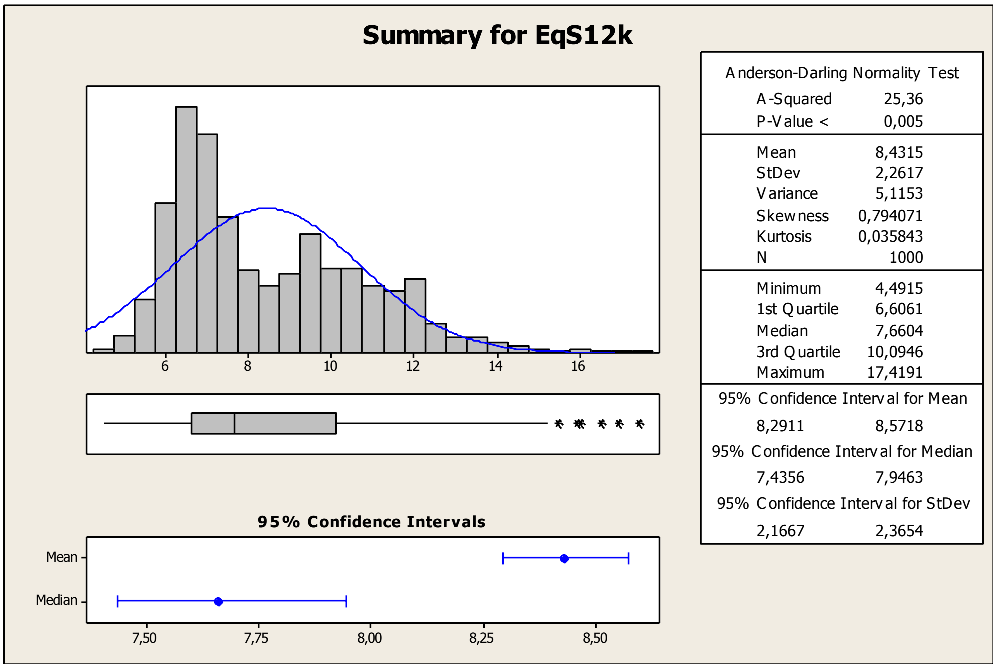
Anderson-Darling Normality Test
A-Squared 34,43
P-Value < 0,005

Mean 12,920
StDev 2,915
Variance 8,496
Skewness 1,40828
Kurtosis 2,28999
N 1000

Minimum 8,170
1st Quartile 10,922
Median 11,977
3rd Quartile 14,260
Maximum 26,871

95% Confidence Interval for Mean
12,739 13,101
95% Confidence Interval for Median
11,867 12,171
95% Confidence Interval for StDev
2,792 3,048

*Figure 55: Short term; fleet sailing at maximum speed (high demand)*



Anderson-Darling Normality Test
A-Squared 25,36
P-Value < 0,005

Mean 8,4315
StDev 2,2617
Variance 5,1153
Skewness 0,794071
Kurtosis 0,035843
N 1000

Minimum 4,4915
1st Quartile 6,6061
Median 7,6604
3rd Quartile 10,0946
Maximum 17,4191

95% Confidence Interval for Mean
8,2911 8,5718
95% Confidence Interval for Median
7,4356 7,9463
95% Confidence Interval for StDev
2,1667 2,3654

*Figure 56: Short term; fleet sailing at 12 knots (high demand)*

## Deciding factors

An interesting follow up is to determine what the deciding factors for changes in the spot rate at the different places at the supply curve are. As the distributions were quite similar in short term for the different speed regimes, we will only study the effects on the speed optimized regime. In order to estimate this, we have performed the same simulation as above on the speed-optimized fleet, when holding either the bunker price or demand fixed

### Low demand

At first glance the distribution when the demand is fixed and when the bunker price is fixed seems very similar. At closer inspection however it becomes clear that the spot distribution when the bunker price is fixed has a much lower standard deviation than when the demand is fixed. This is because a change in the bunker price will change the cost efficiency of the marginal vessel and thus shifting the supply curve either upwards or downwards. When the demand changes on the other hand the marginal vessel changes, because of the homogeneity of the fleet the new marginal vessel will not be very different from the previous one, and the spot rate will therefore not change considerably.

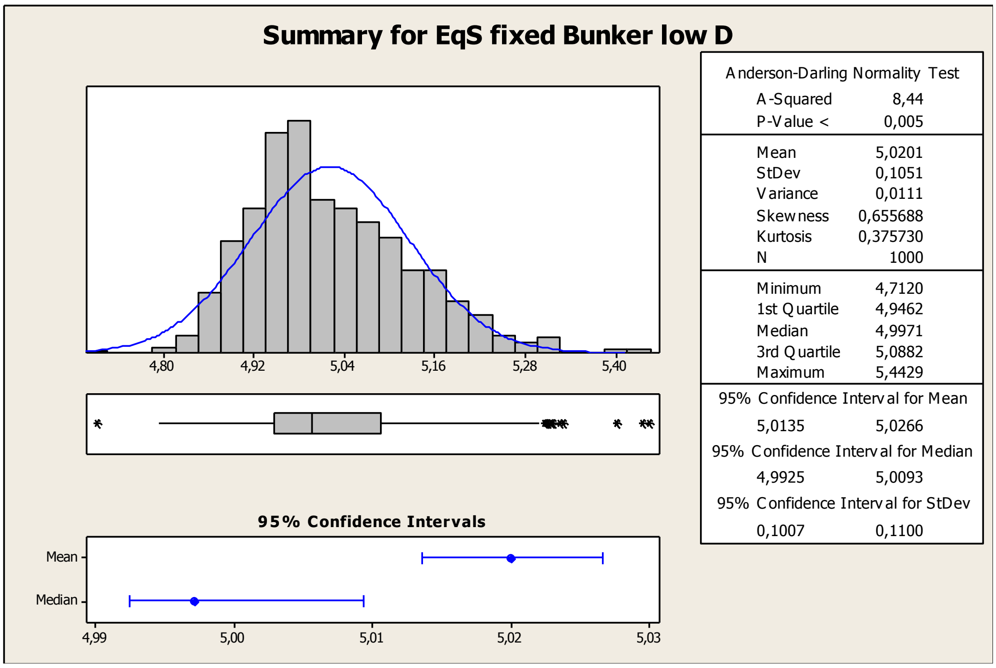


*Figure 57: Fixed supply at low spot rates*

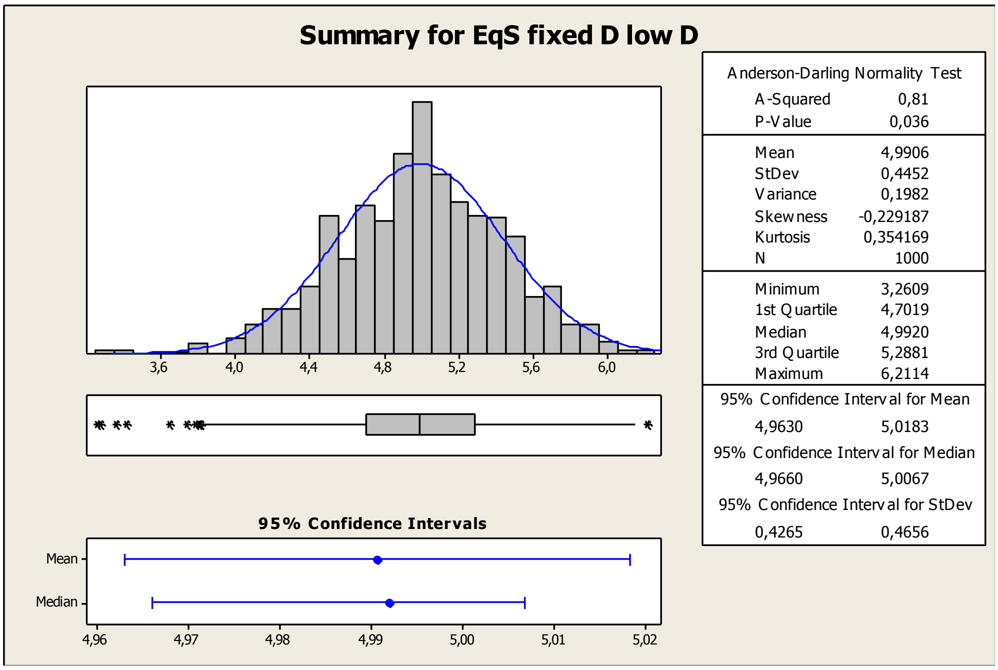
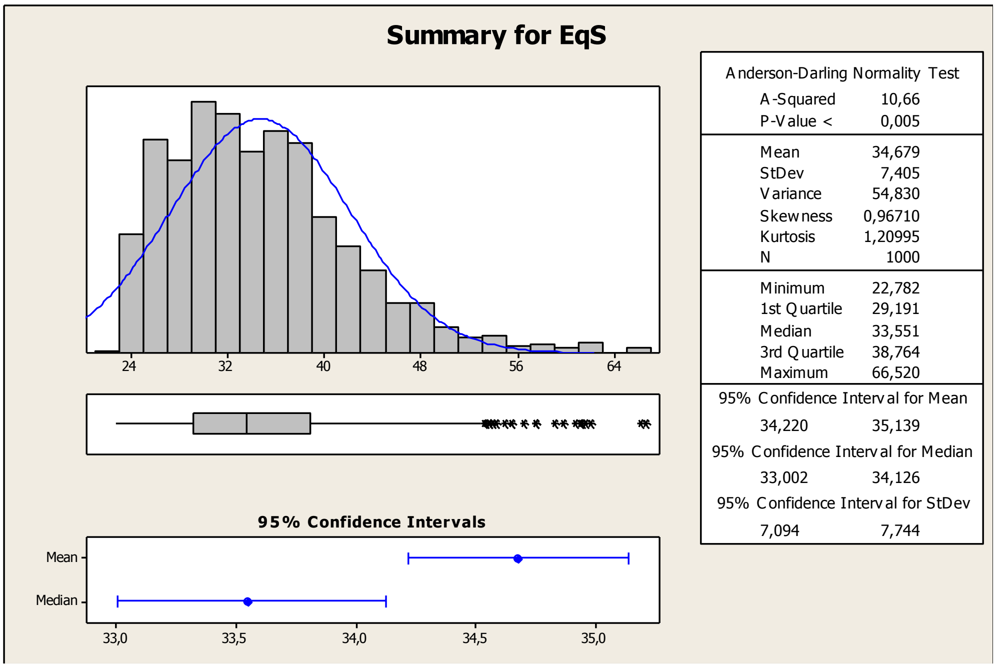


*Figure 58: Fixed demand at low spot rates*

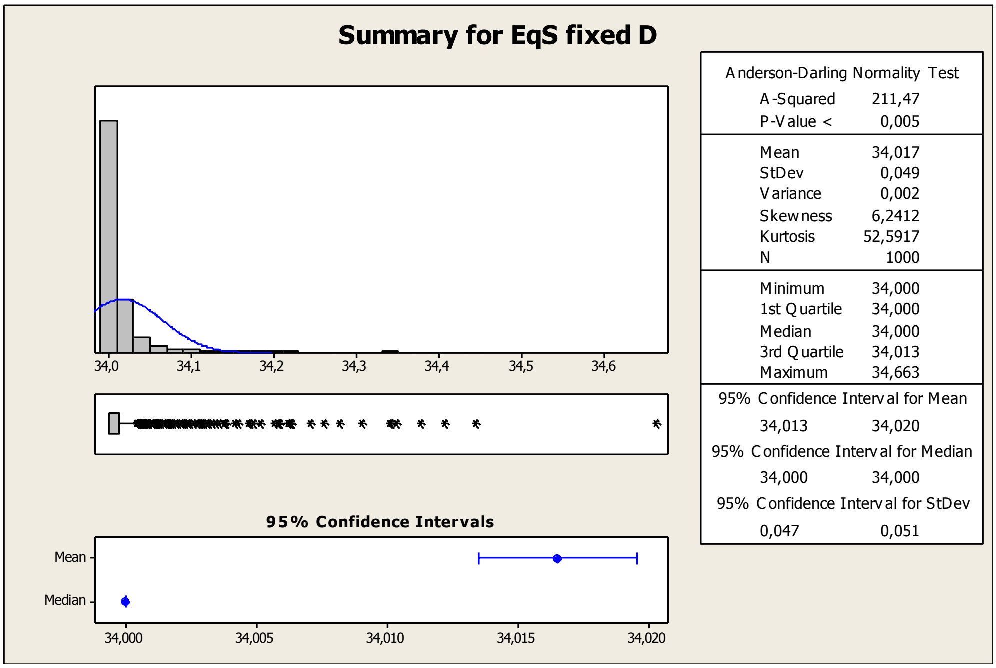
## High demand

The distribution of the spot rate is clearly different when the demand is fixed and the bunker price is fixed when the spot rate is already high. Changes in the bunker price do not have any large effect on the spot rate. This is while the spot rate is normally set by the marginal cost of the marginal vessel. The marginal ship when demand is high is the least cost efficient ship on the fleet, and even when that ship is fully operational there is still demand for more transport. The available capacity will therefore be distributed to those who are will are to pay the most for it and the price will be set more in an auction form than on the basis of marginal costs. Changes in marginal costs will therefore not have any particular effect on the determination of the spot rate. An change in demand will however affect the spot rate as it is a measure of how much the market is willing to pay for transport. When the spot rate is set in the form of an auction higher or lower willingness to pay will affect the price. The distribution is positively skewed because if the demand increases it will lead to higher spot rates, while a large enough decrease in demand can lead to the marginal vessel determining the spot rate as is the case under normal market conditions.



| Anderson-Darling Normality Test | |
|---|---|
| A-Squared | 10,66 |
| P-Value < | 0,005 |
| Mean | 34,679 |
| StDev | 7,405 |
| Variance | 54,830 |
| Skewness | 0,96710 |
| Kurtosis | 1,20995 |
| N | 1000 |
| Minimum | 22,782 |
| 1st Quartile | 29,191 |
| Median | 33,551 |
| 3rd Quartile | 38,764 |
| Maximum | 66,520 |
| 95% Confidence Interval for Mean | |
| 34,220 | 35,139 |
| 95% Confidence Interval for Median | |
| 33,002 | 34,126 |
| 95% Confidence Interval for StDev | |
| 7,094 | 7,744 |

*Figure 59: Fixed bunker price at high spot rate*



| Anderson-Darling Normality Test | |
|---|---|
| A-Squared | 211,47 |
| P-Value < | 0,005 |
| Mean | 34,017 |
| StDev | 0,049 |
| Variance | 0,002 |
| Skewness | 6,2412 |
| Kurtosis | 52,5917 |
| N | 1000 |
| Minimum | 34,000 |
| 1st Quartile | 34,000 |
| Median | 34,000 |
| 3rd Quartile | 34,013 |
| Maximum | 34,663 |
| 95% Confidence Interval for Mean | |
| 34,013 | 34,020 |
| 95% Confidence Interval for Median | |
| 34,000 | 34,000 |
| 95% Confidence Interval for StDev | |
| 0,047 | 0,051 |

*Figure 60: Fixed demand at high spot rates*

# 7. Concluding remarks

Our first main goal in this thesis was to explore the development of the VLCC fleet from 1995 into the homogenous fleet it constitutes today. By using data provided by Clarksons SIN comprising new builds, scrapped, and converted vessels on within the VLCC fleet, we were able to reconstruct an accurate approximation of the fleet at different time periods. By looking at specific values for fuel consumption, design speed, engine type, -make and vessel size, we assessed how these factors had changed from 1995 to the fleet of today. In cases where vessel data was unavailable, specifications of comparable vessels were applied. We found a distinct chronological developmental pattern in terms of fleet homogeneity, culminating in the highly homogenous fleet it is today.

Supply curves were created for specific time periods by applying speed and consumption data derived from the data set, along with calculations of β-values for specific ships according to build year. As a general observation we note that, overall, the supply curves have the same characterization as described in classic economic literature (Koopmans, 1939; Stopford, 2009). We demonstrated that the homogenization of the VLCC fleet have resulted in a more J shaped supply curve at fixed speed regimes, i.e. where supply remains extremely elastic up until the entire fleet is utilized, at which point supply becomes perfectly inelastic.

We proceeded by simulating the development of the VLCC market for the next decade. Our model incorporates stochastic processes surrounding demand, bunker prices, scrapping and new building.

The supply side constitutes the most complex part of our model and, was created by estimating the supply of each ship individually at three different speed regimes at any given oil price.

Through our calculations, we conclude that expected earnings for a speed-optimized fleet are both consistently higher, as well as more stable, than for a fleet sailing at a fixed speed. This is because a fleet sailing at fixed speed will create a J-formed supply curve, denoting that supply remains extremely elastic until the point where entire fleet is utilized and the supply subsequently becomes perfectly inelastic. This leads to a two state market, where spot rates are either near lay-up level or booming. For a speed-optimized fleet on the other hand, ships will not supply at maximum speed simply because it is profitable, but only if the added marginal income gained by an increase in speed will exceed the marginal costs involved. Consequently they will withhold supply where other speed regimes would not, and this in turn generates a higher spot rate. Further, the expected spot rate appeared to be the highest for a fleet with a regime fixed at maximum speed, however this does not appear to result in higher earnings because expected TCE is the lowest for this speed regime. The speed-optimized fleet achieves the highest earnings, despite having the lowest expected spot rate at most times. Additionally, most of the time variation in spot rate and TCE also appeared to be the lowest in a speed optimized regime; this is due to alterations in price elasticity of supply occurring more gradually in the speed-optimized fleet, as opposed to the sudden changes that occur within the fixed speed regimes.

Finally, we studied the distribution of spot rate in the short term. At times with low demand, the spot rate was characterized by a well-fitting normal distribution and a low standard deviation. Contrarily, during times where demand was high, the distribution appeared positively skewed with a greater increase in standard deviation relative to that of the spot rate.

The simulation of supply is the main strength of our analysis. For future research it would be interesting to construct a more sophisticated model involving the processes of scrapping and new build. It is currently based on a stochastic model where spot rate is among the most influential determinants. It would however be preferable for it to be determined by profitability, as the market may be more profitable with a medium spot rate and low bunker price, compared to when both spot rate and bunker price is high simultaneously. Literature on spot rate under conditions where demand exceeds supply is scarce at best, and increasing the available research on this topic could vastly improve our simulation.

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# Appendix:

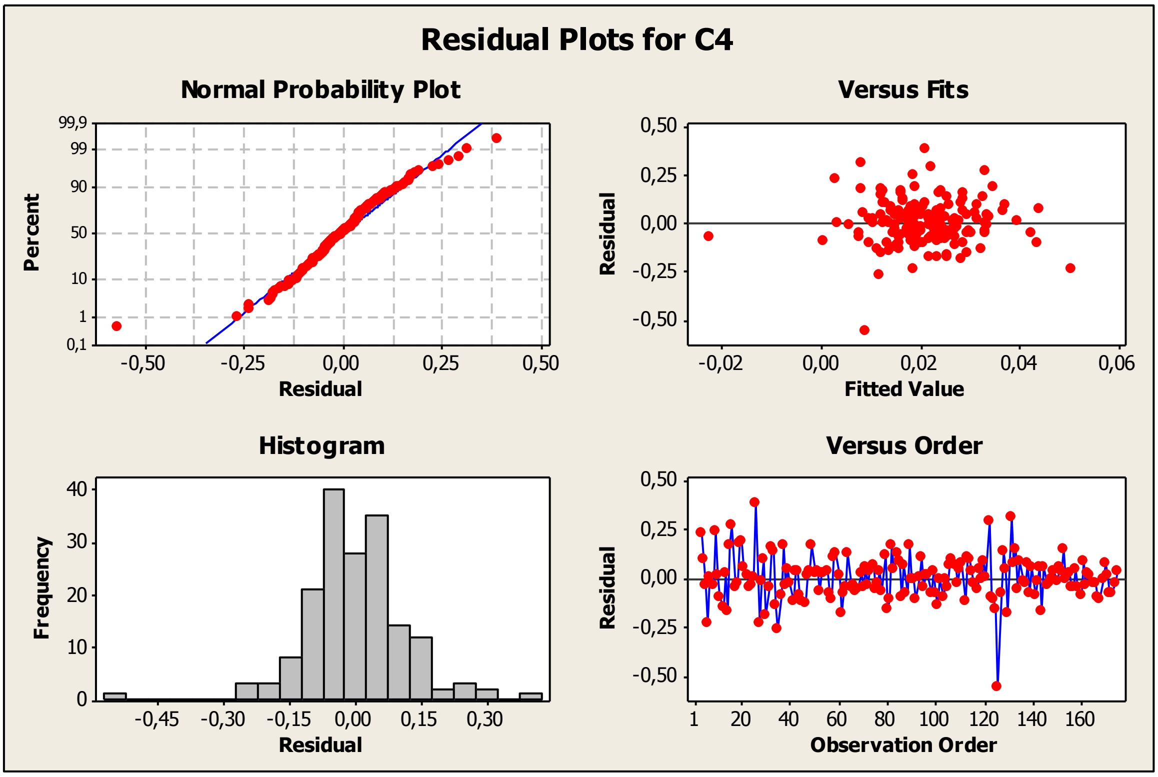
## A. Regressions:

### A1

**Bunker price:**

### Regression Analysis: C4 versus C5

```
The regression equation is
C4 = 0,0196 + 0,0758 C5


173 cases used, 2 cases contain missing values


Predictor      Coef   SE Coef     T      P
Constant   0,019599  0,008727  2,25  0,026
C5          0,07580   0,07528  1,01  0,315


S = 0,113148   R-Sq = 0,6%   R-Sq(adj) = 0,0%


Analysis of Variance

Source           DF       SS       MS     F      P
Regression        1  0,01298  0,01298  1,01  0,315
Residual Error  171  2,18920  0,01280
Total           172  2,20218


Durbin-Watson statistic = 1,90523
```



$$C4 = \frac{B_t - B_{t-1}}{Q_{t-1}}$$

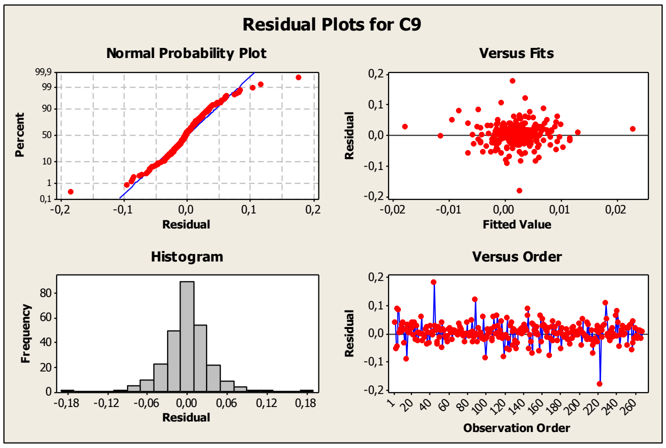
$$C5 = \frac{B_{t-1} - B_{t-2}}{B_{t-2}}$$

| | |
|---|---|
| DF | 171 |
| SS | 2,1892 |
| Var(ε) | 0,012802339 |
| σ (ε) | 0,113147422 |

## A2

## **Demand:**

### Regression with monthly data



Residual plots

The normal probability plot fits well, with the exception of a few extreme values at the tails. The histogram displays an exemplary bell shape. The versus plots appear to satisfy the requirements for’ homoscedasticity’.

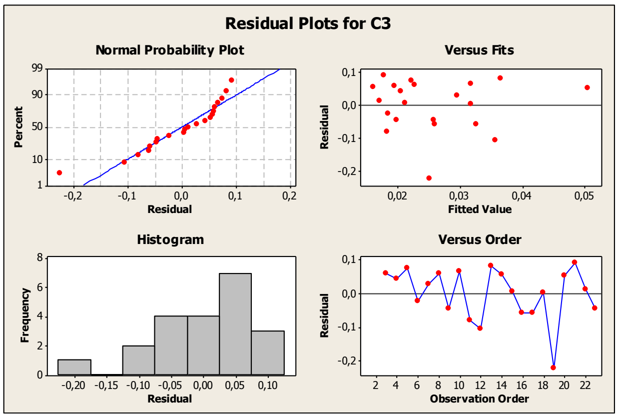
### Regression Analysis: C9 versus C10

```
The regression equation is
C9 = 0,00255 - 0,113 C10


266 cases used, 2 cases contain missing values


Predictor        Coef    SE Coef      T      P
Constant     0,002546   0,002150   1,18  0,237
C10          -0,11316    0,06097  -1,86  0,065


S = 0,0349962   R-Sq = 1,3%   R-Sq(adj) = 0,9%


Analysis of Variance

Source           DF        SS        MS     F      P
Regression        1  0,004218  0,004218  3,44  0,065
Residual Error  264  0,323330  0,001225
Total           265  0,327548


Durbin-Watson statistic = 1,99783
```

## A3

## Regression with annual data

Utilization of monthly data proved difficult due to seasonal variation. To eliminate the seasonal effect, yearly data is used instead, and the variance adjusted accordingly.



It must be taken into consideration that the number of observations are limited, necessitating a slight moderation of our requirements. The normal distribution appears somewhat skewed and it is evident that this is partly caused by one single extreme value. The normal probability plot has a minor degree of skewness, despite it being fairly linear. The versus plot appears to comply with the requirements for homoscedasticity.

## Regression Analysis: C3 versus C4

```
The regression equation is
C3 = 0,0290 - 0,108 C4


21 cases used, 2 cases contain missing values


Predictor      Coef   SE Coef      T      P
Constant    0,02902   0,01875   1,55  0,138
C4          -0,1082    0,2267  -0,48  0,639


S = 0,0797511   R-Sq = 1,2%   R-Sq(adj) = 0,0%


Analysis of Variance

Source          DF        SS        MS     F      P
Regression       1  0,001448  0,001448  0,23  0,639
Residual Error  19  0,120845  0,006360
Total           20  0,122293


R denotes an observation with a large standardized residual.
```

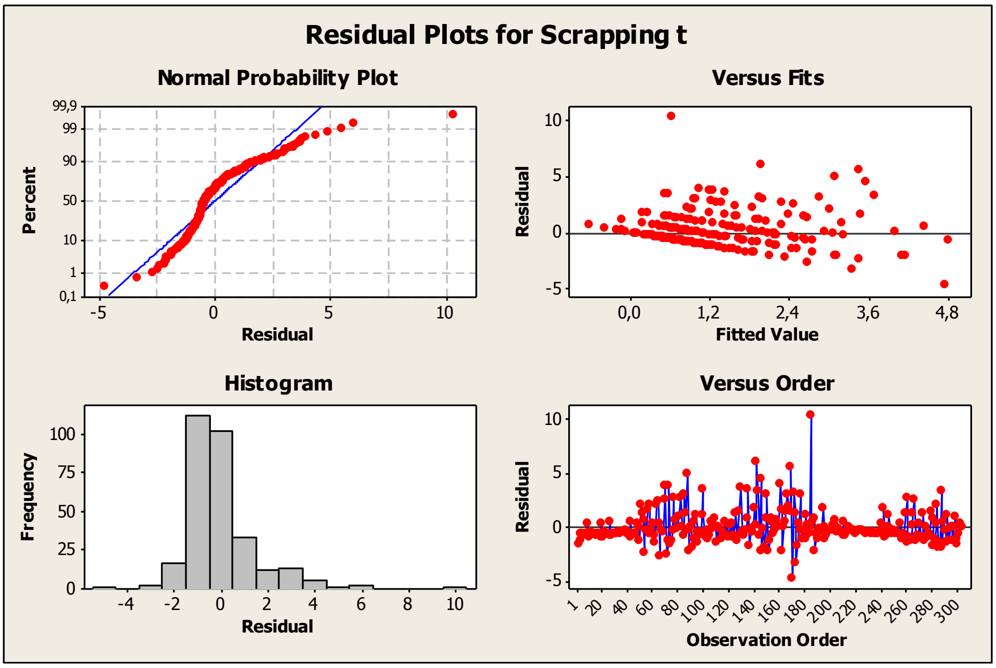
```
X denotes an observation whose X value gives it large leverage.


Durbin-Watson statistic = 2,05465

      Calculation of variance of epsilon
            df                 19
            ss                 0.120845
annual      var epsilon        0.006360263
            st.d. epsilon      0.079751258
monthly     var epsilon        0.000530022
            st.d. epsilon      0.023022205
```

## A4

## Regression Analysis: Scrapping t versus Scrapping t-; Scrapping t-; ...

```
The regression equation is
Scrapping t = 0,981 + 0,326 Scrapping t-1 + 0,248 Scrapping t-2
              - 0,0639 Deliveries t - 0,00447 WS t-1


302 cases used, 2 cases contain missing values


Predictor           Coef   SE Coef      T      P
Constant          0,9815    0,2368   4,15  0,000
Scrapping t-1    0,32577   0,05644   5,77  0,000
Scrapping t-2    0,24831   0,05604   4,43  0,000
Deliveries t    -0,06389   0,04508  -1,42  0,158
WS t-1         -0,004466  0,002301  -1,94  0,053


S = 1,50795   R-Sq = 27,9%   R-Sq(adj) = 27,0%


Analysis of Variance

Source           DF       SS      MS      F      P
Regression        4  261,694  65,423  28,77  0,000
Residual Error  297  675,353   2,274
Total           301  937,046


Source         DF   Seq SS
Scrapping t-1   1  198,908
Scrapping t-2   1   48,877
Deliveries t    1    5,345
WS t-1          1    8,564
```

## Regression - scrapping without deliveries:



When looking at the residual plots it is evident that the histogram is skewed, which is not surprising and agrees with the presumption that scrapping follows a Poisson distribution; the same pattern is depicted in the normal probability plot. The versus fits is evenly distributed, while the versus order does not indicate homoscedasticity, an observation which is not surprising as scrapping today was set to be determined by scrapping 1 and 2 months earlier.

## A5

### Regression Analysis: Scrapping t versus Scrapping t-; Scrapping t-; ...

```
The regression equation is
Scrapping t = 0,845 + 0,322 Scrapping t-1 + 0,243 Scrapping t-2 - 0,00466 WS t-1


302 cases used, 2 cases contain missing values


Predictor             Coef    SE Coef      T      P
Constant            0,8450     0,2167   3,90  0,000
Scrapping t-1      0,32180    0,05647   5,70  0,000
Scrapping t-2      0,24296    0,05601   4,34  0,000
WS t-1           -0,004656   0,002301  -2,02  0,044


S = 1,51050   R-Sq = 27,4%   R-Sq(adj) = 26,7%


Analysis of Variance

Source           DF       SS      MS      F      P
Regression        3  257,127  85,709  37,57  0,000
```

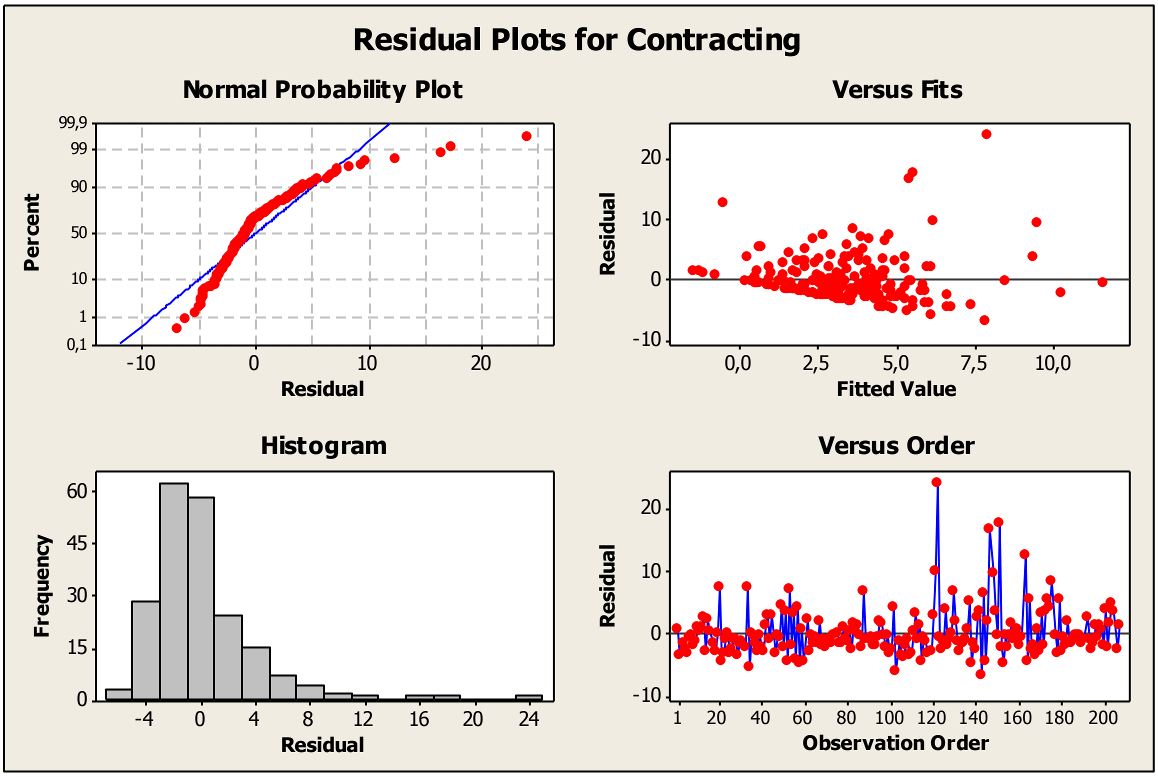
```
Residual Error  298  679,919   2,282
Total           301  937,046


Source         DF   Seq SS
Scrapping t-1   1  198,908
Scrapping t-2   1   48,877
WS t-1          1    9,342
```

## A6

## Regresion deliveries:

The results of the regression analysis follows:

Deliveries



## Regression Analysis: Contracting versus ln(WS); delta O

```
The regression equation is
Contracting = - 5,12 + 1,97 ln(WS) + 0,282 delta O


Predictor      Coef  SE Coef      T      P
Constant     -5,118    2,656  -1,93  0,055
ln(WS)       1,9741   0,6196   3,19  0,002
delta O     0,28198  0,05587   5,05  0,000


S = 3,88610   R-Sq = 21,1%   R-Sq(adj) = 20,3%
```

```
Analysis of Variance

Source           DF       SS      MS      F      P
Regression        2   821,60  410,80  27,20  0,000
Residual Error  204  3080,76   15,10
Total           206  3902,36


Source    DF  Seq SS
ln(WS)     1  436,90
delta O    1  384,70
```

## B. Why skewness is positive.

If we assume utility is given by a utility function U(x) where the moments have alternating signs, where the odd number moments have a positive sign, while the even number moments have a negative signs.

$$U^n(x) > 0, if\ n\ is\ odd$$

$$U^n(x) < 0, if\ n\ is\ even$$

We can further try to estimate the utility function using a Taylor polynomial of 4th order around b.

$$U(x) \approx U(b) + U'(b)(x-b) + \frac{U''(b)}{2!}(x-b)^2 + \frac{U'''(b)}{3!}(x-b)^3$$

If we let b=E[x] and then take the expectation of both sides we get:

$$E[U(x)] \approx U(E[x]) + U'(E[x])E[(x-E[x])] + \frac{U''(E[x])}{2!}E[(x-E[x])^2] + \frac{U'''(E[x])}{3!}E[(x-E[x])^3]$$

$$E[U(x)] \approx E[x] + \frac{U''(E[x])}{2!}Var(x) + \frac{U'''(E[x])}{3!}Skew(x)$$

By inspection we notice that as U’’(x)<0 an increase in Var(x) will decrease expected utility, while an increase in Skew(x) will increase utility because U’’’(x)>0

# C. Estimations of supply curve using macros

We solved this issue by constructing a table over market supply for a given range for both oil price and spot rate, subsequently constructing the supply curve at a given oil price by using a weighted average of the supply curves calculated for the range of oil price. This method is both accurate as well as vastly more efficient regarding the number of calculations needed (after the initial table is constructed). To better understand the process we have constructed a simplified example:

| **Spot Rate** | | **10** | **15** | **20** |
|---|---|---|---|---|
| **Bunker** | **100** | 100 | 120 | 140 |
| **Price** | **200** | 90 | 100 | 110 |

| | | | | |
|---|---|---|---|---|
| | Estimated supply curve | | | |
| **lower weight** | (200-140)/(200-100) | | =0.6 | |
| **upper weight** | 1-lower weight | | =0.4 | |
| **Calculation:** | | | | |
| **Real oil Price** | 140 | 0.6*100+0.4*90 | 120*0.6+100*0.4 | 140*0.6+110*0.4 |

**We then get the following supply curve for a bunker price of 140**

| **Spot Rate** | **10** | **15** | **20** |
|---|---|---|---|
| **Supply** | 96 | 112 | 128 |

One disadvantage of this method is that we cannot use oil prices greater than the maximum value in the table. We will therefore have to set a maximum value for oil price. As a consequence of the simplifications in the programming code when the changes in the oil price as well as the spot rate in the table is equal it will also be smart to set a lower limit for the oil price because the effective supply curve will have too few data points. In order to set the appropriate maximum and minimum values, we use the estimated standard deviation and simulate 10000 different price paths using a geometric Brownian motion. We then count the number of paths that have a price higher than X, then X is adjusted to satisfy that only 5% of the paths have a higher price than X *at any time t* (as opposed to at only the last observed price). We use the same method to estimate the lower limit of the oil price. Because of the positive skewness obtained when using a GBM, and the thick tail that appears on the, setting the cut-off at a 5% significance level will lead to a reduced expected value. As we prefer the expected value to remain neutral (equal to the start value), growth must be added to the

GBM. A similar approach is used to solve this issue, estimating 10000 price paths within the constraints we derived previously, we then change the growth level in order to match the expected price at time T (the last observation), to the start price.

Results of simulation:

| | |
|---|---|
| Upper bound | 3783 |
| Lower bound | 28.345 |
| growth rate | 0.147 % |

## D. Note on programming

The simulation has been done in MS excel and VBA, the code constructed for the simulation is to extensive to write in the appendix, but can on request be forwarded if contacted by e-mail: olav87(at)gmail.com)

## E. Calculation of TCE used as reference.

We have used the TD3 of the Baltic exchange index as the foundation for our TCE calculations in the simulation. We have estimated the fuel consumption curve of the ship in order to calculate the fuel cost according to which speed regime the ship follows.

| Estimated/Assumed parameters | |
|---|---|
| $\beta$ | 2.6 |
| K | 0.076477412 |
| $B_0$ | 0.00086538 |
| G(W) | 119.16 |
| Dwt | 260 000 |
| Min speed | 8.5 |
| Max speed | 16 |

Other variables are set in accordance with the assumptions in the model,(see chapter 6)

The calculation of Baltic Exchange for the TD3 (http://www.balticexchange.com/media/pdf/tce/vlcctcecalculationprocess.pdf)

**TD3:** 265000 mt Ras Tanura/Chiba laydays canceling 30/40 days in advance max age 15 years.

The calculation includes a weather margin of 5% and bunkers based on Singapore 380 CST. 2.5% total commission

**TD3:** The net Timecharter Equivalent is calculated as the income less the total expenses and that result is then divided by the number of days of the voyage's total duration of employment.

**Expenses**

- Initially laden and ballast days are calculated. The **laden days** are derived by adding a weather factor (5%) to the laden miles (6,655) and dividing the result by the daily speed (14.5 knots per hour multiplied by 24 hours). The **ballast days** are calculated in the same manner, with the ballast miles (6,650) being used instead of the laden ones.

- The next step is establishing the **bunker costs**.

□□For the trip's IFO (Intermediate Fuel Oil) consumption while loading, the loading days (2 days) are multiplied by the daily IFO loading consumption (20 mt per day). For the trip's IFO laden consumption, the laden days (20.08) are multiplied by the daily IFO laden consumption (100 mt per day). For the trip's IFO (Intermediate Fuel Oil) ballast consumption, the ballast days (20.06) are multiplied by the daily IFO ballast consumption (80 mt per day). For the trip's IFO consumption while discharging, the discharging days (2 days) are multiplied by the daily IFO discharging consumption (85 mt per day). Finally for the trip's IFO consumption while waiting, the waiting days (1 day) are multiplied by the daily IFO waiting consumption (10 mt per day). Adding the results from the calculations described above generates the trip's total IFO consumption. This figure is then multiplied by the IFO market price per mt (based on Singapore 380 CST and supplied by Bunkerworld), which produces the **total IFO cost** for the trip.

- The trip's **Total Expenses** are calculated as the sum of the total IFO cost, the load port charges (Ras Tanura) and the discharge port charges (Chiba – This figure is divided by the USD/Yen rate as this port's charges are provided in Yen). Foreign exchange rates (including SDRs) are sourced from XE.com. All port cost related information is provided by Cory Brothers Shipping.