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The Product Tanker Investment Decision

The Impact of Oil Price Volatility and Ship Design Issues

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Abstract

The purpose of this thesis is to assess the key factors determining the profitability of an investment in a product tanker newbuilding. The analysis evaluates whether ship design issues have become more important for the product tanker investment decision through the impact of new environmental regulations, and whether recent oil price volatilities have changed such investments in fundamental ways.

The case of a 38 500 DWT product tanker was applied in order to meet the research objective. First, an investment model was constructed to measure the impact of different investment factors; freight rates, newbuilding prices, bunker fuel prices, and interest rates. The volatility of the crude oil price was then assessed, and a one-year ahead forecast was constructed through econometric modelling. Thirdly, the profitability of ECA abatement strategies and their sensitivity to different oil price scenarios was evaluated. Lastly, the impact of ECO ship design, the EEDI, and fuel-efficient design on the investment were assessed.

The thesis concludes that key factors that drive the profitability of a product tanker investment have not changed. Freight rates have the largest impact of profitability, and the effects of newbuilding prices can be crucial through the dynamics of timing of investments. However, more stringent regulations in the shipping industry have made ship design issues more important for the investment decision. The optimal choice of abatement technology in complying with ECA regulations is highly sensitive to oil price volatilities. The results of the crude oil forecast exhibited increased oil price volatility, which therefore also implies more vigorous effects on relative design profitability.

Findings also show that the optimal choice of abatement strategy is highly sensitive to the amount of time spent within an ECA. These dynamics are argued to be transferable to the enforcement of a global sulphur cap. The decision by the IMO to implement targets in 2020 instead of 2025 would imply a larger fraction of the vessel's commercial life sailing under a 0.5 per cent sulphur limit. Consequently, the uncertainty of when the global sulphur cap will be enforced implies a high degree of uncertainty for the profitability of the ship owner's investment.

This implies that ship owners are faced with larger uncertainties in 2015 and going forward than prior to 2006.

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1. Introduction

The *Valuation Principle* states that an investment decision increases the market value of the firm when the value of its benefits exceeds the values of its associated costs. The comparison of costs and benefits is however complicated; they might occur at different points in time, occur in different currencies, or be associated with different risks and uncertainties (Berk & DeMarzo 2014).

Cost and demand uncertainties are widely discussed in investment literature (e.g. Pindyck 1988; Fuss & Vermeulen 2004; Bond & Lombardi 2004; Lee 2005; Bloom, Bond & Van Reenen 2007). According to Pindyck (1988) most major investment costs are to some extent irreversible, as the firm often has limited ability to disinvest. The irreversibility often stems from investments being industry- or firm-specific, and affects expenditure decisions, capacity choice, and the firm's value. When an investment is irreversible and future cash flows are uncertain, the investment expenditure involves the exclusion of the opportunity to invest more productively in the future. This constitutes a substantial dilemma within investment decision-making; the investor forfeits the opportunity to wait for new information that can affect the attractiveness or timing of the investment, as it cannot be disinvested if unfavorable market conditions occur.

Stopford (2009) distinguishes investments in the shipping industry from other investments, due to their combination of volatile earnings and low returns. This is referred to as the *shipping return paradox*. The return on shipping investment (ROSI) model is characterized by its dual life nature, which offers both opportunities for ship owners who want to take on additional risk to earn extraordinary profits, and for ship owners who value security over potentially high returns.

A distinctive trait of the shipping industry is that it is characterized by market cycles, which Stopford (2009, p. 101-102) describes as "at the heart of shipping risk". The shipping cycles can either be long, short or seasonal, and are typically characterized by booms and busts. Grammenos (2013) describes the cycles as steering inflows and outflows of cash in the shipping market, and as the main force behind chartering and shipping investment. As shipping cycles are not predictable or regular, they can be linked to the uncertainty of cash flows that pose an evident issue for investments in general.

In more recent years, the shipping industry has been subject to several changes that may potentially influence the strategy of ship investments. According to the Third IMO GHG Study 2014, the global shipping industry emitted 796 million tonnes of CO2 in 2012, which amounts to 2.2 per cent of the total global CO2 emissions for the respective year. The European Commission has previously expressed concerns regarding the emission levels of the industry. In a scenario where no reduction measures are taken, emission levels were expected to double within 2050 (European Commission 2015). Accordingly, the environmental awareness in the industry is increasing and regulations are becoming more stringent. The International Maritime Organization (IMO) has therefore taken several initiatives to reduce emissions in the shipping sector (International Maritime Organization 2014).

The rules and regulations developed by the IMO focus predominantly on safety and security, and the prevention of pollution from ships (IMO n.d.*c*). Although their regulations are at large of a more general nature, their enforcement has the ability to influence ship design in fundamental ways (Wijnolst & Wergeland 2009).

The Energy Efficiency Design Index (EEDI) and Emission Control Areas (ECAs) are among the initiatives imposed and revised by the IMO. The EEDI sets a required level of design efficiency for new builds ordered after 1 January 2013 or built after 1 January 2015, and the index level is tightened by 10 per cent in both 2020 and 2025. From 2025 and onward, the EEDI requires applicable new builds to comply with a 30 per cent reduction in CO2-levels, compared with the average efficiency of vessels built between 2000 and 2010 (IMO n.d.*b*). Ships travelling within the ECAs are legally restricted to comply with a maximum sulphur level of 0.1 per cent since 1 January 2015, and the next tier of NOx regulations[1] further tightens emission levels from 1 January 2016 (IMO n.d.*f*).

Moreover, the shipping industry has experienced a rapid development in ship design. Over the past decade, a relatively high oil price has contributed to a growing interest in fuel efficiency in shipping (Faber & Hoen 2015). In 2011, reports on ECO ship design began to emerge and the concept has mainly been marketed for its fuel efficiency (Poten & Partners 2014; Baltic and International Maritime Council 2013b). Since then, ECO ship design has replaced previous designs as the new

[1] Tier III requires a maximum of 3.4 g/kWh for engines with a rated speed less than 130, and 2.0 for engines with a rated speed less or equal to 2000 (IMO n.d.*e*)

standard of all new buildings ordered today. Considering the development in design and the consequences of the imposed environmental regulations treading into force, one might argue that role of design efficiency has become more prevalent in the shipping industry.

Stopford (2009) highlights bunker prices as one of the most critical elements in the cost of running a ship, and Alizadeh and Nomikos (2009) define bunker price risk as the largest source of risk in shipping operations. The volatility of crude oil has been increasing at a higher pace than other commodities over the past decade (Ebrahim et al. 2014), an issue made particularly evident through the recent collapse of the oil price (Bunkerworld 2015a). Considering the evident role of bunker prices in shipping operations, the recent oil price volatilities therefore stand out as an evident uncertainty in the ship owner's investment decision.

A central issue in the shipping industry is therefore whether shipping companies are facing different uncertainties than previously or whether the pressures shipping companies are facing are of such nature that the ship investment decision and the dilemmas it involves has changed fundamentally since 2006.

1.1 Purpose and scope

The purpose of this thesis is to assess the key factors determining the profitability of an investment in a product tanker newbuilding. The analysis will evaluate whether ship design issues have become more important for the profitability of such an investment, hereunder considering the potential impact of new environmental regulations, and whether the oil price volatility over the past decade has altered the investment decision in any way.

Specifically, the thesis aims to answer the following research question:

What are the key factors determining the profitability of an investment in a product tanker newbuilding?

- *Have ship design issues become more important to the profitability of such investments? Why or why not?*
- *Has the recent oil price volatilities changed product tanker newbuilding investment decisions in fundamental ways? Why or why not?*

1.2 Delimitations

The research question is restricted by a number of delimitations, in order to concentrate the analysis and thus increase the quality of the areas assessed.

1.2.1 Profit maximizing behaviour

This study primarily focuses on the monetary impact of the factors and solutions considered. Conclusions were drawn on the basis of the economic theory of rational choice, which assumes that decisions are made with the purpose of maximizing utility (Hernstein 1990). Conclusions regarding investment decisions were therefore based on monetary values and numerical evaluations, as well as legislative restrictions and regulations. The behavioural psychology or irrational behaviour of a ship owner has not been considered.

The ship design process is an evident part of the investment in a product tanker newbuilding. When purchasing a newbuilding, the ship owner has a deciding role in the design process. The ship owner's incentive to maximize profits over the commercial life of the vessel was taken into account as the bottom line of the monetary calculations. The conflicting interests of the ship owner and the shipyard building the vessel, which has the short-term incentive to maximize profits of the construction (Wijnolst & Wergeland 2009), were however not considered.

Although it is acknowledged that the operation of a vessel affects the cash flow of the vessel, these factors were considered to be out of scope for the purpose of this study.

1.2.2 Second hand market and retrofitting of vessels

According to Stopford (2009), the shipping company's decision of purchase and sale of new ships depends on future freight rates, newbuilding prices and the price of second-hand vessels. However, an analysis of the second-hand market is considered to be outside the scope of the research objective, and this market will only be considered in discussion related to the analysis of the investment in a newbuilding product tanker.

For the purpose of this dissertation, the debate on whether to purchase a new vessel or to retrofit a vessel to comply with regulations in ECAs will not be considered. The costs of abatement strategies for complying with ECA regulations were evaluated for newbuildings, rather than for retrofitting older vessels. The purpose of this evaluation was to assess the cost differences between the different options, and to estimate whether these costs were significant in relative amounts with regard to other key factors such as timing of investment and financing terms. It is recognised that an investment in a newbuilding is not the only option for complying with these regulations, and that the trimming of a certain design or operational aspects of an existing vessel can potentially create huge differences in fuel consumption. However, as retrofitting is beyond the scope of this thesis, this option will not be included as an investment strategy.

1.2.3 Time chartering market versus the spot market

Agnolucci et al. (2014) presented the first study on the allocation of fuel saving premiums between ship owners and charterers, in the time charter market. In their study on the Panamax segment, they found that ship owners on average only retained 40 per cent of the savings from bunker costs from fuel-efficient vessels. In an interview with Sand (Appendix B.2), he explained that although a ship owner in theory should be able to claim the entire fuel saving premium in higher time charter rates, this is seldom the case in practice. The ship owner's ability to reap the benefits of a decrease in the bunker cost in the time charter market depends on the negotiating power between the owner and the charterer. Sand (Appendix B.2) therefore estimates that the ship owner can receive anything from zero to 75 per cent of the bunker cost saving in higher charter rates. Due to the lack of reliable data on this issue, this dissertation will assume in all calculations that the owner operates in the spot market, and thus any potential saving in bunker costs are allocated to the ship owner in its entirety.

The assumption of the ship owner operating in the spot market impacts the results of the investment analysis. If the calculations were to rather assume a ship owner operating in the time charter market, the charterer would bear the fuel cost and consequently any risk and premium related to bunker cost. Hence, oil price volatilities would have less impact on the ship owner. Moreover, the impact of different levels of negotiating power between the owner and charterer would have had to been included as increased levels of freight rates from a HFO price decrease. Considering the findings of Agnolucci et al. (2014), this suggests that decreasing fuel prices would have generated a lower level of investment profitability change than those observed in the calculations based on a spot market assumption.

1.2.4 Product tanker investment

It is acknowledged that several of the issues addressed in this dissertation apply to most tanker, dry-bulk, and container vessels. However, in order to limit the scope of the study, the case of a product tanker has been applied when assessing the question of fundamental changes in the ship owner's investment decision and profitability. The transferability and similarity to other vessel types and segments will not be assessed and are considered beyond the scope of this thesis.

Due to data availability of factors such as fuel consumption, engine power, and the cost of abatement strategies for complying with ECAs, a 38 500 DWT product tanker was selected for the analysis conducted in order to meet the research objective.

1.2.5 The term ECO ship

The term "ECO ship" or "ECO ship design" may be considered to be vague, as it can comprise a number of different combinations of ship design features. Koutroukis et al. (2013) describe ECO ship design as more competitive than conventional tonnage, with lower operational costs. In 2013, the Baltic and International Maritime Council (BIMCO) described ECO ship design as being "marketed for its fuel economy in an era where fuel prices have become almost unsustainable", and separated the design from the "conventional ship" on the basis of it being more fuel efficient, faster and reducing emissions. The ECO ship is said to incorporate design features that are "state of the art". The design includes sophisticated engineering solutions and features of a more efficient underwater form to potentially reduce the speed loss in head seas and to make the propeller more efficient through forcing the flow of water to the rear of the vessel. The engine of an ECO vessel often uses sophisticated fuel injection systems, as well as methods for efficient use of exhaust heat.

While there is still no universally accepted definition of the term, Eason (2015) argues that a consensus of what it comprises has been reached, that is; "a ship built to a set of new standards". In interviews with Skovbakke Juhl (Appendix A.2) and Sand (Appendix B.2), they both agree that all ships ordered today are ECO ship design, and thus represent the new standard of ship design. For the purpose of this study, it was therefore assumed that all product tanker newbuildings ordered today are ECO ships. The evolution of the concept of ECO ship design has been included in the discussion regarding ship design issues and their importance for a product tanker investment decision.

1.2.6 Time period for potential fundamental changes

The purpose of the analysis in this dissertation was largely based on potential impacts from changes in ship design and oil price volatility. The definition of a time period from which fundamental changes were to be assessed was therefore based on what we consider to be pivotal regulatory events within the shipping industry, as well as the basis for recent changes in oil price volatilities.

In 2006, the Baltic Sea became the first fully implemented SOx ECA (IMO n.d.*f*), and therefore represents an important point in time for regulatory changes impacting the choice of HFO as fuel. Following the first ECA, the North Sea, North American ECA, and United States Carribean Sea came into effect as ECAs in 2007, 2012 and 2014, respectively. In order to test for differences in oil price volatilities between time periods, the time series for the oil price analysis was divided into three different time series. The last series runs from 2006 to 2015, and consequently represents the time frame considered for the recent changes in oil price that act as base for our analysis. The starting point of this series was based on convenience of the time frame, and the fact that it represents a potentially important year for changes in fuel price volatility through the choice of different abatement strategies for complying with ECA regulations.

In 2011, the compulsory standards of the EEDI were introduced (IMO n.d.*a*) and the first reports on ECO ships appeared (Poten & Partners 2014). During the following years, the EEDI was enforced and ECO ship design became the new standard of newbuilt ships, and this period is therefore assessed as focal for recent changes in ship design issues in regards to newbuilding.

In order to fully incorporate these changes for the shipping industry, this dissertation has considered the impact of changes since 2006 and going forward. The purpose is to assess whether the issues highlighted constitute a fundamental change in the product tanker investment decision from recent maritime economics literature and the investment decision prior to 2006.

2. Literature review

A deductive literature review has been conducted in order to advance our research question and introduce the study in a structured manner. The following section presents relevant literature that emphasizes the significance of our study and its placement in the on-going literary discussion in shipping (Creswell 2014).

2.1 The shipping investment decision

Stopford is widely recognized as one of the main contributors to maritime economics literature, for which he received the Onassis prize in 2015 (Hine 2015). Grammenos (2013) refers to Stopford's Maritime Economics as "a veritable compendium of the economic history of the shipping industry and research pertaining to it", and Zhang (2014) refers to it as a "masterpiece". Subsequently, the contribution of Stopford is especially evident in the following presentation of literature regarding the shipping investment decision.

2.1.1 The shipping market model

The shipping market model presented by Stopford (2009) states three main components that control shipping investments: *demand*, *supply* and *the freight market*. The supply and the demand are determined separately in the market, and are in turn linked by freight rates. The model further highlights ten influencing factors that are of particular importance for the shipping market. As illustrated in Table 2.1, five factors affect the demand of sea transport, and five affect the supply.

	Demand		**Supply**
1.	The world economy	1.	World fleet
2.	Seaborne commodity trades	2.	Fleet productivity
3.	Average haul	3.	Shipbuilding production
4.	Random shocks	4.	Scrapping and losses
5.	Transport costs	5.	Freight revenue

Table 2.1 Ten key variables in the shipping market model (Stopford 2009).

The mechanics of the market model are illustrated by an explanation of how the world economy determines the broad volume of traded goods at sea through business cycles and regional growth trades. In turn, both developments in specific commodity trades and the average haul over which the cargo is transported may modify growth trends.

On the supply side, the world fleet provides a fixed stock of transport capacity in the short term. The fleet may be increased by building new ships, or reduced by scrapping vessels. However, only part of the fleet may be trading when demand is low. The amount of transport that the existing fleet can provide is influenced by its logistical efficiency, also known as fleet productivity. Moreover, the impact of bank policies and regulators impact the supply side of the shipping market (Stopford 2009).

In response to changes in the balance of supply and demand, freight rates are constantly adjusted. It is the changes in the freight module that create the flow of money, which in turn drives the shipping market. A balance between the supply and demand is rare within shipping, due to the dynamics of the two modules. Demand changes quickly in an unpredictable manner, and is hence highly volatile. In contrast, supply changes slowly. The dynamics of the supply "chasing" demand creates an almost constant imbalance between the modules. Even with a tightly balanced market, the freight mechanism has a tendency to amplify even the slightest imbalances. Stopford (2009) also states that shipping consists of four closely related markets; the freight market, the sale and purchase market, the newbuilding market and the demolition market. As these markets interact with each other, the response of freight rates to changes in the balance of supply and demand, ripples through the other markets. As such, the decision to invest in a new vessel does not only involve the expectation of future freight rates, but also the expectation of future prices of newbuildings, second-hand vessels and scrap value (Stopford 2009; Karaktiksos & Varnavides 2014).

The shipping market model provides a theoretical explanation to how freight market cycles are generated, and Stopford (2009) emphasises that it only includes the mechanisms that "determine freight rates in a consistent way". With the shipping market model as a basis, the ship owner can then aim at taking advantage of the peaks and troughs of the freight market cycles to best manage his investments.

The freight rate generation mechanism presented by Talley (2012) is consistent with the dynamics of Stopford's shipping market model. External factors influence freight levels by changing the demand for transport services. The feedback from the new freight rate levels will then influence the shipping market state, and these changes will in turn affect freight rate levels again. Thus, freight rates are constantly adjusted in response to changes in the supply and demand balance, which is coherent with the dynamics of supply "chasing" demand suggested by Stopford (2009).

Lorange (2009) also argues that the ship owner's understanding of the shipping markets, and his ability to forecast their direction, is a key factor for return on investment. As prices in both the newbuilding and second-hand market will respond to fluctuations in freight rates, Lorange (2009) argues that the understanding of such movements will always be important for the ship owner and influence long-term rates of return.

2.1.2 "The three R's of profit"

According to Stopford (2009), if a shipping company is successful at navigating through the volatile turns of the shipping industry in the long run, their performance will be reflected through the "Three R's of Profit"; remuneration for the use of capital, return for good management, and risk premium. If one considers the perspective of the individual shipping company, all ship owners will face the challenge of navigating through the booms, recessions and depressions of the shipping market. However, the normal profit[2] earned by a shipping company will in the long run even out to an average level that reflects their performance in "Three R's of profit".

Stopford (2009) clearly states that capital dominates the shipping business. Even though the reduction of costs and increasing efficiency are important aspects of the business, the returns for good management are argued to be relatively small. Thus, despite the fact that the primary objective of the business is to provide transport, *capital* management has the dominant role. Through careful management, a shipping company could save a few hundred thousand USD annually. However, the value of a ship could change by this amount in a period of a few days.

The potentially high returns from capital management are explained through playing the cycle correctly in the volatile shipping industry. This is where the risk aspect of profit is central. Through differences in risk, Stopford (2009) therefore emphasizes the differences between ship management and asset management. The diverging focuses are likely to generate very different financial returns. A ship owner who focuses solely on the actual business in the form of transport will expect low returns due to a less risky business. In contrast, a ship owner who focuses on asset management can

[2] The normal profit is expressed by Stopford (2009, p.325) as "the return needed to keep investors in business in the long term".

potentially offer very large returns to those prepared to take the risk. A shipping company's risk and consequent financial return is therefore determined by the business strategy of the ship owner, not the prevailing market cycles. These issues are of major relevance in shipping due to the high dominance and liquidity of capital in the industry.

However, many individual firms overestimate their ability to respond to common shocks, which leads to excessive industry investment during booms. When freight rates increase and improve the financial performance of a shipping company, ship owners tend to accept higher newbuilding prices for their investments. As new ships will often not be available for two to three years, the process often goes into reverse as the new ships arrive on the market. Ship owners will consequently start paying for their newbuilds as freight rates start to fall. Alternatively, a ship owner can attempt to time his investment such that the vessel's date of delivery matches a period of market improvement. This again illustrates the effect capital can have on financial return if a ship owner is prepared to take the risk of going against the movements of the freight market cycles (Stopford 2009).

2.1.3 Financial performance for the individual shipping company

The financial performance of a vessel is achieved through the revenue from operating the ship, the cost of running the ship, and the method of financing the business (Stopford 2009).

Stopford (2009) attributes ship revenue as depending on cargo capacity, productivity and freight rates. Cargo capacity can be utilized through flexible ship design, and productivity can be enhanced through careful management of operations in order to increase the proportion of revenue earning days. As it is the changes in freight rates that create the flow of money that drives the shipping market, freight rates have the largest influence on a ship's value. Talley (2012) also highlights the major impact of freight rates on the ship owner's profit or loss margins. In identifying sources of price risk, he points to freight rates as the fundamental origin of risk in the shipping company, and as the most valuable variable in describing the state of the shipping market. As such, the understanding of cyclical patterns in freight rates is a critical factor for the ship owner's return on investment (Lorange 2005; 2009).

Karakitsos and Varnavides (2014) emphasize that the timing of the purchase and sale of vessels is critical to the expectation of future earnings. The uncertainty of the distribution of these earnings can potentially have a major effect on the success of a ship owner's business. For instance, by misjudging the high end of the earnings distribution, a ship owner could sell his vessel too early and thus forfeit the opportunity to reap the full potential benefit of his investment. Due to the high correlation between freight levels and vessel prices, this again highlights the central role of the freight market in the ship owner's investment profitability.

The uncertainty related to distribution of earnings means that careful management of cost levels can be the key to survive periods of low earnings (Karakitsos & Varnavides 2014). Stopford (2009) highlights that the cost of running a ship depends on external changes such as oil price variability, but also on the owner's choice of method to manage and finance the business. Running costs can also be an important factor in the decision between whether to scrap an old vessel or to keep the ship idle (Lorange 2005).

According to Stopford (2009), voyage costs and capital costs account for 40 and 42 per cent of total costs for a ship, respectively. Consequently, both cost classifications have a major influence on the financial performance of a vessel. In turn, bunker prices are identified as having the largest impact on voyage costs and are highlighted as one of the most critical elements within the costs of running a ship (Lorange 2005; Stopford 2009; Talley 2012).

Capital is the cash flow item over which the ship owner has the largest initial control over. In contrast, operating and voyage costs can only be adjusted marginally over time. However, the cash flow effect of capital should be considered in relation to running costs, which also influence the cost of a ship. For instance, modern vessels with a larger initial capital expense will have more reliable and fuel-efficient machinery and less maintenance requirements, and thus cost less to run over the life of the vessel (Stopford 2009).

Lorange (2005) defines the decision to focus primarily on either operations or asset play as an important parameter for an effective shipping strategy. The understanding of shipping markets and prediction of turning points is the key to successful timing of the purchase and sale of vessels. Ultimately, the ship owner seeks to sell when the market is high and purchase when the market is low. The timing of a newbuilding contract is therefore critical, as it influences both the achievement of a favourable purchase price and beneficial financing terms. This is important, as a low cost base acts as one of the main principles in a good shipping strategy (Lorange 2009).

With regard to asset price risk, Talley (2012) argues that the effect of a change in vessel value is twofold. It affects the profitability of a shipping company, as well as the credit ratings of the company. However, Talley (2012) does not mention the difference between ship- and asset management strongly emphasized by both Stopford (2009) and Lorange (2005).

Lastly, Stopford (2009) emphasizes that the method of financing is crucial. If the investment in a newbuild is financed by debt, the shipping company will be tied to a schedule of capital repayments, regardless of the point in the market cycle. Shipping companies can consequently have a large influence on their future cash flow, by carefully considering the choice of finance. As such, Karakitsos and Varnavides (2014) suggest that debt service costs may in many cases be more important than operating costs.

Talley (2012) highlights the effects from interest rate risk and credit risk on profitability. Interest rates have the potential of amplifying the financial problems of shipping companies, and credit risk is argued to be very important in the cyclical nature of the shipping industry. The total leverages can lead to extreme alternations in high profits and major losses for ship owners, and consequently affect their risk of default. Nonetheless, it would be incorrect to say that ship finance drives the market. Careful management of finance does however have the potential to “ease the difficulties" of operating a highly volatile industry.

2.1.4 Key factors determining the profitability of a product tanker investment

In summary, it is the imbalance between supply and demand that creates constant fluctuation in freight rates. Consequently, the ship owner has to navigate through the peaks and troughs of the freight market cycles in order to manage his investment. Overall, the maritime economics literature suggests that the financial performance of the shipping company is driven by three fundamental variables; freight rates, the cost of running a ship, and financing (Lorange 2005; 2009; Stopford 2009; Talley 2012; Karakitsos & Varnavides 2014).

Freight rates have the largest influence on a ship’s value, as their changes are the source of shipping market cycles and highly correlated with asset price risk. However, the cost of running a ship also has a major impact on the cash flow of the shipping company. Among the costs facing a ship owner, voyage costs and capital costs are both highlighted as major influential factors and there is particular emphasis on the effect of bunker fuel prices. Bunker price volatility is consequently an important consideration in profitability of shipping companies.

Lastly, ship owners can have a large influence on their future cash flow through the method of financing their investment. Factors of credit risk, degree of leverage and fluctuations in interest rates are consequently crucial for an investment decision, even though financing does not drive the shipping market.

2.2 Oil price volatility

Alizadeh and Nomikos (2009) describe bunker fuel prices as the greatest source of risk in the costs of shipping operations. The cost of bunkers depends, among other factors, on the size of the engine of the vessel and the vessel's efficiency.

In assessing the impact of bunker fuel and oil price volatility, shipping literature to a great extent focuses on the effect on freight rates and stock prices. Dikos (2004) analyses the destabilizing role of newbuilding prices, in which he emphasizes that an increase in demand for oil increases time-charter rates, which in turn increases the investments in new vessels.

Kavussanos (2003) shows how risks in the freight and time-charter market are not constant over time. The analysis shows high levels of volatility following shocks and instabilities in the market, illustrated by the oil crisis in 1980-1981 and the sharp decline in oil prices in 1986, among others. In comparing the effects of different macroeconomic risks on stock return, El-Masry et al. (2010) show that shipping firms are more impacted by exchange rate exposure than by interest rate and oil price exposure. They suggest that this is due to the use of hedging strategies to reduce the effects of such risks and that effects from increases in oil prices have generally been beneficial for stock price return on their sample from 1997-2005.

Shi et al. (2013) confirm the results of El-Masry et al. (2010) to some extent, as they suggest that other shocks affect the tanker market in a greater manner than crude oil. The study looks specifically at the tanker market, and emphasizes the importance of differentiating between various shocks in tanker operations. The study separates crude oil price shocks into supply shocks and non-supply shocks and investigates the relationship between the oil price and the freight market. Results indicate a significant impact of crude oil supply shocks on the tanker market, but insignificant effects from non-supply crude oil shocks.

Faber and Hoen (2015) contribute part of the growing interest in fuel efficient ship design in recent years, to the relatively high oil prices that have prevailed in the market until a significant decline in the second half of 2014 (Bunkerworld 2015a). This brings forth a need for studies assessing the impact of bunker fuel volatility on investment profitability, in terms of the effect of the volatility witnessed over the past decade and whether this has been observed before.

2.3 Ship design

2.3.1 Ship design and fuel price

According to Stopford (2009), the fuel price is the single most important aspect of voyage costs. He illustrates the shipping industry's response to extreme changes in bunker prices, and the consequent close connection between ship design and fuel price. As oil prices were low in the early 1970s, the level of interest of ship design was low. When oil prices rose again during the 1970s, more attention was paid to fuel costs through ship design. In 1986 bunker fuel prices fell again, along with the interest in ship design. The design of ships has consequently responded to changes in costs.

These fluctuations in the focus on ship design illustrate the shipping companies' inability to control fuel prices, and their ability to influence the level of fuel consumption in adherence. Stopford (2009) argues that the choice of design for the main engine will have the highest influence on fuel consumption, but the fitting of auxiliary equipment will also greatly affect fuel efficiency. Changes can also be made to the hull and the speed at which the vessel is operating. However, it is also highlighted that the importance of such design- and operational differences are dependent on the price of fuel.

2.3.2 Ship Innovation

Wijnolst and Wergeland (2009) present the history, development and innovation of ship design. The first development phases in tanker ship design from 1850 through 1938 were mainly driven by need for technology to build ships with a safe design. The driving causes of development however experienced a shift in the third development phase following the Second World War and up until 1979. During this period, the demand for oil transportation increased substantially. Combined with an industry seeking to achieve economies of scale, this caused a major increase in the size of tanker vessels and a previously unseen expansion of capacity in the global tanker fleet.

Following the second oil crisis, the demand for tankers collapsed. According to Wijnolst and Wergeland (2009) this declared the first round for “a fundamental restructuring and reduction of the world fleet”. Regardless of the overcapacity facing the industry, regulatory changes such as the U.S. Oil Pollution Act of 1990 (OPA90), enforced development of new designs and building of new capacity on ship owners and shipyards. The OPA90 triggered the introduction of the double-hull tanker. Finally, their prediction for the next phase of the industry was that the tanker industry would face challenges related to exhausted oil reserves and climate change.

Wijnolst and Wergeland (2009) also contemplate the process of ship design. As the financer of the ship, the ship owner has a deciding role in the ship design process when a vessel is ordered. His incentive for the process is to maximize the revenues from the vessel over its lifetime. Conversely, the shipyard delivering the vessel has a short-term incentive for maximizing the revenue from construction. This may result in diverging views between the shipyard and ship owner. Three *other* parties that are associated with the development in ship design are also identified: classification societies, the IMO and the flag states.

The classification societies primarily assess and approve designs, along with survey inspection of the ship during its operational life. The flag state is the country in which the ship is registered. As some flag states have specific requirements for manning, fire fighting or safety equipment, they too have an impact on design. However, the tendency is that most flag states approve of universal standards and thus leave the ship owner with some degree of flexibility.

The IMO is a governing body that develops rules and regulations for the shipping industry regarding the design and operation of ships. According to Wijnolst and Wergeland (2009) these regulations have the ability to influence design fundamentally, although they typically are of a more general nature and not a part of the design itself.

2.3.3 Environmental regulations and policy

Koutroukis et al. (2013) state that the optimization of nearly any ship design process comprises three general targets; *safety* as is termed by the IMO stability criteria, *efficiency* as expressed in the

IMO's Energy Efficiency Design Index (EEDI) and *competitiveness* through the required freight rate. Moreover, they argue that one of the most evident issues for future design is any known or unknown upcoming regulation that vessels must adhere to.

Several studies on energy efficiency in shipping literature focus on environmental aspects at large (see e.g. Longva et al. 2010; Eide et al. 2011; Hoffmann et al. 2012; Balland et al. 2012; Zheng et al. 2013). Numerous stakeholders have provided input to the debate, and contributed to the continuing discussion on environmental effectiveness, which in recent years has resulted in the development of more stringent legal frameworks (IMO 2012).

The IMO has developed a number of technical and operational measures for the purpose of improving shipping energy efficiency and consequently controlling the marine greenhouse gas emissions. These include the EEDI, the Energy Efficiency Operational Index (EEOI) and the Ship Energy Efficiency Management Plan (SEEMP) (Lloyd's Register 2012), which constitute the first legally binding climate change treaties adopted since the Kyoto Protocol. They were entered into force on 1 January 2013 and add a new chapter to MARPOL Annex VI (IMO, n.d.*b*). In particular, the EEDI has had a broad support by governments, associations and organizations (IMO 2012).

2.3.3.1 The Energy Efficiency Design Index

The IMO first adopted the International Convention for the Prevention of Pollution from Ships, MARPOL, in 1973. The convention includes standards to prevent pollution either caused by accident or operations, and has been frequently revised and updated. In 2011 the IMO adopted the EEDI. The EEDI sets emission requirements for ships ordered after 1 January 2013 or built after 1 January 2015, and consequently affects the ship design of new vessels. In 2020 and 2025 the required EEDI level will be further reduced by 10 per cent each time, with the aim to keep pace with technological advancements in emission reducing and fuel efficiency measures (European Commission 2015; IMO n.d.*b*).

The EEDI is a technical measure and is mandatory for all new vessels of 400 gross tonnages and above. It calculates the energy efficiency for different ship types and size segments. The largest and most energy intensive segments of the world fleet are targeted, including oil tankers. The index aims at promoting more energy efficient equipment and engines to achieve lower levels of pollution within the shipping sector (IMO n.d.*b*). The formula of the EEDI is based on the technical design parameters of a given ship and is expressed in grams of carbon dioxide (CO_2) per capacity-mile. The lower the value of a ship's EEDI is, the more efficient it is (IMO n.d.*b*).

The choice of technologies and specific ship design is left to the industry and individual ship owners. This presents ship designers with the possibility of using the most cost-efficient solutions available to comply with the specific benchmarks (IMO n.d.*b*).

Preceding the adoption of the EEDI, Longva et al. (2010) provided a method for using a cost-effectiveness criterion to implement measures for emission reduction. As the EEDI was still under development, their model served as a method to set a required index level for emission reduction. Hoffmann et al. (2012) further developed this notion, through modelling a set-of-measures approach for emission reduction of the world shipping fleet from 2010 to 2030. In their approach, the cost-efficiency is introduced as a link between capital expenditure, and the lifetime costs and savings. Within the approach, they describe how fuel savings for some emission reducing measures can offset the additional capital expenditure and operating costs required for implementation. There is however an absence of considering the profitability of fuel-efficient measures in isolation from the emission reduction aspect.

As the EEDI is exclusively applied to newbuilds, its impact is seen as a gradual step towards a greener shipbuilding industry. Zheng et al. (2013) emphasize that the EEDI will have a significant impact on shipbuilding industries worldwide, in their study evaluating the impact of the implementation of the EEDI on Chinese shipbuilding industry. Their paper concludes that the EEDI will stimulate the technological development in the elements affecting the energy efficiency of ships. Moreover, they emphasize that while the EEDI is a technical measure in essence, the act of slow steaming is in contrast more of a temporary nature. Maloni et al. (2013) emphasize the benefit of adjusting operations and design of an already existing fleet to adhere to indices and policies such as the EEDI. The paper estimates impacts under different vessel speeds, volumes and fuel prices, and conclude that extra slow steaming is the most beneficial vessel speed. It is further suggested that carriers could proactively incorporate the financial benefits of slow steaming into freight rates and hence share savings.

In a report conducted by CE Delft, Faber and Hoen (2015) analyse the history of ship design efficiency. Their analysis measures efficiency by the Estimated Index Value (EIV), as this is the basis for required efficiency levels for new ships made mandatory by the EEDI. The EIV is compared to the reference line of the EEDI. The report presents figures illustrating how design efficiency improved through the 1980's until its peak in the 1990's, after which design efficiency has declined. The changes in the EIV over time for tankers are argued to result from changes in main engine power, capacity and the speed of ships. Moreover, for tankers between 60 000 and 100 000 deadweight tonnes (DWT), they find hull design to be a relevant contributing factor.

2.3.3.2 Emission Control Areas

The IMO's MARPOL defines specific sea areas as special areas. These are chosen due to their oceanographical and ecological condition, as well as their heavy sea traffic. These special areas are provided with higher levels of protection than other areas of the sea, and imply special mandatory methods for ships to comply with in order to prevent pollution.

Annex VI, Prevention of air pollution by ships, establishes certain sulphur oxide (SOx) and nitrogen oxide (NOx) ECAs which include the US coastline, parts of the Caribbean Sea, the North Sea, and the Baltic. Vessels traveling within these areas are required to comply with standards specifically regarding sulphur and nitrogen Tier III emissions. Table 2.2 provides an overview of the location of such ECAs, their adoption, entry into force and date of taking effect (IMO n.d.*f*).

ECA	Adopted	Date of entry into force	In effect from
Baltic Sea (SOx)	26 Sep 1997	19 May 2005	19 May 2006
North Sea (SOx)	22 Jul 2005	22 Nov 2006	22 Nov 2007
North American ECA (SOx and PM)	26 Mar 2010	1 Aug 2011	1 Aug 2012
North American ECA (NOx)	26 Mar 2010	1 Aug 2011	[3]
United States Caribbean Sea ECA (SOx and PM)	26 Jul 2011	1 Jan 2013	1 Jan 2014
United States Caribbean Sea ECA (NOx)	26 Jul 2011	1 Jan 2013	[3]

Table 2.2 Special areas under MARPOL (IMO n.d.*f*).

[3] A ship constructed on or after 1 January 2016 and is operating in these Emission Control Areas shall comply with NOx Tier 111 standards set forth in Regulation 13.5 of MARPOL Annex VI (IMO n.d.*f*).

SOx emission standards apply to all types of fuel oil, combustion equipment and devices on board. Controls therefore include both main and all auxiliary engines, as well as boilers and inert gas generators. Controls differ depending on whether or not a ship operates inside an ECA and the fuel oil sulphur limits are subject to increased stringency over time. Table 2.3 presents and compares the specific limits outside and inside ECA respectively, expressed by weight (IMO n.d.*g*).

Outside an ECA established to limit SOx and particulate matter emissions	**Inside an ECA established to limit SOx and particulate matter emissions**
4.50% m/m prior to 1 January 2012	1.50% m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020[4]	0.10% m/m on and after 1 January 2015

Table 2.3 Sulphur levels outside and inside Emission Control Areas (IMO n.d.*g*).

The methods for meeting the ECA requirements need to be approved by the flag state. However, it is up to the ship operator to choose which approved method to apply in order to meet the sulphur emission requirements (IMO n.d.*c*). One alternative is for ships to switch between different fuel oils to comply with the emission levels. This means that the vessel can use the standard of heavy fuel oil (HFO) when operating outside an ECA, and switch to low sulphur marine gas oil (LSMGO) before entering the ECA. As LSMGO is costlier than HFO, this method incurs higher voyage costs per distance travelled when traveling within an ECA (BIMCO 2013a). Regulations[5] contain specific guidelines as to how the operations of this method are to be handled (IMO n.d.*g*).

The use of exhaust gas cleaning systems (EGCS) is a common alternative to switching between fuel oils throughout the voyage. These are more commonly referred to as scrubbers (Bureau Veritas 2014). The use of scrubbers allows a ship to avoid the premium for distillate fuel and instead run solely on HFO, as the exhaust gas is cleaned throughout the funnel inside the ECA. The main cost difference between the fuel switch method and installing scrubbers is therefore that the first alternative incurs higher voyage costs within the ECA, while the latter incurs a higher upfront cost from installation and investment cost of the scrubber (BIMCO 2013a; Skovbakke Juhl, Appendix A.2).

[4] Is subject to a review to be completed in 2018, or possibly earlier (Einemo 2014), as to the availability of the required fuel oil. Depending of the outcome of such a review, the date of 1 January 2020 could be deferred to 1 January 2025 (IMO n.d.*g*).
[5] Regulation 14 on Sulphur Oxides (IMO n.d.*g*).

In 2013, BIMCO presented a study assessing the conditions for profitability of switching fuel and installation of scrubbers, in order to comply with ECA regulations. In their study, BIMCO (2013a) state that the deciding factors influencing the investment decision of a scrubber are the days spent in an ECA, and the fuel cost spread between HFO and MGO. It is concluded that the question boils down to a comparison of fuel expenses inside and outside an ECA. The study shows that a newly delivered ECO design should spend more than 24 per cent of operating days within an ECA to benefit from a scrubber.

Lastly, the ship operator could choose to comply with the regulations through running the vessel on liquefied natural gas (LNG). This creates a completely different profile compared to operating on heavy fuel oil, as LNG produces fewer emissions than both coal and oil, and is the cleanest burning fossil fuel available (California Energy Commission n.d.). BIMCO (2013a) decided for the purpose of their study, that LNG appeared too expensive in most circumstances. Subsequently, they evaluated scrubbers as the real alternative to fuel switching and did not assess the profitability of LNG.

2.3.3.3 Global sulphur cap

Table 2.3 also illustrates the introduction of a future global sulphur cap, requiring ship owners to only use fuels with a sulphur content of no more than 0.5 per cent. Even though the 2008 amendments to MARPOL Annex VI specify to the global cap must be introduced from 2020, the allowance of deferral until 2025 is a possibility. IMO is mandated to complete a study regarding the availability of compliant fuel before the end of 2018, which will present the decision for the year of enforcement (International Chamber of Shipping n.d.). Lister et al. (2015) suggest that regulatory uncertainties make investments more difficult. The choice of design for newbuildings consequently needs to incorporate the uncertainties of regulatory timing in the shipping industry.

BIMCO (2014b) suggest that the shipping industry will continue to use residual fuels until the implementation of the global sulphur cap, due to the large differences in costs between compliant and non-compliant fuels. A switch to 0.5 per cent sulphur compliant fuels is therefore suggested to happen overnight. As a consequence, there is concern that the infrastructure in place to supply distillate fuels will not be sufficient to meet the demand. Even though the technology of abatement strategies such as scrubbers, LNG and other compliant fuels has already been implemented as a consequence of ECAs, it is not expected that the use will be widespread enough to sufficiently initial distillate fuel demand in 2020. This will not only affect the shipping industry in terms of an increase in the price of distillate fuels, but will also affect on-shore capacity of distillates, as the shipping industry will require a large portion of the production and thus compete against other industries.

As a consequence, the time period between 2018 and 2020 is insufficient for the industry to properly adjust, and BIMCO (2014b) therefore supports the consideration of an early presentation of the 2018 IMO Availability Study. There is a possibility of the review being completed in late 2016 or 2017 (Einemo 2014). However, it is also highlighted that a lack of enforcement would be unsustainable due to the consequences of distorted competition.

2.3.4 Fuel efficiency

In a study conducted by BIMCO in 2012, the commercial viability of an ECO ship is analysed. The study considers an investment in an ECO MR2 tanker with a premium in the newbuilding price of 25 per cent, compared to a conventional MR2 tanker. Based on their calculations and an expectation of higher freight rates, the study concludes that ECO ships seem to be the most profitable investment for the future.

However, since reports of ECO ship design started to appear in 2011, the design has become the new standard for all new buildings ordered today (Synergie Marine Group 2014). The choice between investing in an ECO ship and a conventional vessel is therefore no longer relevant, when considering investments in newbuildings. The relevance of the study lies in the additional capital expenditure a ship owner could accept for a more fuel-efficient vessel.

In general, there is a scarcity in academic literature on the design efficiency of ships (Faber & Hoen 2015). In 2014, Agnolucci et al. presented the first study in shipping literature on how financial savings from energy efficiency are allocated between owners and charterers. In their study on the Panamax ship segment, they find that only 40 per cent of accrued savings were allocated to the owners operating in the time-charter market between 2008 and 2012. This challenges the assumption presented by BIMCO (2013a); that owners of energy efficient vessels can charge an increased time charter rate equivalent to the financial savings of the vessel. As Agnolucci et al. state, the allocation of savings directly affects a ship owner's financial incentive to invest in an energy efficient vessel. Accordingly, if ship owners are not able charge a premium on the market and retain savings, energy efficiency must be introduced by mandatory standards.

2.3.5 The importance of ship design

According to Stopford (2009) and Wijnolost and Wergeland (2009), historic development in ship design has been a consequence of adhering to different phases of the shipping industry. Stopford (2009) contributes part of the ship owners' interest in ship design to changing fuel prices.

In 2009, Wijnolst and Wergeland predicted design changes as a consequence of exhausted oil reserves and climate change. The regulations set forward by the IMO were also highlighted as having the principal ability to influence ship design fundamentally. The fact that EEDI sets requirements for all new vessels, its constantly evolving nature is estimated by maritime literature to have an impact on technological development within the shipping industry (Zheng et al. 2013).

If ship design is restricted by the method of adhering to both current and upcoming regulations, the key is then to invest in the most cost-efficient solution within these restrictions. The conclusions on the financial savings from energy efficient designs are however complex when ship owners operate in the time charter market (BIMCO 2013a; Agnolucci et al. 2014). While BIMCO (2013a) base their profitability analysis of ECO ship design on the assumption that the ship owners can reach increased profitability by charging an increase time charter equivalent to the fuel saving premium, Agnolocci et al. (2014) find that only 40 per cent of savings are actually accrued to ship owners. This challenges the incentive to invest in a vessel that is more energy efficient than what is required by regulations.

In summary, the literature (Stopford 2009; Wijnolost & Wergeland 2009; Faber & Hoen 2015; Zheng et al. 2013; Agnolucci et al. 2014) suggests that ship design is mainly a means of adjusting circumstances within the shipping sector, rather than a drive in itself for an investment decision. The remaining question is which of these underlying forces have the largest impact on the importance of designs for the profitability of a product tanker investment.

3. Presentation of concepts and frameworks

In this chapter the frameworks applied in the thesis will be presented. Moreover, concepts that influence the foundation for assumptions and decisions of the analysis are introduced.

3.1 The revenue of a ship

The financial performance of a vessel is achieved through the revenue received from either operating or chartering the ship, the cost of running the ship, and the method of financing. A ship owner can either operate his vessel in the spot market, or charter the vessel. The revenue from chartering a ship is classified into three different arrangements. These include the voyage charter, time charter and the bare boat charter. Each type of arrangement distributes market risk and operational risk between the ship owner and charterer in different ways (Stopford 2009).

Under a voyage charter contract, the freight rate is paid per unit of cargo transported and the ship owner takes on both the shipping market risk and the operational risk. The ship owner pays all operational costs and is responsible for both the management of running the actual ship and for planning the voyage, while the payment of cargo handling costs is subject to agreement. Under a time charter contract, the charter hire is set as a fixed payment. The ship owner still takes on the operational risk, whereas the charterer takes on the market risk and pays for fuel, port charges, stevedoring and other cargo-related costs. The bare boat charter system is similar to a lease agreement, where the owner solely finances the vessel and receives a payment to cover these expenses. The charterer covers all costs and hence takes on both the operational and market risk.

3.2 The cost of running a ship

There is no internationally accepted cost classification, but Stopford (2009) classifies costs into five categories. The following section provides a closer review of these.

3.2.1 Operating costs

Operating costs are the costs associated with running the vessel on a daily basis. According to Stopford (2009), the operating costs account for about 14 per cent of total costs, and are mathematically expressed in the following manner:

$$OC_{tm} = M_{tm} + ST_{tm} + MN_{tm} + I_{tm} + AD_{tm}$$

where,	M	=	manning cost
	ST	=	stores
	MN	=	routine repair and maintenance
	I	=	insurance
	AD	=	administration

3.2.2 Periodic maintenance

The costs of periodic maintenance depend on age and the condition of the ship, by generally accounts for about 4 per cent of the total costs of running a ship. For insurance purposes, a ship is required to go through a special survey every fourth year, and regular surveys with dry-docking every two years. These surveys tend to involve high expenses in older ships.

3.2.3 Voyage costs

Voyage costs account for 40 per cent of total costs and involve fuel costs, port dues, tugs, pilotage, and canal charges. This relationship is expressed in the equation below.

$$VC_{tm} = FC_{tm} + PD_{tm} + TP_{tm} + CD_{tm}$$

where,	VC	=	voyage costs
	FC	=	fuel costs for main engines and auxiliaries
	PD	=	port and light dues
	TP	=	tugs and pilotage
	CD	=	canal dues

3.2.4 Cargo handling costs

Cargo handling costs represent the cost of loading and discharging, and are made up by cargo loading charges, cargo discharge cost and cargo disclaims. Cargo handlings costs can be reduced by improvements in ship design and are listed as one of the economic parameters for ship innovation by Wiljnost and Wergeland (2009).

3.2.5 Capital Costs

Capital costs differ significantly from other costs, as they are obligations that only affect physical operations indirectly. Capital costs can be classified into the initial purchase and obligation to pay the shipyard, the periodic cash payments to banks or equity investors for the capital involved to purchase the vessel, and the cash received in the case of selling the vessel (Stopford 2009).

The capital to finance a ship mainly comes from short-term debt in the money markets, long-term debt in the capital markets and equity from the stock market. Bank loans are the most important source of capital for financing a ship, as they allow capital to be provided quickly to borrowers, and provide the ship owner with full ownership of their business (Stopford 2009).

The HSBA Handbook on Ship Finance (2014, p. 60), defines the fixed rate of a bank loan to finance a vessel as *LIBOR plus margin plus funding fee.* The margin is an expression of the credit risk premium, or a credit spread, and illustrates the riskiness of the investment.

3.3 Project evaluation techniques

In order to evaluate different investments, standard project evaluation techniques are applied. The techniques are outlined in the following section.

3.3.1 Net present value

Talley (2012) states that the traditional set of criteria used for general investments also can be applied to the investments of ships. The net present value (NPV) technique is a method of discounted cash flow analysis to characterize the value of an investment. The NPV is derived by subtracting the present value of an investment's outflows from the present value of an investment's inflows (DeFusco et al. 2011). The following formula displays the NPV method:

$$\text{NPV} = \sum_{t=0}^{N} \frac{CF_t}{(1+r)^t}$$

where, CF_t = the expected net cash flow at time t

N = the investment's projected life

r = the discount rate

The steps of the method are displayed and summarized in Table 3.1.

NPV method	
1.	Identify all the inflows and outflows of the investment
2.	Identify the appropriate discount rate, r, for the investment
3.	Find the present value of both the inflows and the outflows
4.	Sum all the present values from the previous step. This is the NPV
5.	Apply the NPV rule

Table 3.1 Steps of the NPV method (DeFusco et al. 2011)

Despite uncertainties of income stream, cost stream and cost of capital, the NPV criterion is widely used in the maritime sector (Talley 2012). All components of the formula should be computed as well as possible. When facing high uncertainties, as is often the case in the maritime industry, a comprehensive sensitivity analysis should be performed.

3.3.1.1 The net present value rule

The NPV rule is a method for choosing between different investments. The rule says that an investment with a positive NPV should be undertaken, as the value added by the investment with a positive NPV exceeds the cost of capital, i.e. the opportunity cost, required to undertake it. Conversely, an investment with a negative NPV should not be undertaken. If there are mutually exclusive projects, the investment should be made in the project with the higher positive NPV (DeFusco et al. 2011).

3.3.1.2 The net present value discount rate

For an investment analysis through the NPV method, the discount rate applied should be the best estimate of the opportunity cost of capital. The opportunity cost of capital is the alternative return that the investor waivers by undertaking the investment in question.

3.4 Econometric modelling and volatility measures

For the purpose of analysing the oil price volatility and sensitivity measures, statistical and econometric methods were applied. These methods are introduced in the following section.

3.4.1 Standard deviation

The standard deviation is a measure for the variation or dispersion in a set of data values. Since several observations of the same quantity in general will not produce the same value, the standard deviation is useful as an expression of the distance from the mean (Bland & Altman 1996).

The standard deviation is computed by taking the square root of the *variance.* In accordance with Bessel's correction, the method of computing the variance depends on whether we are calculating the variance of the entire population, or a sample of the population. The correction, *N-1*, is equal to the degrees of freedom in the vector of deviations from the mean, and should be applied to compute the sample variance (Weisstein n.d.).

The population standard deviation, denoted by S_N, is computed by:

$$S_N = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

The sample standard deviation, denoted by S, is computed by:

$$S = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

where,	N	=	number of observations
	X	=	a random variable with the mean value μ, or $\bar{x}$
	$\bar{x}$	=	the mean value of the random variable

3.4.2 Augmented Dickey-Fuller test

The method of statistical analysis of the oil price volatility depends on whether the prices are stationary. If this is not the case, and the price series is non-stationary, then conventional methods for hypothesis testing, confidence intervals and forecast can be unreliable. A data set must follow a random walk[6] for it to be stationary, as opposed to exhibiting a trend (Stock & Watson 2012).

Dickey and Fuller (1979) introduced a procedure to test for a unit autoregressive root, which is consistent with the presence of a stochastic trend in a time series sample. The Augmented Dickey-Fuller (ADF) test is an econometric method to test the null hypothesis of the presence of a

[6] A data set following a random walk constitutes a sequence of random steps, or observations, and thus does not follow a pattern (Stock & Watson 2012).

stochastic trend, meaning that the data needs to be differenced in order to make the data stationary. The alternative is that the data set is stationary, and thus does not exhibit a stochastic trend (Stock & Watson 2012).

The test is done for the following regression:

$$\Delta Y_t = \beta_0 + \delta Y_{t-1} + \gamma_1 \Delta Y_{t-1} + \gamma_2 \Delta Y_{t-2} + \cdots + \gamma_p \Delta Y_{t-p} + u_t$$

In the presence of a stochastic trend in the dataset, the first difference of the data is taken. The ADF test can then be repeated in order to test whether the differencing of data was successful in making the data stationary.

3.4.3 GARCH

Several economic time series exhibit clustering of volatility, meaning that the volatility changes over time. In econometrics this is referred to as conditional heteroskedasticity (Stock & Watson 2012). When volatility appears in clusters, the daily price changes are challenging to forecast. However, the variance of the daily price changes can still be forecasted.

Forecasting the variance of a price series is useful in order to assess the riskiness in owning an asset. It also enables the forecaster to produce accurate forecasting intervals. According to Stock and Watson (2012), in the presence of volatility clustering, small variance in one period tends to be followed by small variance in the next period. The equivalent also holds true for large variance. When the variance of the error term changes over time, the forecasting interval should consequently be adjusted accordingly. In periods with large disturbances or shocks, the forecasting interval should be wide. Conversely, it should be tighter in periods of low variation.

There are two models of volatility clustering; the autoregressive conditional heteroscedasticity (ARCH) model, and the extension of this model; the generalized ARCH (GARCH) model. These can be applied to measure and forecast the time-varying volatility of a time series, and are particularly useful when modelling a time series with a high frequency of observations, such as daily price quotes (Stock & Watson 2012).

The original ARCH model challenges the classical linear regression model. In a standard ordinary least squares (OLS) regression, there is an assumption of homoskedasticity of the residuals. This requires a constant volatility over time. However, for financial data such as commodity prices and stock price indices, this assumption does in general not hold true. When the residuals are not constant over time, and therefore exhibit time-varying heteroskedasticity, there is no longer a certainty that the (OLS) estimators are the best linear unbiased estimator (BLUE).

The ARCH process recognizes the difference between unconditional and conditional variance, and accounts for volatility that changes over time. The conditional variance is handled by the process through allowing it to change over time as a function of the past errors of the sample (Engle 1982). The ARCH model is given by the following autoregressive equation:

$$\sigma^2_t = \beta_0 + \Sigma^m_{i=1} \beta_i \varepsilon^2_{t-i}$$

where, β_0 and β_i = parameters of lagged squared error terms in the variance model
i = 1,..., m.

The GARCH process developed by Bollerslev (1986) is an extension of the ARCH that allows for a longer memory of past values and a more flexible lag structure. Bollerslev (1986) argued that the ARCH model was over-parameterised and therefore added to the technique of ARCH in the GARCH model by assuming that the variance is dependent on both its own lagged values and the lagged squared error terms. The equation for the GARCH model is presented below.

$$\sigma^2_t = \beta_0 + \Sigma^p_{i=1} \beta_{1,i} \varepsilon^2_{t-i} + \Sigma^q_{j=1} \beta_{2,j}\, \sigma^2_{t-j}$$

where, $\beta_{2,j}$ = the lagged variance parameters and therefore the dependence of the conditional variance on its lagged values.

The number of lagged error (p) and variance (q) are denominated as GARCH (p,q) and are called the order of the GARCH model (Alizadeh & Nomikos 2009).

3.5 Nominal and real prices

Saunders and Gilliard (1995) express nominal monetary values as current prices that are unadjusted. In contrast, real monetary values are expressed as constant prices adjusted for the effects of changing price levels. Real monetary values are obtained through adjusting nominal monetary values with the Consumer Price Index (CPI). The CPI measures the change in the weighted average price level of a fixed basket of goods and services.

The real price is calculated as:

$$P_{real} = P_{nominal} \frac{CPI_{base}}{CPI_i}$$

where, P_{real}	=	the real price
$P_{nominal}$	=	the nominal price
CPI_{base}	=	the base CPI
CPI_i	=	the CPI for the given quote

4. Methodology

In this section, the considerations regarding the research design, strategy of inquiry and research method of the thesis will be presented. The selection of a suitable method depends on the objective, resources and circumstantial factors of the research. This is a critical choice in order to obtain the desired cognition and knowledge that ultimately forms the outcome of the research (Olsson & Silkoset 2008).

4.1 Research objective

As mentioned previously, this thesis aims to clarify whether there has been a fundamental change in the drivers behind the ship owners' investment in the product tanker newbuilding market. Careful consideration was put into the process of shaping the research objective.

4.1.1 Construction of research question

The research question forms the basis for the study in its entirety, and its construction is a critical step in the process of forming the research. Saunders et al. (2007) emphasize the distinction between *"what"* and *"why"* questions, and explain how they reflect different types of research. While the "what" question is in general descriptive, the "why" question is of a more analytic nature, seeking explanations instead.

Due to the analytical nature of the "why" questions, they require a more in-depth method in order to answer the questions sufficiently. Consequently, they form a major part of the analysis as made evident in Chapters 4 and 5.

4.2 Research design

The design of the research is structured through the application of a mixed methods approach. The approach was selected in order to form a more complete understanding of the research question than either a quantitative or qualitative approach would provide by itself. A mixed methods approach enables the study to benefit from both the flexibility of qualitative inquiry, and the structure of a quantitative approach (Creswell 2014).

4.2.1 Mixed methods approach

Within the mixed methods approach, a sequential procedure is applied in order to elaborate on the findings of one method with another method (Creswell 2014). Qualitative interviews were first conducted for explorative purposes, in order to structure and define the research area. Through the qualitative approach, the relevance of factors influencing the investment profitability in newbuilding investments were discussed, in order to select a set of appropriate factors for further analysis.

The ship owner's investment decision ultimately comes down to the expectation of the return on the investment. Quantitative analysis was therefore applied to elaborate on the initial findings and to generate concrete, numerical findings. Finally, the analysis, discussion and conclusion bring together the two approaches in a concurrent procedure to give a comprehensive analysis of the research problem. This entails that the study relies on both numerical and theoretical analysis in answering the research question, through use of data triangulation (Creswell 2014).

Most mixed methods studies tend to weigh heavier in either a quantitative or qualitative direction (Creswell 2014). Due to the selected order of the sequential approach, this study at large relies on quantitative analysis to draw conclusions. The research method applied is therefore influenced by the fact that the study leans more towards quantitative method.

4.2.2 Primary and secondary data

Olsson and Silkoset (2008) make the distinction between primary and secondary data. Primary data is data collected directly by the conductor of the research. By contrast, secondary data is collected from a second-hand source. In answering the research question of this thesis, both primary and secondary data was applied. Primary data was first collected through two interviews. For the following quantitative analysis, secondary data was collected from financial and statistical databases, financial reports and previous research.

In order to mitigate the risk of biased results, it has been of high priority to handle the data with objective and neutral care. The findings and discussion of the dissertation aim to draw conclusions from several sources whenever possible. That is, we seek to strengthen the analysis and reduce uncertainty through data triangulation (Alman 2003). This is based on the intuition suggested by

Webb et al. (1966), that “the most persuasive evidence comes through a triangulation of measurement processes”. The specific data collected will be presented in Section 4.3.3.

4.3 Research method

The research method comprises forms of data collection, analysis and interpretation. As mentioned previously, the method of this dissertation relies on a rational investment perspective, and this has heavily influenced the research methods applied.

4.3.1 Methodological framework for analysis

Stopford (2009) emphasizes the importance of forecasting for the investment decision of ordering a new ship. However, the performance of shipping forecasting is known to be rather poor, mainly due to the long-term horizon of investments and the high level of uncertainty of important factors influencing investment profitability. The maritime industry is to a high degree concerned with freight rates, for which levels depend on the number of ships that are ordered, and is particularly unpredictable at extremes of the shipping cycle. Moreover, the world economy affects factors such as bunker fuel prices and the shipping cycle in itself, and economic cycles, crises and political factors are far too complex to forecast with any degree of certainty (Stopford 2009).

A long-term forecast basing its duration on the life of a vessel will not be able to account for the major changes that are bound to affect the environment of the investment during the time period. Therefore, a long-term time-scale is most useful for strategy purposes of the shipping company (Stopford 2009). For the purpose and scope of this study, the ultimate goal was not to forecast the profitability of the investment in a ship with the highest degree of certainty. Rather, the study aims to assess the impact of different factors in relation to each other over the lifetime of an investment, and thus their importance for the investment decision.

Based on the theory of a rational economic decision maker, importance of one factor is attributed by its value in monetary terms in relation to the monetary value of another factor. The monetary values are expressed in dollars, in present value terms.

The analyses carried out to answer the research question cover different considerations for the investment viability, and is outlined in the following section.

4.3.2 Outline of analysis

The analysis in this dissertation comprises four main factors. First, an investment model for a 38 500 DWT product tanker is constructed. Second, the oil price volatility between 1987 and 2015 is assessed and applied in a forecast of future oil price volatility. The third section considers different abatement strategies for complying with ECA regulations, as a measurement of the profitability of different elements of ship design. Lastly, an evaluation of different levels of fuel consumption is presented and discussed in relation to ECO ship design and the EEDI. For several parts of the analysis, sensitivity analyses of the different variables are applied in order to measure the impact of fluctuations in each variable that affects the investment.

4.3.2.1 Investment model

First, an investment model for a 38 500 DWT product tanker newbuilding investment was constructed. In order to assess the impact of different investment factors, a sensitivity analysis was applied to the model, considering an isolated change in each variable at a time.

In order to test the theories of Stopford (2009), the impact on investment profitability from isolated changes in freight rates, bunker fuel prices, newbuilding prices and interest rates were assessed. The investment model disregards the effects of operating the vessel within ECAs. These effects were instead evaluated separately under the assessment of the importance of ship design.

4.3.2.2 Oil price volatility

The volatility of the crude oil price was then assessed. The movement of crude oil price is highly correlated with that of bunker fuel prices (Alizadeh & Nomikos 2009; UNCTAD 2010), and has been selected due to data availability over a long time-horizon. The volatility patterns and clusters over different time periods were examined, in order to assess whether the recent oil price volatilities are significantly different from what has been observed previously. Following this, a forecast based on historical data was constructed. The similarities or differences in this forecast from historical observations of the past, indicate whether the future of the shipping industry has a fundamentally different fuel price reality to accustom to than previously.

The analysis was done through measurements of standard deviation, conditional estimated variance and GARCH modelling. All econometric analysis was done in SAS Enterprise Guide 6.1, unless stated otherwise. The program will hereby be referred to as SAS.

4.3.2.3 ECA regulations

The abatement strategies for complying with ECA regulations were assessed through a NPV-model. In order to estimate the importance of ship design to the profitability of product tanker investments, the calculations assumed a scenario where the ship owner has the option of choosing between three different abatement strategies for his newbuild to comply with ECA regulations. These alternatives and their assumptions are expressed in Table 4.1.

Abatement strategy	Use of fuel inside ECA	Use of fuel outside ECA
Fuel switch	LSMGO	HFO380
Scrubber	HFO380	HFO380
LNG	LNG	HFO380

Table 4.1 Abatement strategies for complying with ECA regulations

The LNG strategy costs presented in Section 4.3.3.2.7 represent an investment in a newbuild with a dual fuel engine. According to the Danish Maritime Authority (2012), the dual fuel engine enables the vessel to run on LNG inside ECAs and let the fuel used outside such areas to be determined by relative prices. Due to currently low HFO prices, the fuel assumed to be used outside ECAs is therefore HFO.

As the time spent within an ECA affects the optimal ship design (BIMCO 2013a), calculations were made to determine the minimum amount of days which a vessel will have to sail inside an ECA for the scrubber and LNG alternative to be profitable in relation to switching between LSMGO and HFO. Profitability was measured in terms of net present value, and the differences in cash flows stem for differences in fuel cost and capital- and operational expenditures. The profitability of a scrubber and LNG design was measured as the difference in net present value from the LSMGO-HFO switch baseline.

As the effect of different ship designs is in focus, only machinery-related costs for the different strategies were included. For simplicity and isolation purposes, ship design calculations assumed that the different alternatives were financed without a loan. For the same reasons, scrap value was also disregarded in these net present value estimations. The calculations were based on the same 38 500 DWT product tanker as in the investment model and as previously, no attempt was made to optimize earnings by adjusting speed.

The study acknowledges the fact that all three abatement strategies are approved by the IMO (den Boer & Hoen 2015) in order to recognise which measures to realistically consider in calculations regarding ship design importance. However, further environmental assessments of such strategies will not be given as this is considered to be outside the scope of this dissertation.

4.3.2.4 Fuel efficiency

Although ECO ship design lacks a clear definition, there appears to be a general consensus that the design has superior fuel efficiency to previous designs (BIMCO 2013b; Koutroukis et al. 2013; Eason 2015). As there is a range of sub-brands within the concept of an ECO ship, different investments in product tanker newbuilds also include the choice between different equipment and thus also variations in levels of fuel efficiency (Skovbakke Juhl, Appendix A.2).

The impact of ECO ship design and the design efficiency requirements set by the EEDI were assessed through calculations on fuel efficiency. The impact of the consumption level of a vessel on the net present value of the investment was calculated, before different fuel price scenarios were applied. Subsequently, vessels of different consumption levels could be compared to the base case vessel under different oil price scenarios, and the financial performance of a vessel of a given consumption level could be compared across fuel price scenarios for the same vessel. Consumption levels based on a change of 10, 30 and 50 per cent were selected to illustrate the differences between ECO ships design, the EEDI requirements in 2025, and the impact of over-achieving the EEDI, respectively.

4.3.2.5 Sensitivity analysis

As Stopford (2009, p. 701) states, "the purpose of *rational forecasting* is not to predict precisely, but to reduce uncertainty". In dealing with uncertainty, this study has examined the impact of change in different variables through sensitivity analyses. That is, the change in a model as a result of a small change in one of the assumptions (Stopford 2009).

Each model contains baseline values for each variable, which were chosen from the most reliable data available for the present day values[7]. However, as most of the factors included in our model are highly volatile, the assumption that these values will stay constant over 20 years is not realistic.

[7] Present day values are in this dissertation considered as data collected from 8 June 2015, or the corresponding week, month, or year.

To evaluate the impact of change in each variable, the impact of small changes in the variables can be assessed through the change in result of the model in its entirety. It is understood that several of the factors are highly correlated, and thus a change in only one variable while holding the others constant is not realistic. Nevertheless, for the purpose of assessing the importance of each factor for an investment decision, we are interested in the isolated effects of change in order to compare the relative monetary terms of investment profitability.

4.3.2.5.1 The Change in Variables

In order to compare the impact of the different variables, a 20 per cent increase and decrease was applied to each variable, one at a time. Due to the high degree of uncertainty, it is considered that the results are more reliable if they still provide the same answers when adjusting the variables. If they do not, it implies a sensitivity of the model to the variable in question.

Further, the volatility in each variable was assessed in order to take into account volatility differences in the variables. If one variable exhibits higher volatility than another, then the effect of a higher volatility should be examined in order to assess the impact of a more realistic change in the value of the variable.

For the purpose of the sensitivity analysis described above, the changes in the fixed interest rate were based on a change in the LIBOR rate. It should be recognized that different shipping companies have different credit ratings, depending on their credit history and consequently their risk of default (Stopford 2009). However, for simplicity reasons, a representative value for the credit margin was selected (Pinnacle Marine Corporation 2011). This value was kept constant over the sensitivity analyses. Consequently, differences in interest rates stem solely from fluctuating LIBOR rates. The study acknowledges that this is not completely realistic. However, as it was assumed that the ship owner has a relatively constant risk of default, more volatile LIBOR rates were assessed in order to illustrate a larger overall effect on the total interest rate for a bank loan.

As the LIBOR rates are currently at a historical low, it would not be fully realistic to assume a decrease in the rates based on a calculated volatility. Instead, two higher scenarios were selected, one from 2000 and one from the height of the financial crisis in 2008. The historical LIBOR rates in USD through the date of collection are illustrated in Figure 4.1.

Figure 4.1 Development in LIBOR rates 1986-2015 (MacroTrends 2015)

4.3.3 Data collection

The collection of data included both primary and secondary data. The primary data was collected as part of the qualitative inquiries, while secondary data was collected for the quantitative analysis.

4.3.3.1 Primary data collection

Primary data is a valuable source of information when exploring an area that has not yet received much attention. Although ECO ship design and the recent oil price volatilities have been frequently discussed in media sources and industry reports, their relation to the ship investment decision appears to be absent in academic literature. Therefore, primary data has been collected through two interviews (Appendices A; B) in order to obtain a greater depth in our analysis (Kothari 2004) and to provide a more comprehensive understanding of the research problem. They were held as semi-structured interviews, in order to maintain an organized collection of data, while allowing the flexibility of asking probing questions (Morse 2012).

4.3.3.1.1 Semi-structured interviews

A researcher conducting individual interviews can hold them as structured, semi-structured or unstructured interviews. In semi-structured interviews, the researcher prepares an interview guide covering themes and questions of relevance to the area to be studied. However, in contrast to structured interviews, the guide is not necessarily followed to the point. This allows a flexibility to ask probing questions and adjust to the conversation as new areas of interest arise, while others might be omitted (Morse 2012; Saunders et al. 2007).

Subsequently, interview guides were constructed prior to the interviews (Appendices A.1; B.1). These were constructed with the aim of collecting comparative data, while at the same time adjusting the questions to each participant's area of expertise. As the interviews had an explorative purpose, the interviews held were based loosely on the guides, while adjusting the direction of the conversation underway as relevant topics were uncovered. Both interviews were recorded and transcribed (Appendices A.2; B.2), in order to secure a detailed and accurate collection of data.

4.3.3.1.2 Interview subjects

Both the interview participants held positions at BIMCO. BIMCO is the largest international shipping association in the world and has a close connection to the industry through its large member base spread across the globe.

The participants were both selected due to their proximity to BIMCO's research on ECO ship design, their academic background and their positions in the organization. Jeppe Skovbakke Juhl is a naval architect and Senior Marine Technical Officer at BIMCO. In 2012 he held a presentation at the Blue Conference in Denmark on the concept of ECO ships. His technical understanding and general knowledge of ECO ship design contributes to the uncertainty in defining the term and development in technology. Furthermore, his background and experience makes him an interesting voice in discussing the impact of environmental regulations on the viability of ECO ships.

Peter Sand is an economist and holds the position as Chief Shipping Analyst at BIMCO. He conducted the BIMCO study on commercial viability of ECO ships in 2012 and is therefore the ideal participant to answer questions regarding the assumptions and to elaborate on the figures in the study. Moreover, his background as an economist contributes as a nuance to Skovbakke Juhl's background as a naval architect.

4.3.3.2 Secondary data collection

In order to conduct the quantitative analysis, secondary data was mainly collected from the database Bloomberg, U.S. Energy Information Administration (2015), previous studies and financial reports.

In order to obtain reliable data, and to collect historical figures to assess the variation over time, time series data from Bloomberg and other databases was the prioritized resource for data collection. When data was not available from these sources, it was collected from previous studies and financial reports based on assessment of which available data was most reliable and compatible with other data collected.

For comparability purposes, all data was collected to correspond with the same date when possible. For daily quotes, this corresponds with 8 June 2015, and the corresponding week or month for other quotation intervals.

4.3.3.2.1 Fuel prices

Fuel price data is available from different ports across the world and the geographical choice of fuel purchase in ship operations depends on several factors. There are operational considerations that can be optimized to retrieve the best economic benefit, with regard to food, crew and fuel. For instance, the choice of port may incur slightly higher costs for fuel, but cheaper flight tickets for the crew and cheaper food.

However, for the purpose of this study, the fuel factor will be considered in isolation of these factors. Rotterdam and Singapore are the most common places for fuel purchase, and the cheapest ports of purchase simply due to volume. As calculations do not refer to a specific route, and for comparability across variables, bunker fuel prices from the port of Rotterdam were selected for analysis purposes. The decision was based on the fact that the port is considered the main bunkering port in Europe and is geographically located within an ECA (Ship & Bunker 2014; Maritime Cyprus 2014).

Oil price volatility

Crude oil prices were used as a proxy for the purpose of measuring historical volatility in fuel costs, due to a high correlation with bunker costs and availability of data. According to Alizadeh and Nomikos (2009), bunker fuel prices are driven by crude-oil prices, and shocks and disturbances in the global oil market translate into fluctuations in the bunker fuel market. Furthermore, the United Nations Conference on Trade and Development (UNCTAD 2010) reported a historical correlation between crude oil and bunker fuel prices of 0.98 in 2010. Their study concluded that there is a considerable correlation between crude oil prices and bunker fuel prices.

Daily data of the Europe Brent Spot FOB was collected from the U.S. Energy Information Administration (2015). The data is quoted in USD per barrel. The European index was selected in favour of the standard Brent crude oil index, due to geographical comparison with the bunker fuel data collected, as described above. Although oil prices in different geographical regions move together in the long term, there are short-term imbalances due to factors such as local supply and demand (Alizadeh & Nomikos 2009).

Prior to conducting the analysis of oil price volatility, the data obtained was closely examined. As the Europe Brent Spot FOB index is quoted in nominal values, the impact of nominal versus real values on returns[8] was assessed.

The Consumer Price Index (CPI) quoted by the U.S. Energy Information Association (2015) in their conversion of the Imported Crude Oil Price was applied to adjust nominal values to real prices[9]. The CPI is quoted monthly, and the base CPI (CPI_B) is set as the CPI for June 2015. The real price conversion (Appendix F.2) is done by the method described in Chapter 3.4

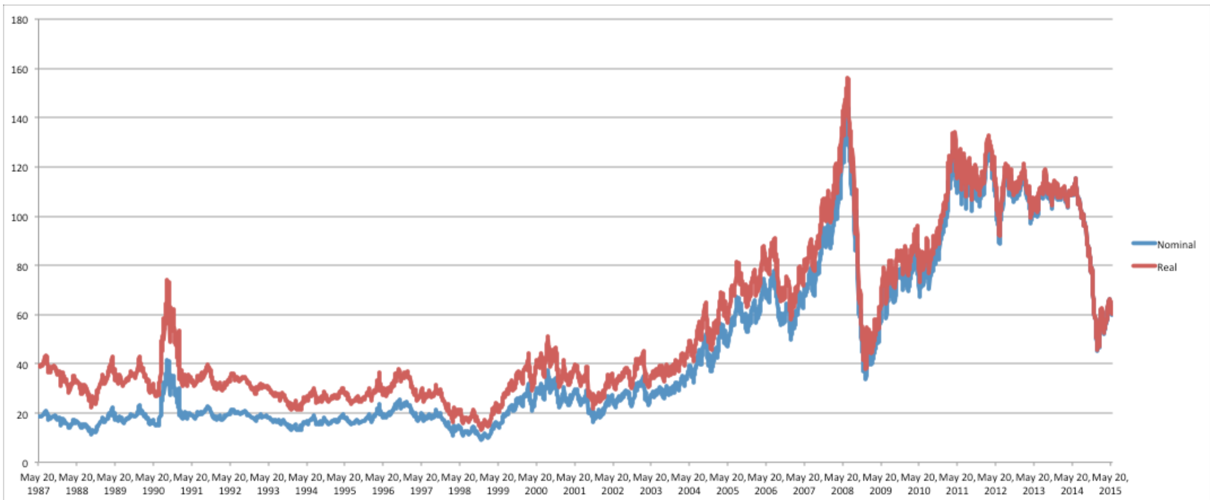

Figure 4.2 Europe Brent Spot Price FOB in nominal and real values, 1987-2015 (Appendix F.2).

The absolute difference between return of real and nominal values for the times series amounts to 0.9249, while the sum of absolute real return is 111.6645 over 7115 observations (Appendix F.2). The benefit of using the transformed data was therefore considered to be less than the potential

[8] Since volatility measurements are based on return data, as described in Chapter 3.
[9] The Imported Crude Oil price could not be applied for the analysis, as the GARCH model in the analysis required data quoted in daily observations.

costs, including the risk of human error, and the increased potential of erroneous data when using two sources, rather than one. Moreover, for the purpose of this study, the factor of interest is the historical development in *volatilities*, rather than the real historical *prices*.

The subsequent analysis is therefore based on the Europe Brent data set in its collected form, i.e. in nominal values, and the Europe Brent Spot FOB is the source referred to when discussing oil price volatility throughout the study.

HFO

Data on heavy fuel oil (HFO) was retrieved from Bloomberg and is the *Cockett Marine Rotterdam 380 centistoke bunker fuel spot price*. Prices are expressed in USD per metric tonne and are available from 1992 through the date of collection.

LSMGO

From 1 January 2015, the permitted SOx emission level was reduced to 0.1 per cent within ECAs. Previously, vessels could switch to marine gas oil (MGO) before entering such areas. Following the new limit, vessels are now required to use low sulphur MGO (LSMGO) to adhere to regulations (IMO n.d.*g*). As LSMGO prices were not available in Bloomberg, data was retrieved from Bunker World (2015b). As time series data was not available, quotations were only given for the date of retrieval. The LSMGO price is expressed in USD per metric tonne.

LNG

The pricing of natural gas is a contentious issue. In the US and UK, spot gas prices are in set by reference to prices prevailing at free-floating gas trading hubs; Henry Hub in the US and National Balancing Point in the UK. Gas is in these hubs priced based on regional supply and demand balance, and are therefore similar to the crude oil market (Reynolds & Richardson 2012).

For comparability with the bunker fuel prices from Rotterdam, the scope of this thesis is restricted to fuel and alternative fuel sources from the European region. The National Balancing Point was therefore selected as a basis for the liquefied natural gas (LNG) prices applied in the calculations.

The study however acknowledges the differences in natural gas prices across the world (PwC 2013) and the insufficiencies regarding the Asian LNG price levels[10] were taken into consideration when making this decision.

Data on the LNG fuel price was retrieved from Bloomberg, and is the *National Balancing Point within day natural gas spot price*. Prices are originally expressed in USD per therm and are available back to 2010. For comparability purposes, the LNG price was converted to USD per metric tonne (Unit Juggler 2015).

The National Balancing Point presents a natural gas priced at a lower level than both HFO and MGO respectively. However, the price at which suppliers import LNG is not the same as the retail price for end users. The import price mainly involves costs of winning, liquefaction and large scale transportation, whereas small scale distribution also relate to the costs of transport to stations, bunker solutions and refueling stations. Hence, the specific cost of small scale distribution should be added to the price presented by the National Balancing Point. The difference between the delivered LNG price and the price available at an LNG bunkering facility is however difficult to forecast. This translation difficulty stems from the fact that the added cost is set globally (PwC 2013). For the analysis in this dissertation, a small-scale distribution cost of USD 4/mmBTU was assumed. The figure is estimated by Lyder et al. (2011), and is assumed to be constant over time.

The prices for HFO380, LSMGO and LNG respectively are presented in Table 4.2. Quotations from 8 June 2015 were used, and are expressed in USD per metric tonne.

Fuel type	**Price, $/MT**
LSMGO	550.5
HFO380	330.5
LNG	536.9

Table 4.2 Fuel prices, 8 June 2015 (Bloomberg; Bunkerworld 2015b).

[10] Asia lacks a LNG trading hub. Instead, the market has been characterized by long term LNG contracts. Even though the future may entail a more liquid spot market (Rogers et al. 2014), the region currently has no readily identifiable hub that serves as regional distribution point where gas pricing can be easily determined. LNG contract prices are therefore to a large degree linked to regional crude oil prices (Investopedia n.d.).

4.3.3.2.2 Newbuilding prices

The VESPMRTL Index was retrieved from Bloomberg and expresses the vessel price for newbuild MR tankers. Newbuilding prices are expressed in USD and the quotation used in the analysis is from 8 June 2015.

4.3.3.2.3 Voyage and operational costs

Specific voyage and operational costs were retrieved from NORDEN's annual report of 2014. The fleet includes 19 Handysize and 27 MR vessel product tankers, and the vessels mainly transport clean petroleum products. Table 4.3 presents the figures retrieved from the annual report (see Appendix D.1 for further details).

Costs	Tanker, $/year	Total fleet, $/year
Charter hire for vessels	146 322 000	1 159 244 000
Voyage costs	191 625 000	990 087 000
Other vessel operating costs	48 827 000	102 365 000
Other external costs	2 094 000	18 057 000
Staff costs, onshore employees	4 379 000	37 758 000

Table 4.3 Cost figures from NORDEN's annual report 2014 (NORDEN 2014).

As the calculations of the analysis required exact figures of bunker costs in order to evaluate the effect of volatile fuel prices, NORDEN's specific bunker costs were subtracted from the voyage costs. As bunker costs were only available for the whole fleet, the percentage of total bunker costs/total voyage costs was calculated, and used to estimate a representative value for NORDEN's tanker bunker costs in order to deduct them from tanker voyage costs.

As the investment model assumes that the ship owner operates in the spot market, charter hire for vessels in NORDEN's annual report was excluded from the operational costs. The calculations also exclude other voyage- and operational costs from chartered vessels, by using the percentage of owned vessels out of MR and Handysize tankers respectively. Tables 4.4 and 4.5 illustrate these figures (see Appendix D.1 for further details).

Tanker size	Owned, %	Chartered, %	Days at sea
MR	29.6	70.4	10 114
Handysize	63.2	38.8	6 833

Table 4.4 Owned and chartered vessels from NORDEN's annual report (NORDEN 2014).

Type of cost, owned tanker	Cost, $/day
Operational costs	7 563
Voyage costs (less bunkering costs)	4 672

Table 4.5 Calculated operational and voyage costs for owned tankers.

4.3.3.2.4 Freight rates

The Baltic Clean Tanker Index (BCTI) was retrieved from Bloomberg, and expresses tanker rates for six Baltic International Tanker Routes. Rate assessments are quoted in Worldscale rates, and are expressed in USD. However, in order to convert tanker rates from Worldscale to levels expressed in USD per tonne, the Worldscale flat rate (WS100)[11] must be applied. These rates are however not readily available for private use and have therefore not been obtained. The historical values of the BCTI have therefore been used solely for volatility calculations.

Instead, the 2015 Clean MR Spot Earnings were retrieved from the Oil & Tanker Trades Outlook presented by Clarkson (2015a). Clarkson is the world's leading provider of shipping services, and its freight data is therefore is therefore deemed highly reliable. As Clarkson (2015b) has had access to the Worldscale flat rate, the shipping service has been able to estimate voyage revenue through freight rates converted from tanker rates. Spot earnings have been calculated in the following manner:

$$E = (R - C)/D$$

where, E = voyage earnings, USD/day
R = voyage revenue, USD
C = voyage costs, USD
D = voyage time, days

The voyage costs retrieved from NORDEN's (2014) annual report were assumed to be similar to those used by Clarkson (2015a) in calculating spot earnings for a MR tanker. The reports are conducted around the same point in time, and therefore present voyage costs based on similar bunker prices. As voyage costs will change depending on the bunker price, it has been deemed

[11] The WS100 is the base for the index. The Worldscale association publishes an annual list for WS100 for all routes, and the basic principle of the system is that similar oil tankers should earn the same daily gross revenue, regardless of the route of the oil tanker (Talley 2012).

necessary to estimate a figure for annual voyage revenue in order subtract specific voyage costs based on different fuel price scenarios. Consequently, the voyage costs (less bunkering costs) retrieved from NORDEN's annual report and specific calculated bunkering costs based on current fuel prices were added to the 2015 Clean MR Spot Earnings to estimate a representative value for *annual voyage revenue* for the base case of the investment model. For changes in fuel prices, earnings were subsequently affected, while other voyage costs were held constant throughout the calculations. Table 4.6 illustrates the figures used for the base case of the investment model, using the current HFO380 quotation of 330.5 USD per MT.

Source	Freight data	Rates, $/year
Clarkson	Voyage earnings	8 051 900
NORDEN	Voyage costs (less bunkering costs)	1 705 275
Calculated figures	Bunkering costs	2 645 157
Calculated figures	Total voyage costs	4 350 432
Calculated figures	Voyage revenue	12 402 332

Table 4.6 Summary of freight data and calculations (Clarkson 2015b; NORDEN 2014).

4.3.3.2.5 Financing

The study acknowledges the fact that there are different methods of raising finance. Even though this is an important aspect of a ship owner's investment strategy, Stopford (2009) states that bank loans are the major source of finance for owners. It was therefore assumed that the investment in a new product tanker was financed through a bank loan.

The HSBA Handbook on Ship Finance (Schinas et al. 2014, p. 60) defines the fixed rate of a loan to finance a vessel as *LIBOR plus margin plus funding fee*. For simplicity, the investment model in this study omits the funding fee. The fixed interest rate applied in the model is equal to LIBOR plus a 375 basis point credit range. The margin was collected from Pinnacle Marine Corporation (2011); a brokerage firm specialized in providing assistance in locating vessel-financing packages.

The 12-month USD LIBOR expressed by the Federal Reserve was applied in the calculation of the fixed interest rate (MacroTrends 2015).

4.3.3.2.6 Scrap value

The current scrap value for tankers has been retrieved from Charles R. Weber (n.d.), an independent full service shipbroker and marine consultant. Scrap prices are presented from India, China, Bangladesh and Pakistan, which represent some of the largest ship breaking industries in the world. Although Bangladesh has the largest market for shipbreaking (Stopford 2009), the scrap price from the Chinese market was selected. This is due to the fact that the weight of the assessed product tanker used from the den Boer and Hoen (2015) report is quoted in DWT. The Chinese scrap value price is the only source from Charles R. Weber (n.d.) quoted per DWT. The calculation of the scrap value can be found in Appendix D.1.

4.3.3.2.7 Abatement strategy costs

The assessment of the impact of ECA regulations required cost data on both capital- and operational expenditure for the different abatement alternatives. The only relevant and current figures that were obtainable for a product tanker are presented in the Delft CE report presented by den Boer and Hoen (2015). The report reviews the available literature on scrubbers, partially to assess the design's economic viability in comparison to other ways of being compliant with legal requirements. The lack in availability of current cost data is confirmed, and a compilation of presented cost figures from the most recent studies is therefore provided. Den Boer and Hoen (2015) consider figures from two reports to be the most reliable; *North European LNG Infrastructure Project* presented by the Danish Maritime Authority (DMA) in 2012, and *Green Ship of the Future* by Klimt-Møllenbach et al., presented by Green ship in 2012. Both reports refer to contacts with different engine manufacturers and shipyards for data collection.

Klimt-Møllenbach et al. (2012) however only provide retrofit costs. As the purpose of this study is to evaluate the key factors determining the profitability of an investment in a newbuilding, the report by the DMA (2012) was selected as the reference for costs of the different abatement strategies. The figures in the report are based on newbuild costs, but only refer to tanker vessels in general. However, as costs are expressed in relation to engine power (EUR per kW), and applied to the case of a product tanker newbuilding in den Boer and Hoen (2015), they were regarded as the best available data for the purpose of this thesis.

Tables 4.7, 4.8, and 4.9 provide the costs retrieved from DMA (2012). As calculations solely focused on differences between the abatement strategies, only machinery related costs are included (see Appendix L.1 for more details). *Installation SCR* represents the installation costs for the selective catalytic reduction (SCR). The SCR is an internal engine process to prevent the formation of NO_x by controlling the combustion process, and is designed to adhere to the Tier III level set for ships constructed on or after 1 January 2016 (Man Diesel & Turbo 2013). Ship design calculations therefore assumed an investment date after 1 January 2016. The installation costs for SCR are however equal for the different abatement strategies.

LSMGO	**Up-front costs, €**
Investment motor conversion/fuel cooler/fuel pumps	100 000
	Up-front costs, €/kW
Investment engine	180
Investment generators, electric system, propulsion steering	240
Installation SCR (including installation)	45

Table 4.7 LSMGO strategy costs (DMA 2012).

Scrubber	**Up-front costs, €/kW**
Investment scrubber	150
Investment engine	180
Investment generators, electric system, propulsion, steering	240
Installation cost scrubber	180
Investment SCR (including installation)	45

Table 4.8 Scrubber strategy costs (DMA 2012).

LNG	**Up-front costs, €/kW**
Investment dual fuel engine	280
Investment generators, electric system, propulsion, steering	400
Investment LNG fuel gas supply system + tank	245
Installation cost	100
Investment SCR (including installation)	45

Table 4.9 LNG strategy costs (DMA 2012).

As capital expenditure and installation costs for product tanker newbuilds fitted with the different abatement strategies were retrieved from the DMA (2012) report, the estimated operation and maintenance costs were collected from the same source. Apart from fuel costs, there are generally no significant differences in the operational costs between different fuel alternatives. Additional equipment however, such as scrubbers and SCR, involves additional capital expenditure and differences in operational costs (DMA 2012).

Table 4.10 provides the operation and maintenance costs for the different options. Figures are based on energy production (main engine power [kW] * hours at sea [hours/year]) and will therefore change depending on the amount of days at sea spent in an ECA (see Appendix L.1 for more details).

Abatement strategy	Operation and maintenance costs, €/kWh
LSMGO	0.007
Scrubber	0.0095
LNG	0.007

Table 4.10 Operation and maintenance costs for ECA abatement strategies (DMA 2012).

As costs are expressed in EUR per kW, engine power data were retrieved from the den Boer and Hoen (2015) report, which presents a case study for a product tanker. These figures were used to calculate costs to absolute figures. Costs were also converted from EUR to USD. As the DMA report was written in March 2012, an average of historical exchange rates from this period was calculated in order to translate figures into USD (International Monetary Fund n.d.). Engine power and the calculated absolute costs for the different abatement strategies are presented in Tables 4.11 and 4.12.

Engine type	Engine power, kW
Main	9 480
Auxiliary	2 880

Table 4.11 Engine power of product tanker (den Boer & Hoen 2015).

Abatement strategy	Up-front costs, $	Operation and maintenance costs, $/h
LSMGO	2 713 797	80.5
Scrubber	7 381 322	109.3
LNG	9 613 122	80.5

Table 4.12 Summary of calculated costs for ECA abatement strategies.

4.3.3.2.8 Fuel consumption and days in operation

Figures on specific fuel consumption for MGO and HFO were retrieved from the report presented by den Boer and Hoen (2015). These figures are in turn based on data from Klimt-Møllenbach et al. (2012). As the report specifically considers a product tanker vessel, its figures on fuel consumption are deemed more relevant than those of DMA (2012), which considers tanker vessels in general. Fuel consumption figures for MGO and HFO are presented in Tables 4.13 and 4.14, expressed in metric tonnes per day. It has been assumed that fuel consumption for LSMGO is similar to MGO.

MGO	Fuel consumption, t/d
At sea, main engine	27.0
At sea, auxiliary engine	3.5
Harbour, idling	4.1
Harbour, unloading	11.9

Table 4.13 Fuel consumption of product tanker running on MGO (Klimt-Møllenbach et al. 2012).

HFO	Fuel consumption, t/d
At sea, main engine	28.7
At sea, auxiliary engine	3.7
Harbour, idling	4.3
Harbour, unloading	12.7

Table 4.14 Fuel consumption of product tanker running on HFO (Klimt-Møllenbach et al. 2012).

Figures for HFO with a scrubber and LNG were retrieved from the DMA (2012) study. These were not retrievable from Klimt-Møllenbach et al. (2012). For comparative purposes, the HFO/HFO ratio with a scrubber and the HFO/LNG ratio from DMA (2012) were applied to construct comparable fuel consumption figures for the product tanker case. Albeit a simplification, it serves the purpose of illustrating the differences in fuel consumption between the various alternatives. The raw DMA (2012) fuel consumption data for HFO with a scrubber and LNG is presented in Table 4.15, and the final calculated figures for the 38 500 DWT product tanker are presented in Tables 4.16 and 4.17 (see Appendix C for further details).

Type of design	Fuel consumption, g/kWh
MGO	203
HFO	213
HFO with scrubber	217
LNG	183

Table 4.15 Fuel consumption for different ECA abatement strategies (DMA 2012).

HFO with scrubber	
Type of operation	**Fuel consumption, t/d**
At sea, main engine	29.20
At sea, auxiliary engine	3.78
Harbour, idling	4.41
Harbour, unloading	12.90

Table 4.16 Calculated fuel consumption for product tanker running on HFO with scrubber.

LNG	
Type of operation	**Fuel consumption, t/d**
At sea, main engine	24.70
At sea, auxiliary engine	3.19
Harbour, idling	3.72
Harbour, unloading	10.90

Table 4.17 Calculated fuel consumption for product tanker running on LNG.

The study acknowledges that weather and water conditions also influence fuel consumption (Scorpio Tankers 2013). Such factors are however disregarded for the purpose of simplicity.

The calculations were based on the assumption of 220 days at sea, 115 days idling and 30 days unloading. These figures were retrieved from the den Boer and Hoen (2015) case study for a product tanker.

4.3.3.2.9 Further assumptions

All calculations further assume a commercial life of 20 years for newbuildings, and a 7 per cent discount rate.

4.3.4 Measurement of data

Oil prices are in general available as daily, weekly, monthly, quarterly and yearly quotations, and the selection of data intervals will depend on the purpose of the analysis. For the purpose of this dissertation, and given data availability, quotes per quarter or year will amount to too few observations to make any robust statistical conclusions.

Daily quotations were selected as this is necessary for the purpose of constructing a robust GARCH model (Stock & Watson 2012). Subsequently, the volatility of crude oil prices was at first also based on daily observations, although monthly observations were included for elaborative purposes. For the measurement of volatility of HFO, LSMGO and LNG, weekly observations were applied. The time series for measuring the volatility was established by computing the compounded returns of the data.

4.3.5 Evaluation of data

As both the process of constructing research objectives and conducting the subsequent analysis of this dissertation relied heavily on a number of data sources collected, these were evaluated thoroughly in order to assess the impact of any weaknesses on the results of the research and that the benefit of using the data was greater than the costs (Saunders et al. 2012).

4.3.5.1 Primary data

The use of interviews can aid the researcher in formulation of a research questions and objectives. In this dissertation, semi-structured interviews were applied in order to obtain a deeper understanding of the research objective and the reasons behind certain results. However, there are a number of data quality issues that need to be acknowledged when assessing the robustness of the information received from semi-structured interviews (Saunders et al. 2012).

4.3.5.1.1 Reliability

A general concern of reliability in semi-structured interviews is their lack of standardization. There is a risk that qualitative research may not lead to similar information when done by alternative researchers (Saunders et al. 2012). Due to the very open nature of the questions posed to Skovbakke Juhl and Sand (Appendices A; B), the lack of standardization is an issue to highlight in regard to reliability. A larger focus may have been given to some areas than others, and specific follow up questions to certain aspects may have steered the interviews in different directions. On the other hand, one might argue that the flexibility of being able to steer the interview during its course was necessary, as the purpose of the interviews was of an explorative nature rather than an evidence gathering one.

The timing of the collection of primary data may also add to the issue of reliability. Although the main purpose of the interviews was to gain further knowledge to create an accurate research question, conducting the same interviews at a later stage of the dissertation would likely have led to dissimilar information. A wider knowledge of the subject of study, and a clearer focus of the objective at hand, would have changed the focus of the questions asked during the interviews.

However, as Saunders et al. (2012) mention, results retrieved from non-standardised data collection are not necessarily intended to be repeatable. Instead, they reflect the reality at the time they were derived, in a situation that may still be subject to change.

4.3.5.1.2 Forms of bias

The issues of reliability are also related to *interviewer bias*. The tone in which questions are asked or comments which are made may steer the interview in certain way and bias the way the interviewees respond. The interviewer may attempt to impose his or her own beliefs through the questions asked. In addition, there may also be a bias in the way the responses are interpreted (Saunders et al. 2012).

Skovbakke Juhl was interviewed a few weeks prior to Sand. During discussions with Skovbakke Juhl and during the time period between the two different interviews, certain aspects were added and discarded as a more realistic understanding of the research topic was developed. Even though many questions were similar, the focus of the interviews somewhat changed. However, one could argue that this method of collecting primary data created a wider knowledge spectrum of the topic at hand.

Saunders et al. (2012) also mentions the issue of interviewee bias, and the consequent possibility that certain aspects could be over- and underemphasized during interviews. Due to the clear differences in background and position of Skovbakke Juhl and Sand, this type of bias is likely to be apparent for our collection of data. The interview participants even highlight this issue themselves, and explain the differences in perception between having a technical and an economic perspective.

Nevertheless, the evident divergence in perceptions has in the case of our study been assessed as beneficial for the purpose of the interviews. As previously stated, the main purpose of the interviews was to gain a greater understanding of the fundamental changes facing the shipping industry at large. In effect, the ability to retain information from two interviews with participants of two diverging areas of expertise suited the purpose of the primary data collection.

4.3.5.1.3 Validity and generalisability

In relation to primary data collection, validity refers to the degree of which the researcher gains access to the interviewee's knowledge, and is able to infer the intended meaning of the interviewee from the responses given. Due to the semi-structured nature of our interviews, they have been assessed to have a high level of validity. This stems from the ability to clarify questions and meanings of responses, as well as discussing topics from a variety of angles (Saunders et al. 2012).

Qualitatively based interviews often have apparent issues of generalizability through the inability to make statistical generalisations of an entire population (Saunders et al. 2012). This issue should be acknowledged with regard to the conducted interviews, as the primary data in this dissertation would have been strengthened through a larger number of participants. The fact that both participants represent the same organisation further weakens the generalisability of the interviews. Information from specific shipping companies regarding their strategies of investment, and their view on ship design and volatile fuel prices could have further broadened the understanding of the research objective. Saunders et al. (2012) however state that findings strengthened by existing theory contribute through reinforcement of the theoretical significance of the results. To minimize the issue of generalisability, data triangulation has therefore been applied throughout the study.

4.3.5.2 Secondary data

The use of secondary data is argued to be beneficial, due to the researcher’s ability to evaluate it before use. According to Saunders et al. (2012) the researcher should evaluate the overall suitability of the data to research questions and objectives, and the precise suitability of data for analyses needed to answer research questions and meet objectives.

4.3.5.2.1 Overall suitability of data

4.3.5.2.1.1 Measurement validity

According to Saunders et al. (2012), one of the most important criteria for the suitability of a data set is *measurement validity*. Consequently, this was a main concern during the data collection process of this study. The measurement validity concerns whether the data collected actually measures what the researcher needs to measure, in order to answer the research question or meet the objectives of the analysis. If the data fails to do so, this will lead to invalid results.

The collection of HFO, LNG, and LSMGO data have high standards of measurement validity, as this data serves the objective of measuring differences in fuel costs, both in terms of the variation within each time series and the difference between each fuel type. As previously described, they also serve the larger purpose of measuring the profitability of different abatement strategies for complying with ECA regulations.

However, the assumptions on the geographical choice of fuel purchase challenge the measurement validity. Even though the choices of port and hub to retrieve fuel prices have been deemed the most suitable for the purpose of the calculations, the divergence in fuel prices across the world must be highlighted. Differences in LNG price levels are perceived as especially high and could consequently affect the choice of using a ship design constructed to run on LNG within ECAs. For instance, LNG is priced at higher levels in the US than in Europe, and the use of this specific fuel type may therefore possibly be more profitable in relation to alternative fuels (PwC 2013).

The collection of the crude oil prices using the Europe Brent Spot FOB serves its intended measurement purpose. However, one may argue that the EIA Imported Crude Oil Price (U.S. Energy Information Association 2015) would have been a better fit. The term “imported” means that it includes the costs that incur up to the end user, and the prices are quoted in real terms. This is important for the purpose, as it affects the volatility measures, and as the rest of the investment analysis, to which any amount is to be compared, is quoted in present value dollars. However, as the data was only available in monthly quotations, it was not suitable for the econometric modelling of the volatility forecast. Subsequently, the Europe Brent Spot FOB is considered to be the best suited available data.

Although Europe Brent Spot measures crude oil price and not actual bunker fuel prices, UNCTAD (2010) suggests a considerable correlation between crude oil prices and bunker fuel prices. This is also supported by Alizadeh and Nomikos (2009). The Europe Brent Spot has consequently been deemed sufficiently suitable as a proxy for bunker fuel volatility measures, as the purpose of the analysis of the data is to consider movements in price development.

The use of constant values for costs, revenues, interest rates and credit ratings over the lifetime of the vessel in the investment model and ship design calculations further challenge the measurement validity of the study. Obviously, these are not fully realistic assumptions, yet it has been crucial to add simplicity and clarity to calculations. Sand (Appendix B.2) strengthens this argument by stating that firm assumptions need to be made in order to reach results, despite uncertainties in specific figures.

For ship design and operational specifications, measurement validity was ensured through collection of specifications such as engine power and fuel consumption for a product tanker. Scrap value prices were collected per DWT, in order to calculate the correct price in accordance with the 38 500 DWT product tanker applied in the calculations of the den Boer and Hoen (2015) report.

The differences in size and type of transported cargo between the segments impact the common routes of the product tankers. LR tankers are mainly employed on long or intermediate distances[12] (Danish Ship Finance 2012). In contrast, MR tankers are very rarely employed over longer distances. Instead, their small size allows for shorter distances as they can access most ports (U.S. Energy Information Administration 2014).

A further issue regarding measurement validity is the unavailability of the Worldscale flat rate. The use of a representative value of annual voyage revenues using figures from Clarkson (2015a) and NORDEN (2014) has however been considered as the best alternative to calculating freight rates using the BCTI. Both reports provide recent data and fit the specifics of the ship described above.

Furthermore, the use of ratios to determine representative values for the purpose of the product tanker investment calculations could affect the accuracy of the analysis. The ratio of total bunker cost over total voyage cost has been applied to values from NORDEN's annual report in order to deduct the bunker costs from the voyage costs[13]. The same method has been used to compute representative figures for fuel consumption of HFO with a scrubber, and LNG. Possible uncertainties in these estimates are however assessed to be relatively small in relation to other variables, and are the best available estimates for the analysis.

4.3.5.2.1.2 Coverage

The second criterion for overall suitability of data that Saunders et al. (2012) emphasize is *coverage*. This criterion concerns whether the secondary data applied covers the correct population, time period and variables that enable the analysis to contribute to answering the research question and meet its objectives. For secondary data, the two main issues are whether unwanted data can be excluded and whether the remaining data is adequate for the purpose of the analysis.

The calculations of volatilities for time series data have taken the differences in coverage of time period into consideration, by only using data which can be dated back to the same week for all variables compared in the same model. An exception to this is newbuilding prices, where data was

[12] LR1 tankers are mostly employed in the Middle East, Northern Europe, the Caribbean and the Far East.
LR2 tankers mainly transport clean products from the Middle East to Asia or Northern Europe, and dirty products from the Black Sea to the Mediterranean or the US, or from the Baltic or North Sea to Northern Europe or the US (Danish Ship Finance 2012).

[13] The ratios are solely based on and applied to values for *product tankers* in the NORDEN fleet.

only available from 2013, and therefore considered to have weak coverage. As the volatility measurements would suffer more from low coverage in all variables than a weakness in comparability of one variable, the volatilities of the other variables are based on longer time periods. The volatility of newbuilding prices is instead supported in the analysis by quotes obtained from other sources, in order to assure reasonable estimation of impact in the sensitivity analysis.

The same method has been applied for the choice of ship design to adhere to the existence of ECAs; LNG prices only date back to 2007 and older HFO data has therefore been excluded for the purpose of comparative volatility calculations. This is deemed as an adequate horizon for volatility calculations. However, as time series data was not available for LSMGO, this volatility is based on a quote from Bunkerworld (2015b).

The capital costs and consumption figures collected from the DMA (2012) and Klimt-Møllenbach et al. (2012) reports further challenge the coverage criterion. Figures measure cost and consumption levels from 2012, rather than present-day values. As more recent or reliable data has not been available, the discrepancy between the 2012 and present day levels has not been possible to assess.

According to Danish Ship Finance (2012), the most common product tanker segments are the LR2, LR2 and MR segments. The MR segment consists of tankers greater than 25 000 DWT and smaller 45 000 DWT and mostly transports refined petroleum products (U.S. Energy Information Administration 2014). The vessel used in the calculations of this study therefore fits the measurements of a MR product tanker. The LR class ships are of larger size. As they carry both refined products and crude oil, the U.S. Energy Information Administration (2014) therefore states that LR size product tankers are the most common in the global fleet of tankers in general. Even though the 38 500 DWT MR vessel used in this study is definitely a representative size of a product tanker, results can consequently not be fully drawn to apply to product tankers in general.

The variations in size, route and distance between the different types of product tankers will have evident effects on costs, revenues and consequent investment decisions based on profitability. Even though the size of vessel has been chosen to fit with other figures retrieved from the den Boer and Hoen (2015) report, the inability to draw more robust conclusions for products tankers in general is a clear weakness of the study.

The choice of voyage and operational costs retrieved from NORDEN's annual report (2014) also affects the coverage of data. Consequently, the use of data from a specific shipping company slightly affects the ability of applicability to product tankers in general, as it does not provide an indication of the state of the industry as a whole. In comparison, the source of freight rates better suit the criterion of coverage as it has been retrieved from an Oil & Tanker Trades Outlook presented by Clarkson (2015a).

Generally, there are evident challenges to the overall suitability of secondary data. Mostly, the uncertainties stem from the need to make simplified assumptions using highly volatile and diverging figures in order to fit the purpose of the study. The unavailability of some data also adds to a certain level of imprecision. However, as previously stated, the aim of the study is not to forecast the profitability of the investment in a ship with the highest degree of certainty. Instead, the purpose focuses on evaluating the importance of different factors in relation to each other, in order to assess their importance for an investment decision. For this specific purpose, the collected data is considered adequate. Any uncertainties are tested through the use of sensitivity analyses, in order to strengthen the validity of the study's calculations and its assumptions.

4.3.5.2.2 Precise suitability of data

The *reliability*[14] and *validity*[15] of the data depends on the method by which it has been collected, and its source. These issues can be assessed through evaluating the source of the data, and its authority and reputation (Saunders et al. 2012).

The sources for data collection have been selected carefully in order to secure that they are as reliable as possible. Saunders et al. (2012) consider survey data from large and well-known organisations to be reliable, as their continued existence is based on the creditability of their publications. The sources in this dissertation mainly comprise well-known research organisations, government agencies, shipping companies or brokerages that are highly specialised within shipping. Consequently, their procedures for collecting and compiling the data are likely to be well thought

[14] Saunders et al. (2009, p. 156) define reliability as "the extent to which your data collection techniques or analysis procedures will yield consistent findings".
[15] Saunders et al. (2009, p. 157) define validity as being "concerned with whether the findings are really about what they appear to be about".

through and accurate. The figures retrieved from these sources have often been displayed in official publications (e.g. DMA 2012; Klimt-Møllenbach et al. 2012).

Saunders et al. (2012) however stress the potential impact of *measurement bias* on the precise suitability of data, which can arise due to either “deliberate or intentional distortion of data” or “changes in the way data are collected”. Deliberate distortion of data entails that the primary source deliberately recorded the secondary data inaccurately.

For instance, Saunders et al. (2012) call attention to the frequency of deliberate distortion in organisational records. There is consequently a possibility that the NORDEN annual report (2014) used to retrieve operational and voyage costs is not completely objective. Managers may have incentives for misreporting in order to improve their reports or further a particular cause. This may lead to more distorted data than in the case of research organizations and government agencies reporting on developments in the industry in general. Although deliberate distortion is difficult to detect, it is important to consider the potential pressure or strain on the primary source that may cause incentive for purposeful bias of data (Saunders et al. 2012).

5. Analysis

In this chapter, the results from the analysis conducted in order to answer the research questions will be presented. First, a discounted cash flow analysis of a product tanker investment was conducted, including a sensitivity analysis measuring the impact of a change in each variable in isolation. Following, an extensive analysis on the oil price volatility from 1987-2015 was conducted, as well as a forecast for oil price volatilities one year head. Subsequently, the profitability of abatement strategies for complying with ECA regulations was assessed and measured against the selected baseline value; switching between HFO and LSMGO. The effects of the EEDI and ECO ships were lastly discussed through calculating differences in profitability under different fuel efficiency levels.

5.1 Investment model

5.1.1 Base case

In order to create a baseline for the evaluation of a variable change, the financial performance of a product tanker at present day values[16] was evaluated. The key data and assumptions included in the computation of the baseline investment model are presented in Table 5.1. More detailed calculations for the base case of the product tanker investment model can be found in Appendix D.2.

Input variables	Base case present values
Newbuilding price, $	37 610 000
Loan-to-value ratio	0.6
Loan, $	22 566 000
Maturity annuity loan, years	15
Quarterly payments, $	519 938
Discount rate, %	7
LIBOR, %	0.77
Credit range, %	3.75
Interest rate, %	4.52
Fuel price, $/MT	330.5
Clean MR Spot Earnings, $/day	22 060
Life of vessel, years	20

Table 5.1 Input variables for profitability assessment of a product tanker investment, base case.

[16] All data is collected from quotes on 8 June 2015, unless otherwise stated in the presentation of data in Section 4.

The estimation of the profitability of a product tanker investment is based on the cash flows presented in Table 5.2. The cash flows are derived from the variables in Table 5.1, and the data described in Section 4.3.3.2. As presented in Table 5.1, the investment model assumes that 60 per cent of the vessel is financed by an annuity loan, serviced by quarterly payments and with a maturity of 15 years. All other annual cash flows are expressed over 20 years, which is the assumption of the lifetime of the vessel.

Cash flows	**Base case values, $**
Annual freight revenue	12 402 332
Annual voyage costs	4 350 432
Annual operational costs	2 760 342
Annual debt service	2 079 752
Initial equity outlay	15 044 000
PV Scrap value	2 277 456
Net present value of investment	**24 350 100**

Table 5.2 Profitability of a product tanker investment, base case.

All calculations of voyage- and operational costs are based on the assumption of 365 operating days, of which 220 days are at sea, 115 days are idling and 30 days are unloading. See Appendix C for specific fuel consumption levels for each type of operation.

5.1.2 Sensitivity analysis

In order to measure the impact of fuel price, freight rates, newbuilding price and interest rates, an isolated 20 per cent change was calculated for each individual variable, while holding all other factors constant. The change in each input variable is illustrated in Table 5.3. More detailed calculations for the sensitivity analysis of the product tanker investment model can be found in Appendix D.3.

Changed input variables	**Base case value**	**Increase 20%**	**Decrease 20%**
HFO price, $/MT	330.5	396.6	264.4
Clean MR Spot Earnings, $/day	22 060	26 472	17 648
Newbuilding price, $	37 610 000	45 132 000	30 088 000
Interest rate, %	4.52	5.42	3.62

Table 5.3 Changed input variables for profitability assessments of a product tanker investment, sensitivity analysis.

Each variable change affects different elements of the cash flow from the base case investment model. Tables 5.4-5.7 illustrate the affected cash flow from each variable change, and the consequent net present value. The cash flows that are not included in the table are not affected, and thus equal to the base case value of the cash flow as previously presented in Table 5.2.

For the case of an isolated change in newbuilding price, the loan value is also affected as it is based on a fixed loan-to-value ratio of 0.6. A 20 per cent increase of the newbuilding price yields a loan of 27 079 200 USD, while a decrease will reduce the loan amount to 18 052 000 USD.

Affected cash flows, $	Base case value	HFO price up 20%	HFO price down 20%
Annual voyage costs	4 350 432	4 879 463	3 821 401
Net present value	**24 350 100**	**18 745 534**	**29 954 665**

Table 5.4 Affected cash flows and profitability of a product tanker investment from a 20 per cent isolated change in fuel price.

Affected cash flows, $	Base case value	Freight rates up 20%	Freight rates down 20%
Annual freight revenue	12 402 332	14 012 712	10 791 952
Net present value	**24 350 100**	**41 410 488**	**7 289 711**

Table 5.5 Affected cash flows and profitability of a product tanker investment from a 20 per cent isolated change in freight rates.

Affected cash flows, $	Base case value	Newbuilding prices up 20%	Newbuilding prices down 20%
Quarterly payments	519 938	623 926	415 950
Annual debt service	2 079 752	2 495 702	1 663 802
Initial equity outlay	15 044 000	18 052 800	12 035 200
Net present value	**24 350 100**	**17 552 859**	**31 147 340**

Table 5.6 Affected cash flows and profitability of a product tanker investment from a 20 per cent isolated change in newbuilding price.

Affected cash flows, $	Base case value	Interest rates up 20%	Interest rates down 20%
Quarterly payments	519 938	18 052 800	12 035 200
Annual debt service	519 938	2 208 112	1 955 723
Net present value	**24 350 100**	**23 181 011**	**25 479 748**

Table 5.7 Affected cash flows and profitability of a product tanker investment from a 20 per cent isolated change in interest rate.

As the purpose of the study is to illustrate impact rather than absolute profitability, the level of impact from each change in variable has finally been expressed as the difference in net present value in comparison to the initial base case. The impact of the isolated variable change on the subsequent net present value is presented in Table 5.8.

Difference in NPV from base case, $		
Variable	**Increase 20%**	**Decrease 20%**
HFO price	-5 604 566	5 604 566
Freight rates	17 060 389	-17 060 389
Newbuilding price	-6 797 240	6 797 240
Interest rate	-1 169 089	1 129 647

Table 5.8 Summary of differences in product tanker investment profitability from base case, sensitivity analysis.

5.1.2.1 Freight rates

The initial results of the analysis indicate that freight rates have a substantially larger effect on the financial performance of a product tanker, compared to the other variables considered in the investment model. The 20 per cent change in the value of freight rates results in a difference in net present value from the base case of 17 060 389 USD, which is greater than twice the monetary impact of any of the other variables. Subsequently, the results coincide with the reviewed literature on shipping investment decisions (e.g. Lorange 2005; Stopford 2009; Talley 2012; Karakitsos & Varnavides 2014), which states that freight rates have the single largest effect on a ship's value by increasing the margin for profit or loss for ship owners.

5.1.2.2 Bunker fuel prices and newbuilding prices

The reviewed literature (e.g. Lorange 2005; Stopford 2009; Talley 2012; Karakitsos & Varnavides 2014) also emphasizes the importance of both voyage costs and capital costs for achieving financial performance. Initial results present significant effects from changes in both fuel- and newbuilding prices, indicating a clear impact on profit and loss margins for ship owners. As illustrated in Table 5.8, a 20 per cent variable change increases, or reduces, the net present value of the investment by 5 604 566 USD and 6 797 240 USD, for HFO prices and newbuilding prices, respectively.

5.1.2.3 Interest rates

Stopford (2009), Talley (2012), and Karakitsos and Varnavides (2014) all emphasize a major impact of financing on ship investment. As previously mentioned, the financing terms differ from the other variables of the model, in the fact that they do not drive the market in any way. Rather, careful consideration of both method and terms of financing can ease the difficulties of operating in the volatile shipping market.

The impact form a 20 per cent isolated change in interest rates, is relatively low compared to the other variables in the investment model. This result is however expected, as LIBOR rates are at a historical low and the interest rate assumes a fixed credit margin. Subsequently, assessments based on higher past values of the LIBOR rates are more realistic, and represent a higher difference in value than the 20 per cent variable change. These effects will be presented in Section 5.1.3.

5.1.2.4 Intuition for further analysis

One might question whether variable changes based on more realistic volatilities will affect the results discussed above. The 20 per cent variable change indicates the importance of the different factors affecting the investment decision, and how an equal[17] change in each variable has different impacts on the net present value of the investment. However, this method does not consider that each variable has different levels of volatility. Consequently, the change in each variable may be over- or undervalued. Therefore, the volatility in each variable was assessed in order to evaluate the effects of more realistic changes in the net present value of the product tanker investment. The subsequent results enable more conclusive remarks from the discussions above.

5.1.3 Sensitivity analysis based on volatility

The volatility of each variable was based on weekly data for comparative reasons and all volatilities are expressed in annualized terms. As previously stated, two higher scenarios have been selected for the effects of financing in order to display a more realistic change of the variable. The volatility of interest rates has therefore been excluded from the presentation of volatilities in Table 5.9. More detailed calculations for the sensitivity analysis based on volatilities can be found in Appendix D.4.

Variable	**Annualized volatility, %**
HFO price	37.4
Freight rates	39.1
Newbuilding price	11.3

Table 5.9 Calculated volatilities of investment model input variables, based on data from 2007-2015 for HFO price and freight rates, and on 2013-2015 for newbuilding price.

The volatility of HFO prices and freight rates are based on time series data from 2005. For newbuilding prices, the time series data was only available from 2013. Volatility calculations based on a two-year period can be considered as rather insufficient for assessing fluctuations in variables of an investment over a 20-year horizon. As 11.3 per cent seems unreasonable based on assessments of historical newbuilding price volatility presented in maritime literature (Stopford 2009; Alizadeh & Nomikos 2009), the impact of changes in newbuilding prices are instead based on a reasonability assessment.

[17] Equal in percentage terms.

Figure 5.1 illustrates historical newbuilding price volatility for different sizes of tankers presented by Alizadeh and Nomikos (2009). The figure illustrates a span of roughly 15 to 35 per cent in the volatility for the Handysize tanker[18]. A *newbuilding price volatility of 25 per cen*t has therefore been assessed as realistic to assume for the purpose of illustrating the possible effects on investment profitability from the changing variable.

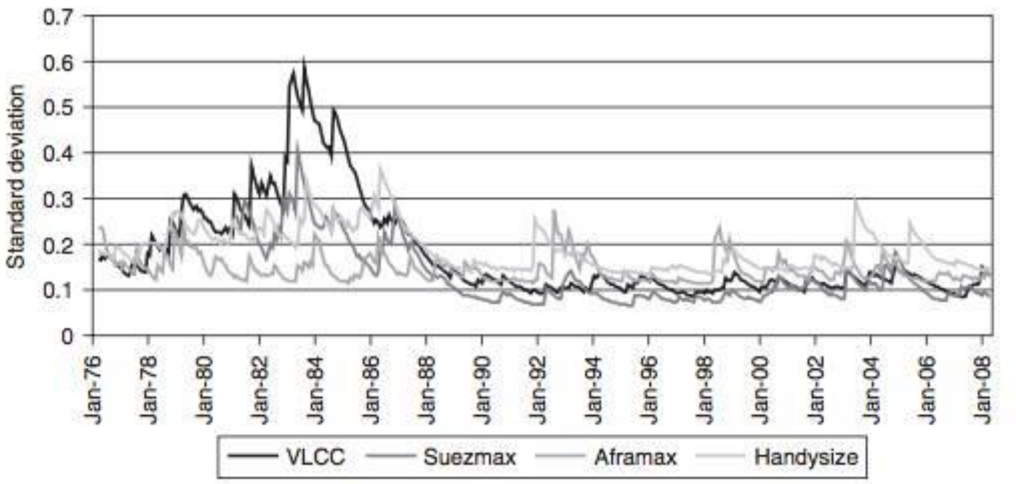

Figure 5.1 Newbuilding price volatility for tankers of different sizes, 1976-2008 (Alizadeh & Nomikos 2009).

The impact of an isolated change in fuel price, freight rates, newbuilding price and interest rates was calculated for each variable, while holding all other factors constant. Table 5.10 illustrates a summary of the affected input values from each isolated variable change in relation to the base case. Tables 5.11-5.14 illustrate the affected cash flows from each variable change in relation to base case cash flows, as well as the computed net present values. As previously, the annual debt service is expressed over 15 years and all other annual cash flows are expressed over 20 years. A 25 per cent variability in newbuilding prices will increase and decrease the loan to the absolute values of 28 207 500 USD and 16 924 500 USD respectively.

[18] The Handysize fits the size of the chosen product tanker for this study (den Boer & Hoen 2015; NORDEN 2014).

Changed input variables	Base case value	Volatility, %	Increase	Decrease
HFO price, $/MT	330.5	37.4	454.1	206.9
Clean MR Spot Earnings, $/day	22 060	39.1	30 688	13 432
Newbuilding price, $	37 610 000	25.0	47 012 500	28 207 500
Interest rate, %	4.52	-	7.71	11.25

Table 5.10 Changed input variables for profitability assessments of a product tanker investment, sensitivity analysis based on volatility

Affected cash flows, $	Base case value	HFO price up 37%	HFO price down 37%
Annual voyage costs	4 350 432	5 339 435	3 361 429
Net present value	**24 350 100**	**13 872 584**	**34 827 615**

Table 5.11 Affected cash flows and profitability of a product tanker investment from a 37 per cent isolated change in fuel price.

Affected cash flows, $	Base case value	Freight rates up 39%	Freight rates down 39%
Annual freight revenue	12 402 332	15 551 395	9 253 270
Net present value	**24 350 100**	**57 711 312**	**-9 011 113**

Table 5.12 Affected cash flows and profitability of a product tanker investment from a 39 per cent isolated change in freight rates.

Affected cash flows, $	Base case value	Newbuilding prices up 25%	Newbuilding prices down 25%
Quarterly payments	519 938	649 922	389 953
Annual debt service	2 079 752	2 599 690	1 559 814
Initial equity outlay	15 044 000	18 805 000	11 283 000
Net present value	**24 350 100**	**15 853 549**	**32 846 650**

Table 5.13 Affected cash flows and profitability of a product tanker investment from a 25 per cent isolated change in newbuilding price.

Affected cash flows, $	Base case value	Interest rates, LIBOR Sep 2008	Interest rates, LIBOR May 2000
Quarterly payments	519 938	637 833	782 905
Annual debt service	519 938	2 551 331	3 131 619
Net present value	**24 350 100**	**20 054 998**	**14 769 784**

Table 5.14 Affected cash flows and profitability of a product tanker investment from an isolated change in interest rates based on LIBOR in Sep 2008 and May 2000.

For the purpose of illustrating impact rather than absolute profitability, the level of impact from each change in variable has again been expressed as the difference in net present value from the initial base case. The results are presented in Tables 5.15 and 5.16.

Difference in NPV from base case, $			
Variable	**Volatility, %**	**Increase**	**Decrease**
HFO price	37.4	-10 477 515	10 477 515
Freight rates	39.1	33 361 212	-33 361 212
Newbuilding price	25.0	-8 496 550	8 496 550

Table 5.15 Summary of differences in product tanker investment profitability from base case, sensitivity analysis based on volatility.

Difference in NPV from base case, $		
Variable	**LIBOR in Sep 2008**	**LIBOR in May 2000**
Interest rate	- 4 295 102	- 9 580 316

Table 5.16 Summary of differences in product tanker investment profitability from base case, sensitivity analysis based on LIBOR in Sep 2008 and May 2000.

5.1.3.1 Freight rates

As presented in Table 5.15, a 39 per cent change in freight rate levels would increase or decrease the net present value of the ship investment by 33 361 212 USD. Consequently, final results still clearly indicate that freight rates have the largest impact on the profitability of the product tanker investment. The conclusion is considered robust, as it is consistent across the sensitivity measures. Moreover, the impact of freight rate levels is substantially higher than the impact of the other variables.

There is consensus in maritime economics literature on that freight rates drive the peaks and troughs of the shipping market, through constantly adjusting to the imbalance of supply and demand, and that revenue is one of the main fundamental variables that drive financial performance (e.g. Stopford 2009; Lorange 2009; Talley 2012; Karakitsos & Varnavides 2014). The continuous adjustment of freight rates is however not considered in the model of this dissertation, as the net present value of the investment models assume constant freight rate levels. Nonetheless, the dual impact of freight rates on ship owners is helpful in understanding the eminent role of freight rate levels on the profitability of the product tanker investment that is suggested by both the analysis and previous literature.

5.1.3.2 Newbuilding prices

An isolated variable change of 25 per cent in newbuilding prices does not impact the net present value to the same degree as a change in freight rates or bunker fuel prices. The analysis does however not consider the second hand market or the potential of extreme changes in the market value of a vessel over short periods of time.

In their paper on trading strategies for the timing of sale and purchase of tanker vessels, Alizadeh and Nomikos (2006) state, “In competitive and cyclical markets, like shipping, timing is in fact everything”. Stopford (2009) supports this statement through presentation of examples through history, of extreme changes in ship value that can influence the profitability of an investment. For example, a VLCC ordered in 1970-1971 at a cost of about 26.4 million USD, could realize a price in the second-hand market of between 61 million USD and 73.5 million USD in 1973. Conversely, VLCCs that had cost 50-60 million USD to build in the mid-1970s fell to a value of only 3 million USD in 1980. This is supported by several examples of extreme asset price changes over a period of only a few years, and illustrates how timing of investment can play a major role in the profitability of ship investments.

Stopford (2009) shows how estimates of the resale price at troughs and peaks can be calculated. At the extremes of the shipping market cycles, peaks and troughs of 70 per cent change in resale value have been observed, which can be applied as a cyclical margin to calculate a value-spread based on the expected resale value of a ship after a given time period after purchase. If one assumes depreciation rate per year of 5 per cent, an inflation rate per year of 3 per cent, and a cyclical margin of 70 per cent, the product tanker considered in this dissertation has a cyclical value range after 10 years of 7.3 million USD and 41.6 million USD.

Residual Value Calculation	
Age at which residual value calculated, years	10
Initial cost of the ship, $	37 610 000
Depreciation rate, % per annum	5
Book value after 10 years	18 805 000
Inflation rate, % per annum	3
Expected residual value, $	24 446 500
Cyclical margin, %	70
Resale price at trough	**7 333 950**
Resale price at peak	**41 559 050**

Table 5.17 Residual value calculation of product tanker at age 10.

In Appendix E the base case investment model has been altered to illustrate the effect of selling the vessel in year 10 at the resale price at a trough and at a peak, in accordance with the values presented in Table 5.17. The model assumes that the remainder of the outstanding debt is settled in year 10, and following the sale of the vessel the cash flows are equal to zero. The NPV of the scenarios are presented in Table 5.18.

Difference in NPV from sale at trough or peak, $	
NPV sale at trough	9 869 523
NPV sale at peak	27 267 828
Difference in NPV	17 398 305

Table 5.18 Differences in profitability from sale at age 10 at trough and peak.

The difference between the NPV of the two scenarios is 17 398 305 USD. It should be emphasized that since the model only considers 10 years of cash flows due to the sale of the vessel, this is a substantial amount when comparing values to the sensitivity analysis based on volatilities. Moreover, if the ship owner were to sell the vessel at the peak cyclical margin value after 10 years, the NPV of the investment would be higher than the NPV from 20 years operation of the vessel presented in the base case.

Based on these indicative calculations and the review of literature, newbuilding prices and timing of investment are considered to be one of the main drivers of the profitability of a product tanker investment. With respect to the initial purchase, the timing of the purchase also affects the capital repayments the ship owner must service over the lifetime of the loan. If a ship owner purchases a vessel when newbuilding prices peak, and the vessel is delivered during a trough in the market cycle, he could experience a negative cash flow, with lower earnings than costs. The fluctuations in the market price of the vessel are also of great interest for banks, as the vessel itself often is the security of the loan (Stopford 2009).

Moreover, Stopford (2009) argues that capital is the cash flow item over which the ship owner has the largest initial control. This factor is not captured by the measured monetary impact on net present value from changes in newbuilding prices.

5.1.3.3 Bunker fuel prices

The impact of a change in fuel prices is substantially higher, when the variable change is based on a volatility of 37 per cent. As illustrated in Table 5.15, the absolute impact on the net present value of the investment amounts to 10 477 515 USD.

Lorange (2005), Stopford (2009) and Talley (2012) present bunker prices as bearing a large impact on the profitability of a ship investment. As the volatility in the price of bunker fuel is underestimated in the 20 per cent variable change, the influence of fuel costs on ship investment profitability is consequently higher than the results presented in Table 5.8. The large impact of bunker fuel prices contribute to the question of whether recent oil price volatilities change the product tanker investment decision in any fundamental way. This issue is further explored in the oil price analysis presented in Section 5.2.

5.1.3.4 Interest rates

Table 5.16 illustrates a significantly higher impact from interest rates based on real historical values. The 12-month LIBOR rate from May 2000 is 7.5 per cent, resulting in an interest rate of 11.25 per cent. The 12-month LIBOR rate from September 2008 of 3.96 per cent, results in an interest rate of 7.71 per cent[19]. This implies that a 20 per cent change in interest rates highly underestimates the real impact that financing can have on the profitability of investing in a product tanker new build. The increases in LIBOR rates reduce the net present value by 9 580 316 USD and 4 295 102 USD, when applying the 12-month LIBOR rate from May 2000 and September 2008, respectively.

As previously presented in Figure 4.1, LIBOR rates have experienced a downward trend and have been at historically low levels following the Financial Crisis of 2008. Although the purpose of this study is neither to assess the historical development in LIBOR rates, nor to make an attempt at forecasting future LIBOR rates, it is feasible to assume that an increase in LIBOR rates at some point in the future is not improbable. A ship owner should therefore not underestimate the effect which the chosen type of financing can have on financial returns of an investment. As companies are tied to a schedule of capital repayments, an unforeseen spike in LIBOR rates could result in a sizeable cost increase, subsequently reducing the profitability of a product tanker investment.

For the lowest increase in LIBOR rates, the effect of the variable change on net present value is smaller than the effect of the volatility-based changes of freight rates and fuel prices. If LIBOR rates were to increase to the level observed in May 2000, the impact on net present value would be almost identical to an increase of bunker fuel prices based on volatility. However, it is important to

[19] As described in Section 4.3.3.2.5, all interest rates applied in the analysis assume a constant credit margin of 3.75 per cent.

emphasize that these variable changes are based on different parameters, and are therefore not entirely comparable.

Nonetheless, the dominance of freight rates, newbuilding prices, fuel prices and financing are considered to be evident based on robust results from the calculations. Moreover, it is considered that the impact of interest rates coincides with the literature, which presents financing terms as a tool for the ship owner to manage his investment, which he has some initial control over.

5.1.4 Part-conclusion

In summary, the results from the investment model calculations are generally in line with the established investment theory presented in maritime economics literature (e.g. Lorange 2005; Stopford 2009; Talley 2012; Karakitsos & Varnavides 2014). Freight rates, newbuilding prices, fuel prices and financing are all key factors that influence the profitability of a product tanker investment. The remaining question is whether the ship owner faces greater uncertainty in the investment decision than previously, based on developments in oil price volatility, ship design and environmental regulations, and how these factors affect the profitability of the investment. These issues are considered in the following Sections 5.2-5.4.

5.2 Oil price volatility

According to Ebrahim et al. (2014), the volatility of crude oil prices has been increasing more rapidly than the volatility for other commodities in the past decade. Although the major impact of bunker price risk on shipping operations is established in literature (e.g. Stopford 2009; Talley 2012; Alizadeh & Nomikos 2009), the impact of a potential change in volatility needs to be considered.

5.2.1 Historical oil price development

As previously mentioned, movements in bunker fuel prices are driven by, and highly correlated with, movements in crude oil prices (Alizadeh & Nomikos 2009; UNCTAD 2010). Consequently, the Europe Brent Spot Price FOB is considered to be a suitable proxy to measure volatility exposure of shipping companies to bunker fuel prices. The time series data from 1987 to 2015 is illustrated in Figure 5.2, and provides the base for the statistical analysis of the crude oil price volatility during this period.

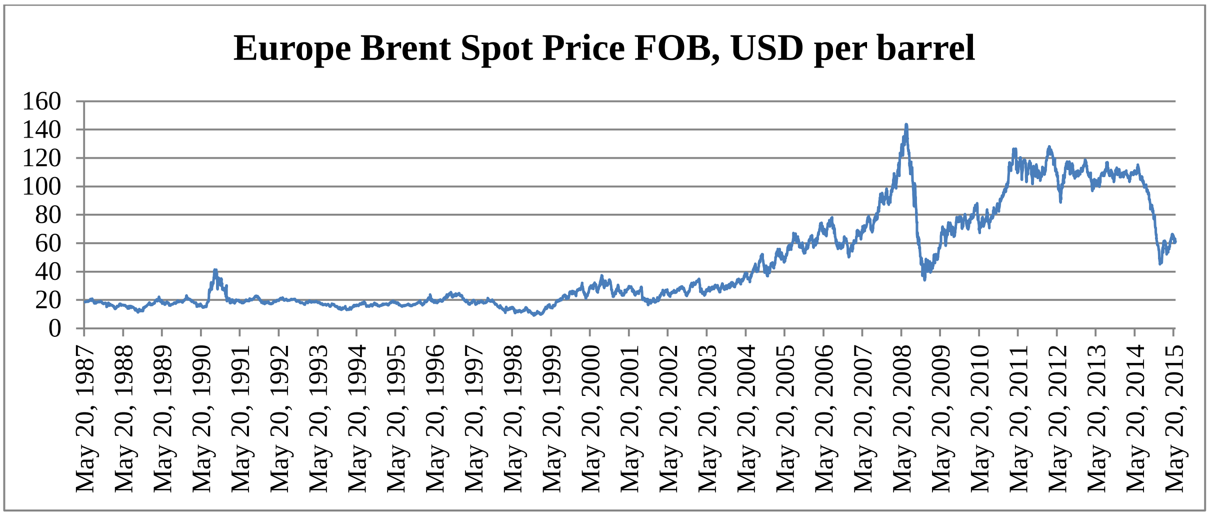

Figure 5.2 Europe Brent spot price FOB (USD per Barrel), 1987-2015, daily quotes.

The time series data has an annual standard deviation over the period 1987-2015 of *36.02 per cent* (Appendix F.1). The standard deviation for each individual year[20] of the series is presented in Figure 5.3.

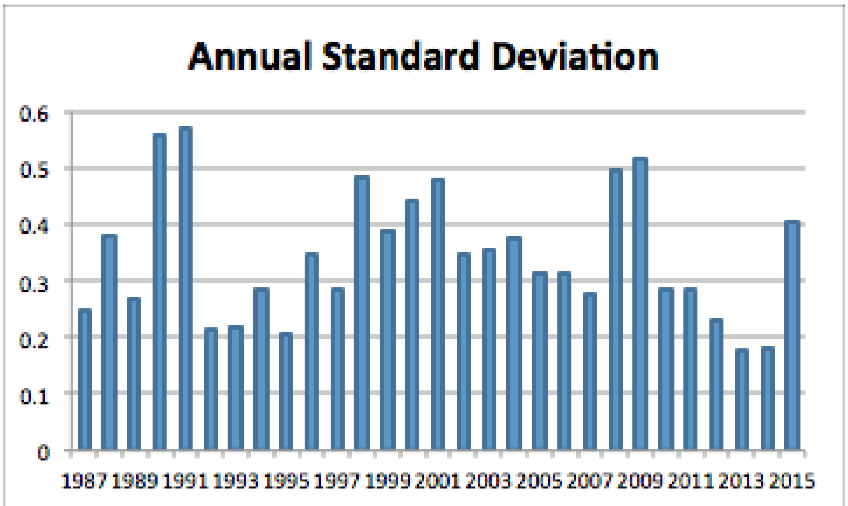

Figure 5.3 Annual standard deviation of Europe Brent spot price, 1987-2015.

The data illustrates a rather stable price development throughout the 1990s, with the exception of the period 1990-1991, which marks the oil price shock driven by the Persian Gulf War. The most apparent oil price shock in the time series is the peak and collapse coinciding with the Financial Crisis of 2008. Following this shock, the development of the crude oil price in Figure 5.1 appears to

[20] Data from 1987 only runs from 8 May, and data from 2015 only runs until 8 June.

be considerably less stable. However, for the years from 2010 up to and including 2014, the annual standard deviation (Figure 5.3) appears relatively low compared to surrounding years. This indicates that the daily changes in return have been lower during this period, than the two previous years of the Financial Crisis. While considering the development in price at the same time (Figure 5.2), it indicates that the price has been increasing steadily, but without periods of large fluctuations relative to the previous two years.

Ultimately, Figure 5.3 implies that the annual standard deviation itself varies to a great extent across the years of the data.

5.2.1.1 Volatility in Different Time Periods

In order to answer whether the oil price volatilities over the past decade have influenced product tanker investments in any fundamental way, it was purposeful to establish whether the volatility during this period was in fact different from the volatilities of previous periods. Due to availability of data, the volatility was assessed from June 1987 until June 2015.

From the annualized standard deviation per year, previously presented in Figure 5.3, there is no obvious tendency of an increase in standard deviation in recent years. In order to test for differences, the time series was therefore divided into three time periods. They run from 1987-1997, 1997-2006 and 2006-2015, and are throughout the dissertation referred to as the 87-97, 97-06 and 06-15 series, respectively[21].

The annual standard deviation, calculated from daily quotes, for each of the three periods is presented in Table 5.19. The period with the highest standard deviation was 97-06, and the last period 06-15 exhibited the lowest volatility, measured in annual standard deviation.

Period	1987-1997	1997-2006	2006-2015
Annualized standard deviation, %	35.53	39.08	33.37

Table 5.19 Annualized standard deviation for Europe Brent spot FOB, daily observations for 87-97, 97-06, and 06-15.

However, one might argue that shipping operations are not as sensitive to daily fluctuations in bunker prices as they are to monthly fluctuations, which indicate the level of price changes over a

[21] As the time series starts and ends on 8 June, the series are adjusted to this accordingly, i.e. each period begins on 8 June in the first year of the respective period and runs until the beginning of the next period.

longer horizon. The annualized standard deviations based on monthly observations are illustrated in Table 5.20. The highest standard deviation is still during the 97-06 series. However, the difference of 0.2 per cent from the 06-15 series is marginal, and can hardly be considered significant. Thus, based on monthly observations, it appears that the standard deviation is lowest in the 87-97 series, while the crude oil price is most volatile from 1997 through 2015.

Period	1987-1997	1997-2006	2006-2015
Annualized standard deviation, %	28.42	32.22	32.02

Table 5.20 Annualized standard deviation for Europe Brent spot FOB, monthly observations for 87-97, 97-06, and 06-15.

It is also noteworthy to mention that the Europe Brent Spot FOB was selected in favour of the EIA Monthly Average Imported Crude Oil Price, in order to be able to construct a GARCH model and forecast the volatility[22]. However, when considering the EIA Monthly Average Imported Crude Oil Price (quoted in real values), the standard deviation measures for the selected time periods show different results than for the Europe Brent Spot FOB, as illustrated in Table 5.21.

Period	1987-1997	1997-2006	2006-2015
Annualized standard deviation, %	24.66	28.44	30.32

Table 5.21 Annualized standard deviation for EIA monthly average imported crude oil price, monthly observations for 87-97, 97-06, and 06-15.

The imported crude oil prices show that standard deviation has been increasing over the three periods. Similarly, the mean of the real crude oil price has also increased over the periods (Appendix F.6). The crude oil import prices are influenced not only by supply and demand, but are recorded at the time of import and include the subsequent cost, insurance and freight (OECD, 2015). Subsequently, they illustrate a more realistic picture of the consumers crude oil cost than the FOB cost, which in a report by Food and Agriculture Organization of the United Nations (2011) is described as having “the disadvantage that the development in transportation costs are not taken into account”.

[22] Imported crude oil prices were only obtainable in monthly quotations, which provided insignificant and erroneous results in the GARCH process modelling.

Figure 5.4 presents the standard deviation based on monthly quotations, measured through a 12-month moving average (Appendix F.3). The variation of the volatility is through this application smoothed out, to some extent, in comparison with the conventional standard deviation calculation. Consequently, the shocks and differences in the volatility are more apparent.

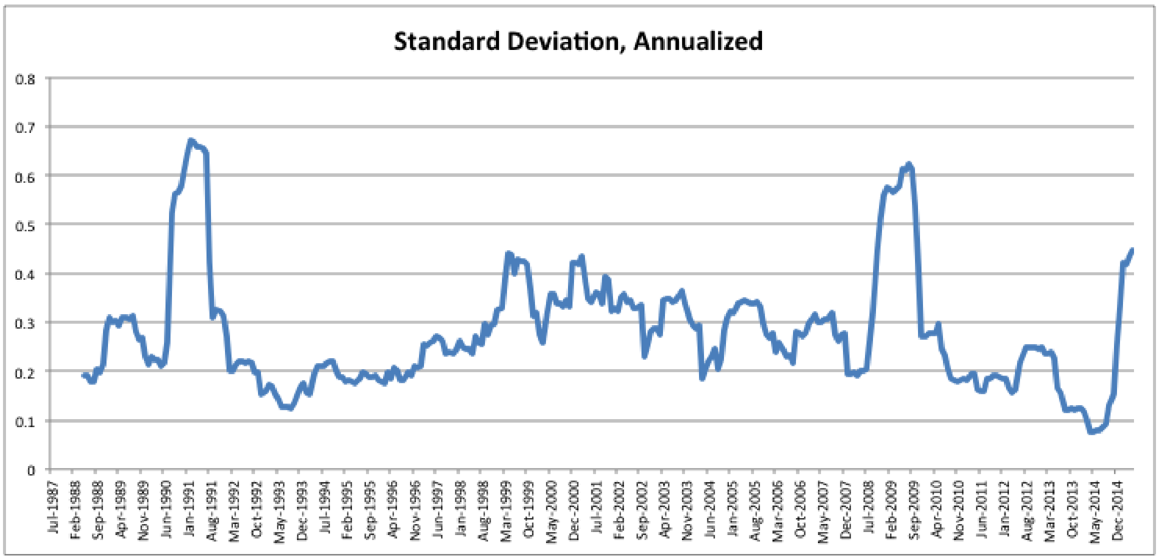

Figure 5.4 Annualized standard deviation of EurBrent 1987-2015, 12-month moving average.

The major spike at the end of the time series marks the recent significant volatility increase during the collapse of the oil price, and illustrates a highly uncertain environment. An oil market report of the International Energy Agency (2015) highlights that the factors contributing to the latest price correction bear little resemblance to previous price drops of 1991 and 2008, and only shares a few common features with the big correction of 1986.

In contrast, in a report for the World Bank Group, Baffes et al. (2015) underline that the recent drop in the oil price is *not* an unprecedented development. During the past three decades, a significant decline of 30 per cent or more has occurred within 7-month periods, and the recent decline bears high resemblance to the decline in 1985-1986. The causes of decline are complex and difficult to ascertain the relative impact of. According to Baffles et al. (2015) they include the increased production of unconventional oil over several years, a weakened global demand, geopolitical risks, the strengthening of the US dollar and a shift in OPEC's policy; renouncing price support.

The different emphasis and interpretation of the oil price development highlights the complexity of the issue, and the difficulty to draw any robust conclusions from simple calculations. This is also illustrated by the results from our calculations in Table 5.19-5.21. However, what we have established with a high degree of certainty is that the period from 1987 until 1997 appears to be the least volatile during the analysed time period. Based on the assumption that the global shipping market is not as impacted by the daily fluctuations in fuel prices, as the more consistent development that is portrayed by the monthly measure of volatility, we assume that the period from 1997 to 2006 is not more volatile than the period from 2006 to 2015. The monthly fluctuations also somewhat reduce the effect of extreme outlier observations. Moreover, as imported crude oil prices provide a more realistic price depiction than FOB prices, it is considered reasonable to assume that the volatility may in fact be highest between 2006 and 2015 as suggested by Ebrahim et al. (2014).

5.2.2 Forecasting volatility

The method of statistical analysis of the future oil price volatility depended on whether the prices were stationary. In the case of a price series being non-stationary, conventional methods for hypothesis testing, confidence intervals and forecast can be unreliable (Stock & Watson 2012). Subsequently, the establishment of this issue, and the handling of the data thereafter, are presented prior to the forecast of the volatility of the crude oil price. For the purpose of forecasting volatility, daily observations have been applied in the econometric modelling in order to produce robust results[23].

5.2.2.1 Stationarity of data

The ADF test for a Unit Autoregressive Root was applied in SAS Enterprise Guide 6.1 in order to test for the presence of a stochastic trend in the crude oil price data.

The results from the ADF test (Appendix G.1) presented an F-statistic for which the null hypothesis of the presence of a stochastic trend could not be rejected. The time series data was therefore differenced and the ADF-test was then repeated on the return series, named dBrent. The subsequent ADF test performed on the dBrent series provided an F-statistic of 923.59, and the null hypothesis was rejected at the 1 per cent-level (Appendix G.3). This means that the data is stationary, and the return series dBrent was therefore considered adequate for the purpose of constructing a GARCH

[23] The GARCH process modelled in Section 5.2.2.2 is not able to produce robust results when applying monthly observations of crude oil data.

model to forecast volatility. The dBrent series is therefore the time series referred to throughout the rest of the analysis of the oil price, unless otherwise stated.

5.2.2.2 GARCH modelling of time series

In order to forecast the volatility of the crude oil price, a GARCH model was constructed in SAS. SAS Enterprise Guide can only build ARCH and GARCH models when the mean equation is estimated through an AR(p)[24] model. We therefore only estimated an AR model (rather than an ARMA or ARIMA[25], which could potentially be a better fit for the mean equation), before we proceeded to model the volatility forecast.

In order to fit an AR model, the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots of the residuals were constructed (Appendix G.4). The PACF appeared to have a significant spike in the first lag. However, as there could be less apparent significant spikes in lags up to 14, a test of the significance in the lags was performed in order to establish which model was the best fit.

The data was tested through 14 lags, and lags of 1, 6, and 14 were found to be significant at the 1 per cent-level (Appendix G.5). To our knowledge, there is no seasonality driver or contracts for crude oil that mature every 6^{th} or 14^{th} trading day. Ideally, one would therefore wish to proceed with the AR(1) specification of the mean equation, in order to fit an AR(p) - GARCH (p, q) in its most common form; the AR(1) – GARCH (1,1).

In order to construct any ARCH model, the data needs to exhibit ARCH disturbances, i.e. volatility clustering. The test for ARCH effects provided a Q-statistic 517.25 at 12 lags. Subsequently, the null of no ARCH effects through 1 to 12 lags was rejected (Appendix G.11). The data is therefore adequate for the construction of a GARCH model to forecast volatility[26].

[24] An AR(p) model is an autoregressive model that relates a time series value to its past value. The p-notation yields the p^{th}-order of the model, specifying the number lagged values used to model the value. In the AR(p) model, the regressors are $Y_{t-1}, \dots, Y_{t-p}$ (Stock & Watson 2012).

[25] The autoregressive-moving average (ARMA) model is an extension of the autoregressive model that models the mean as serially correlated, by including a "moving average" of the unobserved error term. In practice the ARMA model is more difficult to estimate, and to extend to additional regressors, than the AR models (Stock & Watson 2012).

[26] Before modelling the AR(p)-GARCH(p,q) models, AR(p)-ARCH(q) models where constructed in order to see whether they appeared to be a good fit. As the AR(p)-GARCH(p,q) models where a better fit, the ARCH models will not be presented in the analysis. They can be seen in Appendix G.12 and Appendix G.14.

The processes of AR(1)-GARCH(1,1), AR(6)-GARCH(1,1) and AR14-GARCH(1,1) were modelled. From the results presented in Table 5.22, it is apparent that the AR(1) mean equation is the best fit for the GARCH model, as it has both the lowest AIC[27] and SBC[28] values at 29.874 and 29.908, respectively (Appendices G.13; G.15; G.16). As previously mentioned, this is ideal as we are not aware of any seasonal trends that indicate that 6 or 14 are a reasonable specification of lags.

Model	**AIC**	**SBC**
AR(1)-GARCH(1,1)	29.874	29.908
AR(6)-GARCH(1,1)	29.879	29.948
AR(14)-GARCH(1,1)	29.878	30.002

Table 5.22 AIC and SBC values for AR(p)-GARCH(p, q) models.

The parameter estimates from the AR(1)-GARCH(1,1) process modelled in SAS can be found in Appendix G.13. The model estimates the mean equation and the future volatility as:

$$y_t^2 = 0.0280 - 0.0435\, y_t + u_t$$
$$(0.0210)\quad (0.0126)$$

$$\sigma_t^2 = 0.0350 + 0.0759\, u_{t-1}^2 + 0.9206\, \sigma_{t-1}^2$$
$$(0.005169)\quad (0.003455)\quad (0.003727)$$

All the parameter estimates are statistically significant at the 1 per cent-level, except for the intercept of the mean equation. This indicates that the intercept, or the constant term, adds little to the model. Because the intercept is not statistically different from zero, the mean is also not statistically significant from zero (Brooks & Burke 1998). The closer the coefficient of the mean equation is to one, the more the mean equation will resemble a *random walk*[29], where the best prediction of tomorrow’s value is the value of the variable today (SAS Institute 2009). Ultimately,

[27] Akaike’s Information Criterion (AIC) is a measure of the distance between estimated parameters and the true value. When comparing different models, the model with the lowest AIC is the best fit (Hu 2007).
[28] Schwarz Bayesian Criterion (SBC) is also known as the Bayesian Information Criterion (BIC) or Schwarz Bayesian Information Criterion (SBIC). The term is similar to the AIC, but has a higher penalty term for overfitting of models (Bierens 2006).
[29] A data set following a random walk constitutes a sequence of random steps, or observations, and thus do not follow a pattern (Stock & Watson 2012).

due to the presence of volatility clustering, the prediction of price is highly complex, and the model is first and foremost suited for forecasting the volatility (Stock & Watson 2012).

5.2.2.2.1 Fitted volatility of the return series

The fitted volatility (standard deviation) and standardized residuals of the series was computed by extracting an output data set containing the conditional error variance and the residuals from the AR(1)-GARCH(1,1) model in SAS. The variables in the series were computed as following:

vhat = $\sqrt{cev}$

stand_resid = $\frac{resid}{vhat}$

where,			
	vhat	=	the fitted volatility, or standard deviation
	cev	=	the conditional error variance
	resid	=	residuals
	stand_resid	=	standardized residuals

The line plot of the fitted volatility (Appendix G.17) illustrates the conditional, i.e. non-constant, variation in the price movements examined in Figure 5.4 previously. The major spike in volatility observed in the early 1990's is the massive one-day decline in oil prices that occurred on January 17th 1991, when the US President George H W Bush retracted oil from the Strategic Petroleum Reserve prior to the first Gulf War (Musante & Goldman 2008). This is the largest one-day decline observed during the period. With the exception of this extreme outlier, the 97-06 series appears to have more tranquil volatility fluctuations than the subsequent periods.

5.2.2.2.2 Inspection of the autocorrelation function of the standardized residuals and the squared standardized residuals

The ACF of the standardized residuals was inspected in order to assess whether the true variance process is different than the one specified by the model (Engle 2001). The ACF plot of the standardized residuals (Appendix G.18) appears smooth and indicates that the residuals are white noise, i.e. that the model is a good fit. This was confirmed by an autocorrelation check of the standardized residuals, which could not reject the null of white noise through any of the lags at the 5 per cent-level. However, the ACF plot of the *squared* standardized residuals (Appendix G.19) does not exhibit the same smoothness, and the autocorrelation check of the squares has low p-values through the lagged values. This indicates that the true process could potentially deviate from the process of the model. However, with ARCH effects present, and the AR(1)-GARCH(1,1) model being the best fit of the significant ARCH and GARCH models estimated in SAS; it was decided to proceed with the model, and rather handle the results with caution.

5.2.2.2.3 GARCH(1,1) one-year-ahead forecast of volatility

The forecast of the volatility was done by applying the GARCH(1,1) parameter estimates for the volatility equation (Appendix H). 252 out of sample predictions were made based on the assumption of 252 business days per year (Appendix H.3). The GARCH(1,1) estimates of volatility were constructed throughout the data sample, and for 252 out-of-sample predictions where the residuals and cev in the equation are substituted for the previous day GARCH estimated variance. A line plot of the estimates for each day is presented in Figure 5.7.

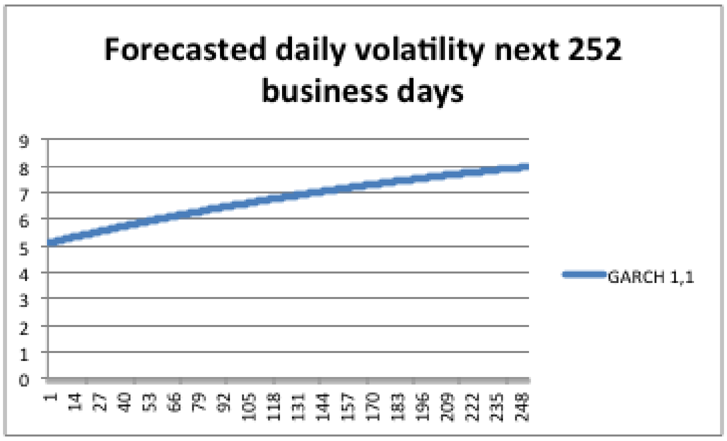

Figure 5.5 One year ahead, out-of-sample predictions for daily variance of crude oil price returns.

The forecasted annualized standard deviation for June 8 2015 through June 8 2016 is then calculated from the out-of-sample predictions as:

Forecasted volatility one-year ahead = $\sqrt{\frac{\sum_i^n GARCH(1,1)_i}{n} * 252}$ = 41.19%

where, $GARCH(1,1)_i$ = the variance estimates out of sample

N = the number of observations, here 252

252 = assumption of business days per year, to annualize the standard deviation

As the GARCH parameter estimates fulfil the condition $\alpha + \beta < 1$, the out-of-sample forecast will move closer towards the long-run standard deviation of 49.62 per cent (Appendix H.4), with each out-of-sample period added. Eventually, the distant-horizon forecast will be equal to the long-run variance (Engle 2001). Consequently, the model predicts a high long-term volatility, as the out-of-sample forecasts are increasing over the one-year period and the predicted volatility of 41.19 per cent indicates a high level of uncertainty. This agrees well with the report "Resilience in a Time of Uncertainty: Oil Prices and the Energy Industry" published by EY in 2015. EY conclude that the oil industry is facing a high level of uncertainty ahead, and emphasize the impact of oversupply of oil in the market and the US shale "revolution", on deteriorating oil prices since the last quarter of 2014. Moreover, they point out these factors and the difficulty of estimating global oil demand as key uncertainties facing the industry.

Applying the volatility to the bunker fuel price with the same intuition as the sensitivity analysis, one could consider the impact of an increase, or decrease, in the price by 41.19 per cent. As previously mentioned, the HFO price on 8 June was 330.5 USD per MT. An increase equal to the standard deviation would therefore result in a price of 446.6 USD per MT, while a decrease would result in a price of 194.4 USD per MT.

Table 5.23 illustrates the cash flow effects of the forecasted volatility. An increase or decrease of 41 per cent in bunker fuel prices, would impact the net present value of the product tanker investment in our analysis by an absolute value of 11 542 603 USD. More detailed calculations on the effects on profitability from the forecasted oil price volatility can be found in Appendix D.5.

Affected cash flows, $	**Base case value**	**HFO price up 41%**	**HFO price down 41%**
Annual voyage costs	4 350 432	5 439 972	3 260 892
Net present value	**24 350 100**	**12 807 497**	**35 892 703**

Table 5.23 Affected cash flows and profitability of a product tanker investment from a forecasted fuel price volatility scenario of 41 per cent.

Within the data sample of the model, the sum of the prediction error of the volatility estimates only sums up to 2.97 percentage points, indicating that the model is a relatively good fit within sample (Appendix H.2). However, a low value of within-model error does not mean that the model correctly forecasts the future. As Fabozzi et al. (2007) emphasize, historical performance does not provide information of the changes in the market and economic conditions that may influence the performance in the future. Nevertheless, these conditions are either highly complex or near impossible to predict, and thus a forecast based on historical values is the best estimate available for the objectives of this dissertation.

5.2.2.2.4 GARCH Modelling of Different Time Series

In order to consider how these periods forecast future volatility in relation to each other, AR(1)-GARCH(1,1) processes were modelled for each time period (Appendices I; J; K).

Each subsequent model could in theory be applied to forecast the volatility for one year ahead of the respective time period. However, Fabozzi et al. (2007) stress that forecasts based on historical data are strengthened by the longitude of the time series. Subsequently, it is assumed that the forecast provided by the GARCH model of the entire time series is a more robust estimate of the future than the information provided by the models for any of the three divided time periods. The models are therefore only used in order to illustrate structural differences.

For all three time periods, the data needed to be differenced in order to reject the presence of an autoregressive unit root (Appendices I.3; J.3; K.3). This procedure was executed in the same manner as for the entire time series data, with an ADF test. The results from the GARCH process modelling are presented in Table 5.24. As for the model of the entire time series, only parameter estimates in the mean equation suffer from insignificance. The results from the entire process in SAS can be found in Appendices I, J and K.

	AR(1)-model	**GARCH(1,1)-model**	**Insignificance**
1987-1997	y_t^2 = 0.000340 - 0.0760 $y_t + u_t$	σ_t^2 = 0.0698 + 0.0989 u_{t-1}^2 + 0.8882 σ_{t-1}^2	AR Intercept not significant
1997-2006	y_t^2 = 0.1260 - 0.0234 y_t + u_t	σ_t^2 = 0.3546 + 0.0841 u_{t-1}^2 + 0.8586 σ_{t-1}^2	AR1 not significant
2006-2015	y_t^2 = 0.129 - 0.0271 y_t + u_t	σ_t^2 = 0.009804 + 0.0473 u_{t-1}^2 + 0.9517 σ_{t-1}^2	AR1 not significant

Table 5.24 AR(1)-GARCH(1,1) models for time periods 87-97, 97-06, and 08-15.

The differences in the equations provide information of to what degree the volatility in the different time periods depends on past values. The most obvious difference in the models is that for the 06-15 series, the model fits the variance as being a lot more dependent on past variance, than the other series. This is expressed in the GARCH1-parameter, which is 0.9517 for the 06-15 series, and 0.8882 and 0.8586 for the 87-97 and 97-06 series, respectively. This could imply that large volatility shocks will be followed by larger volatility to a greater extent than in previous decades. The closer the coefficient of the mean equation is to one, the more the mean equation will resemble a *random walk*[30], where the best prediction of tomorrow's value is the value of the variable today (SAS Institute 2009). Subsequently, this brings forth the question of whether the high volatility in the 06-15 series may in part be a consequence of a high dependence on past values, and thus high levels of volatility clustering.

5.2.3 Implications

The impact of volatility in bunker fuel prices on the global shipping market is a complex matter. Firstly, the impact of the collapse of crude oil prices has had diverging effects for different stakeholders in the global economy, especially with regard to whether countries import or export oil (Baffes et al. 2015). However, a more general view of the impact on the global economy is that it has been weakened by the decreased demand for oil, accompanied by an over-supply of the commodity. This in turn affects shipping markets (BIMCO 2014a).

Stopford (2009) explains how the world economy is a key factor influencing demand in the shipping industry, which in turn influences changes in freight rates. As oil price volatility affects the global economy, one might argue that oil price volatility could have an impact on the ship owner's investment not only through the costs of fuel, but also through extreme oil price fluctuations affecting freight levels. As our investment model in Section 5.1 suggests that freight rates have the largest impact on investment profitability, the impact of oil price shocks may potentially have major effect on the financial performance of the vessel.

As bunker prices make up a large proportion of the cost of operating a vessel, the price decrease also means a significant cost saving. In November of 2014, BIMCO reported that a ship that burns 24 tonnes of fuel per day could save up to USD 1 million[31] in fuel costs per year, when comparing the price at the time with the average price of the first half of 2014. This effect coincides with the analysis results presented in Section 5.1, suggesting high margins for profit and loss from changing bunker fuel costs for ship owners.

[30] A data set that follows a random walk constitutes a sequence of random steps, or observations, and subsequently does not follow any pattern (Stock & Watson 2012).
[31] Based on the assumption of a sailing time of 70 per cent, and HFO prices in Rotterdam of 578 USD and 412 USD, for the average of the first half of 2014 and the time of the report, respectively (BIMCO 2014a).

Moreover the impact of oil price volatility affects the tanker market differently than for instance the dry-bulk market or the container shipping market. Specifically, low crude oil prices strengthen earnings for product tanker vessels as a result of increased demand (BIMCO 2015). Hence, the impact of a low bunker fuel price lies not only in that it decreases voyage costs for the ship owner, but it also increases the earnings through higher freight rates. Ultimately, higher volatility in crude oil prices may in fact increase the uncertainty of product tanker earnings and potentially *increase* the ship owner's margins for profit and loss.

By looking specifically at the nature of oil price volatility of the past decade in relation to earlier periods, the possibility of a fundamental influence on the product tanker investment can further be assessed. The period from 1987 until 1997 exhibits the lowest level of volatility in the EurBrent series to a high degree of certainty, measured by the conventional method of sample standard deviation. The difference in volatility between the 97-06 and 06-15 series is however less clear. The volatility appears to be the highest either in 97-06 alone, or in both series. However, volatility measurements based on the imported crude oil price indicate that the 06-15 series is the most volatile period. Another interesting observation in the 06-15 series, is higher levels of volatility clustering in comparison to previous decades. This could potentially affect the investment decision of ship owners. A higher level of volatility clustering would indicate that large fluctuations in the crude oil price tend to be followed by further large fluctuations[32], and small fluctuations tend to be followed by small fluctuations (Cont 2007). If a market shock affects the global economy, this impact will consequently be felt for a longer time with higher levels of volatility clustering.

The question is what possible effects these indications of increased levels of volatility clustering could have on the ship owner. During periods with bursts of high volatility, it becomes impossible to predict fuel prices. Even though clusters of volatility create a relatively good base for the prediction of volatilities, the GARCH model does not consider direction of such variations in the fuel price. This increases the risk associated with a product tanker investment.

In fact, an isolated variable change coinciding with the forecasted volatility of 41.19 per cent in the investment model shows substantial effects on investment profitability from such variability in the HFO price. It is apparent that an increased volatility in oil prices is important for the product tanker

[32] Fluctuations in volatility, i.e. regardless of whether the change is price is positive or negative.

investment, and bear synergistic effects. However, the effect of increased oil price volatility does not only affect the freight rates and cost levels of the ship owner operating a product tanker in the spot market. In Section 5.3-5.4 the impact of oil price volatility on new uncertainties facing the ship owner's choice of design, due to environmental regulations, will also be assessed.

5.3 Regulations and ship design

The analysis presented in Section 5.1 does not consider the impact of environmental regulations and ship design considerations in the product tanker investment decision. Instead, analysis of the abatement strategies for complying with ECA regulation and impact of the EEDI will be presented in the following section. As previously, monetary values will be derived for each factor, in order to compare the monetary impact with the variables considered in the investment model in Section 5.1.

It should be highlighted that the purpose of the calculations on abatement strategies is not to evaluate the optimal strategy to adhere to ECA regulations. The purpose of the cost comparisons between the various alternatives is rather to illustrate whether current and future regulations have an effect on ship design issues for the ship owner's investment decision.

5.3.1 The importance of ECA Regulations for design issues

The assessment of abatement strategies for complying with ECA regulations derives profitability in each strategy as the difference in monetary value from the base case – the use of LSMGO when travelling within an ECA – from each strategy. The two subsequent strategies considered are the use of scrubbers, and the use of LNG.

Tables 5.25 and 5.26 illustrate the base case for the evaluation of fuel price change, where design profitability is calculated under present day fuel prices[33]. Table 5.25 presents the input fuel prices assumed for the calculations and Table 5.26 illustrates the minimum number of days a year a product tanker must travel within an ECA, for a scrubber or use of LNG to be profitable.

Calculations have measured the amount of days that provide a net present value of 0. Again, all calculations of voyage- and operational costs are based on the assumption of 365 operating days, of which 220 days are at sea, 115 days are idling and 30 days are unloading (see Appendix C for specific fuel consumption levels for each type of operation).

[33] All fuel prices are collected from quotes on 8 June 2015

Fuel type	Base case prices, $/MT
HFO	330.5
LSMGO	550.5
LNG	536.9

Table 5.25 Input fuel prices for assessment of minimum amount of days spent in ECAs for abatement strategy profitability, base case.

Days in ECA, scrubber	Days in ECA, LNG
97	No solution

Table 5.26 Minimum amount of days spent in ECAs for abatement strategy profitability, base case.

Based on the given fuel price levels, a product tanker must sail within an ECA for a minimum of 97 days a year for the investment in a scrubber to be a more profitable alternative than the use of LSMGO. Results also show that option of investing in a new product tanker running on LNG is not feasible under present day fuel price levels and cost of implementation. The up-front costs of a ship design that can run on LNG are significant in relation to using LSMGO, whereas the differences in fuel price levels between LSMGO and LNG are minimal.

5.3.2 Sensitivity analysis

As it is unrealistic to assume that the fuel prices will stay constant over the lifetime of a product tanker, a 20 per cent increase and decrease has been applied to each fuel type. For the profitability assessments, the same method as for the base case has been used. Table 5.27 and 5.28 illustrate the minimum amount of days inside an ECA required for scrubber- and LNG profitability with an increase and decrease of 20 per cent for each fuel type, respectively.

20% fuel price increase			
Fuel type	**Fuel price, $/MT**	**Days in ECA, scrubber**	**Days in ECA, LNG**
HFO	396.6	No solution	No solution
LSMGO	660.6	59	158
LNG	644.3	97	No solution

Table 5.27 Input fuel prices and minimum amount of days spent in ECAs abatement strategy profitability, sensitivity analysis.

20% fuel price decrease			
Fuel type	**Fuel price, $/MT**	**Days in ECA, scrubber**	**Days in ECA, LNG**
HFO	264.4	69	No solution
LSMGO	440.4	268	No solution
LNG	429.5	97	170

Table 5.28 Input fuel prices and minimum amount of days spent in ECAs for abatement strategy profitability, sensitivity analysis.

5.3.2.1 Impact of change in HFO price

A vessel with a scrubber can run solely on HFO within an ECA (see Table 4.1 in Section 4.3.2.3). Subsequently, an isolated 20 per cent increase in the price of HFO makes the investment in a scrubber less profitable. As illustrated in Table 5.27, the investment of a scrubber is not profitable[34] for any amount of days traveling within an ECA in this fuel price scenario. Conversely, a 20 per cent decrease in the HFO price further increases the profitability of an investment in a scrubber compared to the base case. Under this scenario, the ship owner would only have to sail 69 days in a year within an ECA for the scrubber design to be profitable, in relation to the required 97 days for the base case.

Any fluctuations in the price level of HFO do not affect the decision to investment in a product tanker running on LNG. The amount of HFO used outside regulated areas is the same, regardless of the use LSMGO or LNG as fuel inside an ECA.

5.3.2.2 Impact of change in LSMGO price

A 20 per cent increase in the price of LSMGO price makes the design less attractive due to increases in fuel cost, and decreases the required amount of days spent in an ECA to 59 for scrubber profitability. The opposite effects are present during a 20 per cent decrease in the price of LSMGO; a minimum of 268 days in an ECA are required for the choice of a scrubber to be more beneficial than switching between HFO and LSMGO.

Similar to the investment in a scrubber, a 20 per cent increase in the price of LSMGO will increase the economic viability of a vessel running on LNG. For such a price level, a product tanker would instead have to spend 158 days in ECA for the investment to be profitable. However, a 20 per cent decrease in the LSMGO price levels further lowers the viability of an LNG design in relation to the base case.

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[34] Measured in relation to the base case of switching to LSMGO when traveling within an ECA.

5.3.2.3 Impact of change in LNG price

Any changes in the price of LNG, holding other fuel prices constant, will not directly have an effect on the profitability of a scrubber as the design solely runs on HFO. However, a decrease in LNG price levels now makes the design profitable. A product tanker would have to spend 170 days in an ECA for the design to be feasible. As present day fuel price levels illustrated in the base case makes the investment in a vessel running on LNG economically unviable, an increase in the price of LNG will consequently further decrease the profitability of such an investment.

Overall, calculations illustrate that the choice of abatement strategy is highly sensitive to the relative fluctuations in fuel prices. This could suggest that regulations have made design issues in the investment decision more sensitive to fuel price volatilities.

5.3.3 Sensitivity analysis based on volatility

Similar to the sensitivity analysis in Section 5.1, the historical volatility of each fuel type was assessed in order to evaluate the effects of more realistic changes in value. Weekly observations were selected for comparability, and the volatilities were annualized. The LNG price data was available from 2007, and for comparative reason the HFO price volatility was based on the same time period. Calculations presented us with an annualized volatility of 38.9 and 54.4 per cent for HFO and LNG respectively.

As previously stated, time series data for LSMGO was not obtainable. Both the LSMGO price and volatility is therefore based on quotes provided by Bunkerworld (2015b). When annualized, an estimate of 45 per cent for the LSMGO volatility could be made and applied in the subsequent analysis.

Tables 5.29 and 5.30 show the effects on the profitability of the different ship designs from price fluctuations based on the historical fuel price volatilities**.** Due to the high levels of volatility for all fuel prices, the effects on the choice of ship design are higher than for the 20 per cent variable changes in Section 5.3.2. In general, results however indicate effects in the same direction; the designs which were previously profitable from fluctuations in a certain fuel price are still profitable using more accurate volatilities. Although the minimum amount of days required have changed based on a different volatility, there is consequently still a robustness in the effects which an increase or decrease in a specific fuel price will have on the choice of design for a product tanker.

More volatile fuel prices however infer more vigorous effects on the feasibility of the choice of design to adhere to the ECA regulations set by the IMO. This could imply that regulations have caused a higher degree of uncertainty regarding investments in specific ship design, due to the impact of oil price volatility. Ship owners are now faced with the active choice of selecting equipment or designs that require different types of fuels. An increase in the HFO price volatility will not only affect the absolute profitability of the scrubber design running on HFO inside an ECA, but also the relative profitability in regards to designs running on LSMGO and LNG.

Fuel price increase, based on volatility				
Fuel type	**Volatility, %**	**Fuel price, $/MT**	**Days in ECA, scrubber**	**Days in ECA, LNG**
HFO	38.9	459.1	No solution	No solution
LSMGO	45.0	798.4	40	88
LNG	54.5	828.7	97	No solution

Table 5.29 Input fuel prices and minimum amount of days spent in ECAs for abatement strategy profitability, sensitivity analysis based on volatility.

Fuel price decrease, based on volatility				
Fuel type	**Volatility, %**	**Fuel price, $/MT**	**Days in ECA, scrubber**	**Days in ECA, LNG**
HFO	38.9	201.9	54	No solution
LSMGO	45.0	302.6	No solution	No solution
LNG	54.5	245.1	97	83

Table 5.30 Input fuel prices and minimum amount of days spent in ECAs for abatement strategy profitability, sensitivity analysis based on volatility.

5.3.4 Threshold fuel prices for design profitability

In order to further evaluate the increased importance of fuel price volatility for ship design, calculations have been made to assess the fuel price thresholds for scrubber and LNG design profitability in relation to the option of running on LSMGO. The different threshold fuel prices have been reached based on the assumption of one isolated fuel price change. As the time spent within ECAs will affect the given threshold fuel price for a positive profitability of the different abatement strategies, two calculations have been made; one assuming a vessel sailing 100 per cent of its time within ECAs, and one assuming a vessel sailing 50 per cent of its time within ECAs. Conclusions on the differences in design sensitivity of fuel price changes from a more global geographical widespread of sulphur targets can therefore also potentially be made.

Firstly, results in Table 5.31 illustrate how highly the time spent inside ECAs affects the dependence of LNG design on fuel price volatility. If a vessel spends all its time sailing within

ECAs, the *LSMGO price* would either have to increase by 2.43 per cent or the *LNG price* would have to decrease by 2.8 per cent in relation to present day fuel prices for the specific design to be profitable. However, if the same vessel would only spend half of its time inside ECAs, *LSMGO price* levels would either have to increase by 15.9 per cent or *LNG prices* would have to decrease by 21.7 per cent.

This strongly indicates that the choice between a design running on LSMGO or LNG is more sensitive to changes in fuel prices when a vessel spends more time within an ECA. The price of either LSMGO or LNG would only have to fluctuate by a very small isolated amount for the LNG design to become profitable as the regulations set by the IMO become more widespread. As the geographical span of ECAs is subject to a gradual increase over the years (IMO n.d.*g*), the nature of future regulations would therefore affect the viability aspects of running on LNG rather than LSMGO.

The results for the scrubber design have been interpreted in a slightly different manner. If a vessel spends all its time inside ECAs, the *HFO price* can be up to 26.1 per cent higher in relation to current levels for the investment in a scrubber to be profitable. Alternatively, the *LSMGO price* can decrease by down to 23 per cent for the scrubber to be economically viable in relation to using a LSMGO within ECAs. If a vessel instead spends half of its time within ECAs, the *price of HFO* can increase by up to 18.4 per cent for the choice of installing a scrubber to still be profitable. Alternatively, *LSMGO price* levels can decrease by down to 14.7 per cent for the same design to be viable.

Results presented in Table 5.31 of scrubber fuel price sensitivity provide us with the same conclusions as for the LNG design; the choice between a scrubber and running on LSMGO becomes more sensitive to fuel price changes the more time a vessel has to spend within a sulphur regulated area. Design issues are highly dependent on the regulations set forth by the IMO and a future wider spread of ECAs would consequently affect the investment decision in terms of design through a larger sensitivity to fuel price volatility.

The choice between a scrubber and LSMGO design investment decisions is more fuel sensitive than previously as a consequence of ECA regulations, but to a lower degree than for the choice between a LNG and LSMGO design. However, calculations in Section 5.3.3 provide us with high historical annual volatilities of 38.9 and 45 per cent for HFO and LSMGO prices respectively. It is therefore deemed as highly likely for both fuel prices to exceed the threshold values presented for scrubber profitability.

Design	Time spent inside ECAs	Min LSMGO price for profitability, $/MT	Max LNG price for profitability, $/MT	Max HFO price for profitability, $/MT
Scrubber	100%	423.8	No effect	447.6
	50%	469.8	No effect	405.1
LNG	100%	563.9	522.3	No solution
	50%	637.8	441.2	No solution

Table 5.31 Threshold fuel prices for abatement strategy profitability under different amounts of time spent inside ECAs.

It should be highlighted that the lack of infrastructure in many ports poses a challenge for the investment in an LNG design to be profitable. The future viability of LNG as a realistic compliance strategy for ship owners is therefore based on availability and price (Laaveg 2013). Not only must existing large-scale import terminals be expanded, but small- and medium sized intermediary LNG terminals will also have to be established in order to create a full network infrastructure. These small- and medium sized terminals could be established within ports, either as tanks onshore or as vessels offshore (DMA 2012). However, large uncertainties regarding future demand and price of LNG prevent decisions on infrastructure investments to be made. Yet only then can ship owners make the necessary investments needed to standardise engine technology and reduce unit prices (PwC 2013).

5.3.5 Global sulphur cap

Lister et al. (2015) emphasize the uncertainty of the timing of the new global sulphur cap as an evident issue for the ship owner’s investment decision. The global sulphur cap will from 1 January 2020, or in 2025 at the latest, be reduced from the current limit of sulphur content of marine fuels of 3.5 per cent to a new limit 0.5 per cent. The possible deferral of the enforcement is subject to a review by the IMO in 2018 at the latest (IMO n.d.*g*).

The combination of a 0.1 per cent sulphur limit when traveling within ECAs and the future enforcement of a 0.5 per cent global sulphur cap will make the use of residual fuels impossible, regardless of sea route. The largest differences in effects between a global sulphur cap being implemented in 2020 or 2025 will therefore be found in the challenges of fuel unavailability. Even though refineries already are able to produce some global sulphur cap compliant fuel through re-optimisation in response to market signals, the large uncertainties regarding the implementation has a disabling effect on the assessment of the profitability of possible investments to cope with higher supplies of distillates (ICS n.d.). Refineries simply need more time to plan, assess and execute increases in the supply of distillates (Bloomberg 2015).

If the IMO decides on an implementation from 2020, this will not mean that compliant fuel will be unavailable. Instead, the shipping sector will have to compete for distillate fuels with other sectors (Bloomberg 2015). Compliant fuels will consequently become more expensive (Bartlett 2015) and increase costs for ship owners. The evolution of new possible fuel blends could provide shipping companies with a cheaper option than pure distillate fuels when their demand strongly increases, but Bloomberg (2015) suggest that such blends could add complexity to operations and differ in quality.

Even though the increased price levels in pure distillate fuels will apply globally to all ship owners, the way that the sulphur based regulations are implemented will mean that the adherence strategy will still be an active part of the investment decision. If enforcement in 2020 bears the consequence of more expensive fuel prices, than enforcement in 2025, the choice of ship design will also have more extreme effects on investment profitability. An extension of the global 0.5 per cent sulphur cap would therefore be in the financial interest of the ship owner (ICS n.d.). According to the ICS (n.d.), there is however a real potential that the global cap will indeed be implemented in 2020. Ship owners should therefore not assume a deferral of the regulations based on the effects of unavailability of compliant fuel when making investment decisions.

5.3.6 NOx Tier III

As previously presented in Table 2.1, ship owners must comply with NOx Tier III standards for ships constructed on or after 1 January 2016 (IMO 2015). In contrast to SOx emission targets, NOx emissions cannot be reduced directly through the selection of a certain type of fuel. Instead, the emissions are reduced through controlling the combustion process. This can be done through the SCR technology described in Section 4.3.3. As previously mentioned, the installation costs for SCR are included in the calculations for the abatement strategies. The data obtained of additional costs for adhering to NOx standards were the same regardless of fuel type, and thus are not further assessed for any sensitivity with regard to fuel price volatility.

5.4 Fuel efficiency

5.4.1 EEDI

As previously described, the EEDI sets requirements for the design efficiency of built on, or after, 1 January 2015. The unavoidable nature of the regulation, and its impact of efficiency threshold values for the new investments of ship owners, sets it apart from ECA regulations. Moreover, the EEDI is expected to have a large impact on the technological development of the shipping industry (Zheng et al. 2013).

The reference line of the EEDI is a measurement of the efficiency level of the average comparable ship that entered the fleet between 1999 and 2008, for the vessel in question. If a vessel has an Estimated Index Value[35] (EIV) above the reference line, it emits more tonnes of CO^2 per mile than the reference ship under standard conditions, and is consequently *less* efficient (Faber et al. (2015). The development of an increased proportion of tanker vessels with an EIV below the reference line has been observed after 2014, compared to the efficiency levels of tankers built between 2009 and 2014. In fact, the average deviation from the reference line of the EEDI, presented in Figure 5.8, illustrates that tankers built in the 21st century have to a large extent had higher EIVs than the reference line. In contrast, the 1990s stand out as a period of especially high efficiencies for tanker vessels. The recent interest in design efficiency is however acknowledged by Faber et al. (2015), who contribute part of this growing interest to a period of soaring fuel prices.

[35] The Estimated Index Value (EIV) reports the efficiency levels of ships constructed before the implementation of the EEDI regulations (ICS 2013). The EIV is strongly correlated with the EEDI (Faber et al. 2015)

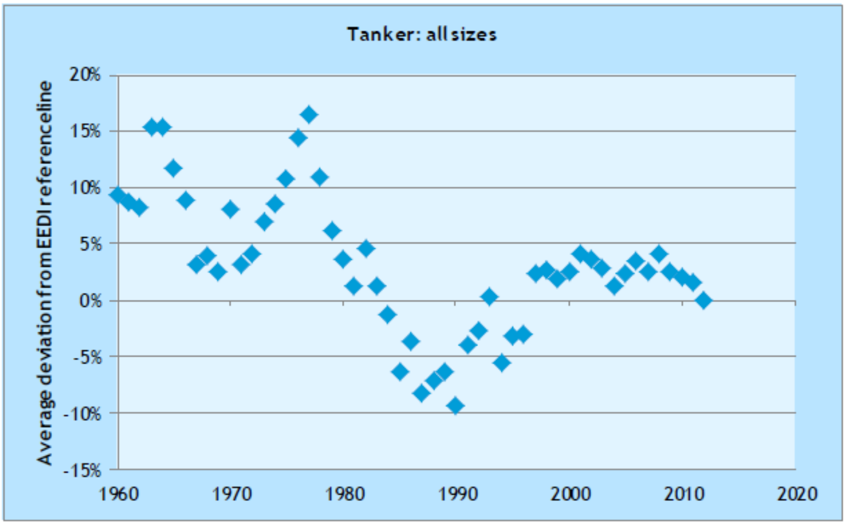

Figure 5.6 Development in the design efficiency of tanker vessels, 1960-2012 (Faber & Hoen 2015).

5.4.2 ECO ship design

In 2012, BIMCO presented a study comparing the profitability of an ECO design product tanker to a conventional product tanker. As all ships ordered today are ECO ships, the decision of investing in a vessel of either "conventional" or ECO ship design is no longer relevant. However, an ECO ship can comprise of several different combinations of design and equipment. In the interview with Skovbakke Juhl (Appendix A.2), he described the concept of ECO ship as an "umbrella" consisting of a range of sub-brands. The multiple options of design and equipment subsequently imply different options of design efficiency.

Consequently, although the ECO ship can be considered as "a ship built to a set of new standards" (Eason 2015), the concept of ECO ship design does not consist of a homogenous group of vessels. Furthermore, the concept seems to have been developed substantially over a short period of time. In the interview with Sand (Appendix B.2), he suggested that ECO ships today could potentially be 15 per cent more efficient than the ECO ships delivered five years ago, and Skovbakke Juhl (Appendix A.2) suggested that without the regulatory changes such as the EEDI, such major changes in design efficiency would not be observed - the new standards facing the shipping industry has induced shipyards to deliver better ships. One might therefore argue that the EEDI and ECO ship design are interlinked with the recent development in fuel-efficient design.

5.4.3 Fuel efficient design

In order to answer the question of the influence of EEDI and ECO ship designs on the investment decision, the effects on profitability from different fuel efficiency levels have been calculated.

Estimations based on historical values do not serve the purpose of evaluating the effects of current and future regulations within the shipping industry. Instead, a preliminary estimation of future developments in fuel efficiency has been made as a basis for our calculations in order to incorporate the effects of evolving shipping regulations. As of 2013, regulations require newly built vessels to establish an EEDI no lower than the EEDI baseline[36]. This target is set to improve up to 30 per cent for all new vessels after 2025 (Faber & Hoen 2015). Both Skovbakke Juhl (Appendix A.2) and Sand (Appendix B.2) argue that only extremely few ship owners are willing to purchase a design which goes beyond the efficiency requirements of the EEDI, as it is simply too expensive.

Fuel efficiency scenarios of 30 and 50 per cent have been selected to illustrate the 2025-target of the EEDI and the effects of purchasing a vessel with a fuel efficiency that exceeds this target. The available data on fuel consumption is retrieved from 2012, and can therefore not be expected to represent the reference line of the EEDI. Nevertheless, the purpose of the calculation is to illustrate the impact of changes in efficiency, rather than measuring the exact profitability of a given efficiency level. Subsequently, a 30 per cent change in fuel efficiency from the levels of 2012 is considered sufficient to illustrate the potential effects of changes in efficiency levels on investment profitability.

Furthermore, the "umbrella" of ECO ship design described by Skovbakke Juhl (Appendix A.2) implies that the design efficiency of new vessels varies depending on ship design and equipment choices. A 10 per cent increase and decrease in fuel efficiency from the 2012 consumption levels was therefore also included as scenarios, to illustrate the possible effects of the combinations of ship design features which a product tanker new builds can comprise of. Moreover, the net present value of such a calculation can give an indication of the additional capital expenditure a ship owner should be willing to accept for a more efficient ship.

[36] The EEDI baseline represents the average efficiency of most new ships that entered the fleet between 1999 and 2008 (Faber & Hoen 2015).

Ship design efficiency is expressed through fuel consumption. The baseline fuel consumption values and the assumed changes in ship design efficiency for our calculations are presented in Table 5.32. As previously, the consumption levels were based on the assumption of 220 days at sea, 115 days idling and 30 days unloading.

	Fuel consumption levels			
Design efficiency of vessel	*At sea - Main Engine, t/d*	*At sea - Auxiliary Engine, t/d*	*Harbour idling, t/d*	*Harbour unloading, t/d*
Baseline value	28.7	3.7	4.3	12.7
10% lower consumption	25.8	3.3	3.9	11.4
10% higher consumption	31.6	4.1	4.7	14.0
30% lower consumption	20.1	2.6	3.0	8.9
50% lower consumption	14.4	1.9	2.2	6.4

Table 5.32 Fuel consumption levels for 2012 base case vessel and different ship design scenarios.

Based on these assumptions in fuel consumption, the sensitivity to oil price volatilities at different levels of fuel efficiency was evaluated. Consequently, the effects of the EEDI and the ECO ship concept on developments in fuel efficiency in relation to recent oil price volatility changes could be assessed.

The sensitivity of investment profitability to changing fuel prices at different levels of fuel consumption is presented in Table 5.34. The profitability values are expressed as the difference in NPV from base cases. The different base cases were calculated based on an HFO price of 330.5 USD/MT under the four different levels of efficiency. For example, for a vessel with a fuel consumption level of 30 per cent lower than levels of 2012, the difference in NPV is measured between a scenario of the baseline HFO price and a change in the HFO price. For comparison, the net present values of the base cases are presented in Table 5.33.

	NPV for base cases, $			
HFO price, $/MT	*30% lower consumption*	*10% lower consumption*	*10% lower consumption*	*50% lower consumption*
330.5	32 756 948	21 547 817	27 152 383	38 361 514

Table 5.33 Product tanker investment profitability at present day fuel price under different fuel efficiency scenarios.

	Fuel consumption scenarios			
Oil price volatility scenarios	*30% lower consumption*	*10% lower consumption*	*10% lower consumption*	*50% lower consumption*
HFO up 37%	-7 334 261	-11 525 267	-9 429 764	-5 238 758
HFO down 37%	7 334 261	11 525 267	9 429 764	5 238 758
HFO up 41%	-8 079 822	-12 696 863	-10 388 343	-5 771 301
HFO down 41%	8 079 822	12 696 863	10 388 343	5 771 301

Table 5.34 Profitability sensitivity to oil price volatility of a product tanker investment under different fuel efficiency scenarios.

Results show that a more fuel-efficient vessel is less affected by changes in the oil price. It should however be highlighted that calculations do not take the price differences between the different efficiency levels into consideration, and it is feasible to assume that a vessel which is 50 per cent more efficient than another is also substantially more expensive. Even though results illustrate that profitability of an investment in a vessel which is 50 per cent *more* efficient than levels of 2012 is less sensitive to that of a vessel which is 10 per cent *less* efficient than levels of 2012, such differences in profitability must also cover the higher costs involved in purchasing a more efficient vessel.

One could argue that the results imply that the introduction of the EEDI has made the profitability of product tanker investments less sensitive to fuel price volatilities in terms of operations, as the implementation and future development of the regulation will mean an increase in fuel efficiency in relation to the levels of 2012. However, this lower sensitivity to fuel price volatility is something which all ship owners will be faced with. As the resulting threshold in design efficiency of the EEDI prevents efficiency levels to fully respond to extreme drops in fuel price levels in the long term, the effects illustrated in Table 5.34 from changing fuel efficiency as a direct consequence of the regulation will not affect the operational profile of the vessel in relation to other ship owners.

As energy efficiency decisions to a large extent therefore are already included in the design development of the shipping industry, the act of adhering to EEDI targets inevitably becomes less of an active choice than choosing the most profitable abatement strategy for ECA regulations. As Section 5.3.4 illustrates the high dependence of ECA abatement strategies on the possible changes of relative fuel costs, ECAs make fluctuations in bunker price an important parameter for the choice of design to a larger degree than the EEDI does. The umbrella of ECO ship designs described by Skovbakke Juhl (Appendix A.2) makes it possible for the ship owner to choose the most viable strategy to adhere to SOx emission targets, while always complying with the EEDI. In other words, the importance of design for the ability to make an active investment decision based on volatile fuel prices and evolving regulations appears to be driven more by the existence of ECAs than of the EEDI.

ECO ship design has become the new standard of ship design, and constitutes an incremental development in the technology of ship design. However, as the development of the ECO ship concept over time is something that affects all ship owners and still provides the ship owner with a variety of options and combinations of design and equipment, the design itself may be argued to not have any fundamental impact on the investment decision. Skovbakke Juhl (Appendix A.2) further suggested that the EEDI has influenced the development of ECO ship design towards becoming the new standard. If this holds true, the EEDI can be said to have had an evident impact on the investment environment in which the ship owner operates in – not only through regulatory requirements, but also in the technological development and supply of design and equipment.

The 10 per cent increase and decrease in efficiency levels in Table 5.34 illustrates possible differences in profitability from choosing between sub-brands of ECO ships as a consequence of diverging sensitivities to oil price volatility. Nevertheless, this aspect is not new to the product tanker investment decision. Ship owners are still faced with the same issues of deciding between different designs and consequent efficiency levels as prior to 2006.

In order to incorporate the aspect of different newbuilding prices for different levels of efficiency, further calculations were made. As we do not have any readily available data on the price differences for the different fuel efficiency levels in ship design, the differences in net present value from the base case vessel express the break-even value of how much more or less a vessel with a different fuel consumption level *could* cost. The results are presented in Table 5.35.

All profitability calculations are now instead evaluated against a base case where the fuel consumption is at the levels of 2012, and the oil price is at present day levels. The NPV of the base case is at 24 350 100 USD. Consequently, the results illustrate how much more a ship owner could pay for a more fuel-efficient vessel for profitability under different oil price scenarios.

	Fuel consumption scenarios			
Oil price volatility scenarios	*10% lower consumption*	*10% higher consumption*	*30% lower consumption*	*50% lower consumption*
HFO up 37%	3 850 034	- 3 850 034	11 550 103	19 250 172
HFO down 37%	1 754 531	- 1 754 531	5 263 594	8 772 656
HFO up 41%	3 956 543	- 3 956 543	11 869 629	19 782 716
HFO down 41%	1 648 022	- 1 648 022	4 944 068	8 240 113

Table 5.35 Product tanker investment profitability for different fuel consumption levels, under different oil price scenarios.

As previously mentioned, a more fuel-efficient vessel would naturally incur higher bunker fuel cost savings and would therefore be less sensitive to oil price volatility. Table 5.35 however illustrates that the price a ship owner could pay for a newbuild has an increasing spread with the increased level of fuel efficiency for the vessel. The business case for a more fuel-efficient vessel is less attractive under lower oil price scenarios.

The combined results from Tables 5.34 and 5.35 illustrate the incentive for the ship owner to overachieve environmental regulations. The fact that an investment in a vessel with fuel efficiency levels higher than what will be required by the EEDI in 2025 is sensitive to oil price volatilities also implies that such an investment would be most beneficial in terms of voyage costs under a scenario of increasing oil prices. This means that a ship owner could pay almost 8 000 000 USD more for a vessel exceeding the EEDI baseline by 50 per cent than for one exceeding by 30 per cent under an oil price *increase* by 41 per cent, but only around 3 300 000 USD more under a 41 per cent oil price *decrease*. There are in other words extremely high uncertainties involved in exceeding such environmental regulations. As oil price volatility already incurs such a large impact on investment uncertainty, it is very unlikely that a ship owner would want to add even further risk to the investment decision. The EEDI therefore sets *both* a floor and ceiling for fuel efficiency levels of newbuilds and consequently allows the ship owner to rely on shipyards to deliver a new build set to the efficiency standards of the time of investment.

6. Discussion

The objective of this dissertation has been to answer what the key factors determining the profitability of a product tanker investment are. The analysis is constructed in order to assess whether a ship owner faces larger uncertainties in his investment decision than previously due to oil price volatilities and environmental regulations, and subsequently whether ship design issues have become more important in light of these considerations.

6.1 Key findings

6.1.1 The profitability of a product tanker investment

The findings in Section 5.1 are in line with the theories of maritime economics literature, and suggest that the key factors that drive the profitability of a product tanker investment have not changed.

Freight rates have by far the largest impact on profit from daily operations of the vessel, and calculations show that fluctuations in freight rate levels based on historical annual volatility would increase or decrease the net present value by greater margins than any of the other considered factors affecting product tanker investment profitability, based on volatility changes. These results are in line with the economic maritime literature, which highlights the major impact of freight rates on the ship owner's profit or loss margins and that a ship owner should consequently take advantage of peaks and troughs of the freight market cycles to improve financial performance (e.g. Lorange 2005; 2009; Stopford 2009; Talley 2012; Karakitsos & Varnavides 2014).

The analysis also illustrates how the effects of newbuilding prices can be crucial for the profitability of a product tanker investment through the dynamics of timing of investments. An illustrative calculation of the effects from extreme cases of resale value of a vessel at cyclical peaks and troughs in the shipping market, suggest that selling a vessel after 10 years at a cyclical margin of 70 per cent at the peak of the shipping cycle could result in a higher net present value than the net present value obtained from operating in the spot market over 20 years before scrapping the vessel. Stopford (2009) presents several historical examples of extreme fluctuations in the market value of a vessel, and the role of timing of investment as a deciding factor for profitability already established in maritime literature is considered to be unchallenged. Among others, Alizadeh and

Nomikos (2006) state that the timing of an investment is the most important factor for the investment decision, through the strategy of buying and selling at "the right time" in the tanker market.

As fluctuations in freight rates from changes in the balance in supply and demand ripple through the other shipping markets, the effects of freight levels and asset play on the investment decision are highly correlated (Stopford 2009; Karakitsos & Varnavides 2014; Lorange 2009). The concept of timing an investment to peaks and troughs of shipping market cycles therefore involves the expectations of *both* future freight rates and asset values. Specifically, a successful product tanker investment would be made such that the vessel's date of delivery matches a period of market improvement and consequently, an increase in freight rates (Stopford 2009). It is therefore the *relationship* between price and earnings that acts as basis for the investment timing strategy (Alizadeh & Nomikos 2006). The respective importance of freight rates and newbuilding prices for the product tanker investment decision therefore essentially reflect the same phenomenon.

The influences of oil price volatility, ECA regulations and fuel efficient design measured in Sections 5.2-5.4 are not considered to impact the *dynamics* of the market value of ships, and the strategies related to timing of investment. Subsequently, a more intriguing part of the findings in this dissertation has rather been the uncertainties that face ship owners, and how these issues impact the investment decisions.

6.1.2 Uncertainty in the investment decision

Even though it is the same factors as previously which dominate the profitability of a product tanker investment, ship owners are faced with new uncertainties in 2015 and going forward than they were prior to 2006. The enforcement of ECA regulations entail that the ship owner can choose between different abatement strategies in order to comply with the given sulphur limits. The optimal choice of ship design is highly sensitive to both operational routes, i.e. the proportion of days travelled within an ECA, and price fluctuations in the different types of fuel associated with each strategy. As such, ECA regulation has made the choice of design for an investment more sensitive to oil price volatilities than previously and relative fluctuations in such fuel prices will therefore cause a higher degree of uncertainty regarding investments in specific ship designs and equipment.

The impact of EEDI regulation appears to not be as forceful on the ship owner's investment decision. The act of adhering to the EEDI is not an active choice, and does not imply the same uncertainty as the ship owner's choice between different abatement strategies in order to comply with ECA regulations. As the EEDI sets fixed requirements for the design of new vessels, the regulation undoubtedly has had an impact on the development in ship design. The threshold in design efficiency provided by the EEDI prevents the development in efficiency levels of the world fleet to respond to extreme drops in fuel prices. Moreover, a natural consequence of lower fuel consumption of a vessel is that the operator is less exposed to fuel price fluctuations. When the vessel consumes less fuel, the total cash flow impact of an increase or decrease in fuel oil prices will be lower than for a vessel that consumes a higher amount. However, with regard to the ship owner's investment decision, it is important to consider that these effects will not in themselves affect the operational profile of the vessel in relation to other ship owners.

The historical levels of design efficiency of tanker vessels presented by Faber and Hoen (2015) illustrate that previous periods have experienced higher average design efficiency than the requirements of the EEDI. At the most, average values were approximately 10 per cent below the reference line during the early 1990s. This implies that the requirements of the EEDI regulation are in fact not that ambitious. Still, the incentive to overachieve the regulation appears to be low. Our results show that the additional price which a ship owner should be willing to pay for a more efficient vessel exhibits a very high sensitivity to oil price volatility. This implies that overachieving the EEDI adds further risk to the investment decision, and given the required additional capital expenditure, one could argue that this risk would appear unreasonable for the rational ship owner.

ECO ship design does not appear to influence the investment decision as strongly as ECA regulations, either. Even though Section 5.4.3 does not present concrete figures on the impact of ECO ship design on newbuilding prices, our results indicate how much more a ship owner *is able* to pay for a more fuel-efficient vessel with the condition of relative profitability[37], under different fuel price scenarios. The differences in fuel efficiency between different designs, and the fact that fuel-efficient vessels are more lucrative investments under higher fuel price scenarios is however nothing new to the product tanker investment decision. Skovbakke Juhl suggested in his interview (Appendix A.2) that ECO ship design has become the new standard of ship design as a result of

[37] The net present value of additional earnings of a vessel with a lower fuel consumption than the baseline value illustrates the break-even value of how much more the ship owner should be willing to pay.

EEDI regulation. This could imply that the development in the standard of ship design is simply a consequent of increased stringency in regulations.

Our results show that scrubbers are a more profitable ECA abatement strategy that running the vessel on LSMGO under the low HFO price scenario, given that the vessel travels within ECAs for a minimum of 54 days a year. Conversely, running the vessel on LSMGO is more profitable than scrubbers under the high HFO price scenario, as the additional capital expenditure required by scrubbers is no longer sufficiently compensated for by voyage cost savings. An isolated decrease in the price of LSMGO, equal to its historical volatility, would make a scrubber investment unprofitable in relation to running on LSMGO, yet an increase of the same magnitude would make the same investment profitable if the vessel spent at least 40 days within an ECA. The same uncertainties as a consequence of fuel price fluctuations are observed for the LNG abatement strategy. Overall, our results illustrate unprofitability of the LNG investment in relation to running on LSMGO. The exception is the scenario of an increase in the price of LSMGO or a decrease in the price of LNG equal to their respective historical volatilities. Under these scenarios the design is profitable relative to the baseline, under the condition of spending a minimum of 88 and 83 days in ECAs, respectively. Ultimately, our findings illustrate that the optimal choice of design and equipment is highly sensitive to fluctuations in fuel prices.

The crude oil price appears to have an increasing volatility over a long-term horizon. Through the GARCH-model forecast, a 1-year out-of-sample volatility of 41 per cent was calculated. The parameters of the forecast model suggest that the volatility is increasing. This not only affects uncertainty related to bunker price risk, but also indicates higher uncertainty in the choice of optimal abatement strategies for complying with ECA regulations. As findings show that higher volatilities in fuel prices infer more vigorous effects on the relative profitability for the choice of design to adhere to ECA regulations, the increase in the price volatility of HFO will subsequently create a higher uncertainty for the ship owner with regard to which strategy is the most profitable to apply in order to meet sulphur targets.

The combination of more stringent ECA regulations and increased volatility in oil prices has increased the importance of ship design in the investment decision. Although Stopford (2009) has established the shipping industry’s response to extreme changes in bunker prices, and the close connection between ship design and fuel price, ECA regulations appear to have influenced this dynamic and increased uncertainty in the ship owner's investment decision. As SOx emissions can be reduced directly through the selection of a certain type of fuel as an alternative to the use of scrubbers, the volatility in HFO prices not only affects the choice of optimal fuel consumption for a certain type of design; it also relates to the profitability of using sulphur target compliant fuel grades. This implies that the effects of volatile HFO prices on ship design have become twofold; ship owners do not only have to adjust fuel efficiency as a consequence of changing HFO prices, but HFO price volatility is also interlinked with the profitability of alternative designs running on other types of fuel due to sulphur related regulations.

Whether the global sulphur cap will be enforced in 2020 rather than 2025 is also a major uncertainty facing the ship owner's investment decision. The results from calculations of ECA compliance strategies illustrate how the optimal strategy is highly sensitive to the amount of time a vessel operates within ECAs. This suggests that the timing of the enforcement of the global sulphur cap can have an instrumental impact on whether the ship owner is making the most profitable investment decision. With the assumption of an investment before 2020, the difference between the cap being enforced in 2020 and 2025 could mean a significant difference in the fraction of the vessel's commercial life being affected by sulphur restrictions.

Concrete calculations have not been provided for the impact of the global sulphur cap being enforced at different points in time, simply because its impact is so complex. One of the greatest potential impacts of an early enforcement is on the price dynamics of low-sulphur distillates (ICS n.d.). Although refineries are able to produce some compliant fuels today, the uncertainty of when the cap will be enforced also has a disabling effect on the development in infrastructure to deliver such fuels and thus also the refineries readability to cope with the vast demand increase that will follow the enforcement. Shipping companies will have to compete for distillates with other sectors, and compliant fuels will become more expensive (Bloomberg 2015; Bartlett 2015).

Lister et al. (2015) emphasize the uncertainty of the timing of the new global sulphur cap as an evident issue for the ship owner's investment decision and argue that the high level of uncertainty related to insufficient decision-making within the IMO in fact may discourage many new investments.

Still, the calculated dynamics of increasing the amount of time a vessel would have to spend within ECAs could be argued to be transferable to the enforcement of the global sulphur cap. This would imply that the choice of design would be less affected by fuel price changes in terms of profitability over the lifetime of the vessel if the IMO decides to defer the enforcement of the global cap until 2025. If such targets were to *not* be deferred, ship owners would also be exposed to more expensive fuel prices due to greater challenges in unavailability of compliant fuel. As such, an earlier sulphur cap implementation would not only mean higher fuel prices, but it would also entail a higher sensitivity to such fuel price changes. Ultimately, the IMO's 2018 deadline for a decision of the time of enforcement may appear tardy to ship owners facing an investment decision. Although there is a possibility of the IMO review being completed by late 2016 or 2017 (Einemo 2014), the uncertainty bears great consequence for the ship owners' investment decision. Whether the global sulphur cap is enforced in 2020 or 2025 has a major impact on which design and equipment will be most profitable, and how the ship owner is affected by fuel price fluctuations. Moreover, the price dynamics of compliant fuels themselves appear to be greatly affected by the decision.

The results presented in Section 5.3 illustrate that the optimal choice of an ECA compliant abatement strategy is sensitive to the amount of days spent within an ECA. For a product tanker investment with a dual fuel engine that enables the use of LNG to be a profitable strategy, a higher amount of days spent within an ECA is required than for the abatement strategy of switching between HFO and LSMGO. One reason for this is the high up-front cost of the technology for the LNG option, while the difference in fuel price levels between LSMGO and LNG are minimal. Transferring these dynamics to the effects of the global sulphur cap, one would assume that for a product tanker investment in 2016, the business case for the LNG abatement strategy would be stronger if the sulphur cap were to enter into force in 2020 rather than 2025. A larger fraction of the vessel's commercial life would then be subject the global cap, and thus make the LNG design more attractive. Lister et al. (2015) have also suggested an increased viability of the LNG design in the case of an earlier implementation of the global sulphur cap.

However, with the current[38] price levels of LNG applied in this dissertation, there is no profitable solution of using LNG as compared to LSMGO. For a vessel running on LNG to be an optimal

[38] "Current" refers to price data collected from 8 June 2015.

choice among abatement technologies, a significant price decrease of LNG is required. The uncertainties regarding infrastructure and availability of both distillates and LNG could therefore imply that the investment in a product tanker with a scrubber, and thus the use of HFO, would be the most profitable option if the global sulphur cap is enforced in 2020. As previously suggested, the inability of the refineries to meet the new demand for distillates and LNG with their production, could mean that the shipping industry will face higher price levels for these fuel types. As a consequence of limited time for the shipping industry to adjust to new environmental regulations, the use of distillates and LNG would therefore add even further risk to the product tanker investment decision. A deferral of the sulphur cap to 2025 would give the industry more time to solve some of these logistical issues and consequently reduce some of the uncertainty in the choice of compliant abatement strategies.

6.2 Impact of findings

The influence of stricter maritime regulations has been highlighted in the maritime economics literature before (Talley 2012; Wijnolst & Wergeland 2009), and Koutroukis et al. (2013) specifically suggest that one of the most apparent issues for future design are the uncertainties regarding upcoming regulations which vessels must adhere to. However, the results of this dissertation contribute to maritime economic literature by illustrating *how* a ship owner faces greater uncertainty and in which manner it affects the investment decision. Stopford (2009) to a great extent presents maritime regulations in an isolated manner, and does not directly link MARPOL Annex VI to the investment decision. By defining and measuring the sensitivities to such regulations, our findings illustrate how sulphur targets directly and actively affect the importance in choice of design for the product tanker investment profitability through an increased sensitivity to relative fuel price volatility. We suggest that ship design has become a more apparent issue for the investment, through enforcement of both ECA regulation and the upcoming global sulphur restrictions. Moreover, our findings suggest both an increasing volatility in oil prices and a heightened sensitivity to such fluctuations. The most profitable choice of abatement strategy in complying with ECA regulation is very much sensitive to fluctuations in fuel oil prices.

Stopford (2009) also describes how ship design has responded to extreme changes in fuel prices historically. The calculations on fuel efficiency of this dissertation illustrate how the effect on the spread in fuel costs from fuel price changes decreases with the consumption level of the vessel. That is, a more efficient vessel is less affected economically by changes in the fuel price than a less efficient vessel, simply due to the fact that it consumes less fuel. We suggest that the requirements of the EEDI act as a threshold efficiency level for product tankers, and that this could potentially mitigate the effect of response in design efficiency to fuel price fluctuations. However, for the ship owner, this factor does not set his investment apart from the investment of other ship owners, as the requirements apply to all new product tanker investments.

Still, the regulation somewhat mitigates uncertainties regarding fuel price volatility. If one considers the scenario of an extreme reduction in bunker fuel prices, Stopford (2009) suggests that the industry will be less concerned with design efficiency. Subsequently, a ship owner who had invested in a highly efficient design at an additional capital expenditure prior to the reduction could be competing against ship owners with less efficient designs, and lower capital costs. The EEDI mitigates such effects of design efficiency trends.

However, fuel consumption depends on both the design of the vessel and the operation. Talley (2012) describes how the simplest method to minimize fuel costs is to reduce fuel consumption through sailing more slowly. The concept of virtual arrival has also been developed in recent years (BIMCO 2013c). It involves an agreement of timing arrivals in order to avoid queues at the terminals and is considered to benefit both owners and charterers by reducing fuel consumption and consequently both costs and emissions (Intertanko 2010).

One might argue that the operation of a vessel would in effect be more responsive to fluctuations, as design efficiency becomes less responsive. Karakitsos and Varnavides (2014) illustrate how the optimal speed is positively dependant on freight rates, and negatively dependant on the price of bunkers. This suggests that ship owners are likely to adjust operations to changes in the shipping market. Skovbakke Juhl (Appendix A.2) also described these dynamics in his interview. He suggested that ship owners would adjust operations to economically benefit from changing circumstances.

On the other hand, Talley (2012) highlights higher or volatile bunker prices and more expensive ECA compliant fuel as two of the main incentives for slow steaming. This means that even when markets are less volatile, ship owners will still experience a fuel cost increase due to the introduction of ECAs and thus have an incentive to slow steam in order to offset the increase in voyage costs. This brings forth the question of whether ECA regulations have also changed the dynamics of operations for ship owners. However, as operational measures were outside of the scope for our research objective, this issue is left as a potential for further research of others.

The calculations regarding ECA abatement strategies illustrate how sensitive the ship owner's choice of design and equipment is to the uncertainty of fuel and marine oil price volatilities. Specifically, for a ship owner facing an investment decision, our results illustrate how the most profitable option of either using LSMGO or the investment in scrubbers for use within ECAs depends on both time travelled within these areas and the price level of HFO and LSMGO. The only calculated scenario, in which LNG was the most profitable option, was under a LNG price decrease equal to its volatility of more than 50 per cent. As the price of HFO and LSMGO were held constant, this is however considered to be somewhat unrealistic. Moreover, the remainder of the calculations illustrate that at the price level in relation to HFO and LSMGO observed today, LNG as a strategy for complying with ECA regulations in 2015 is not the most profitable choice under most scenarios.

However, LNG may be a viable compliance strategy for ship owners in the future if ports expand their infrastructure such that availability is enhanced, and if prices are reduced. The future of supply and demand of LNG is nevertheless a contiguous issue, and these uncertainties themselves have a disabling effect on infrastructure investment decisions (PwC 2013). Consequently, the investment in LNG design and equipment, such as a dual fuel engine, entails high uncertainty regarding future in- and outflows of cash for the ship owner.

6.3 Suggestions for further research

6.3.1 Dynamic variables in the investment model

The models presented in the analysis of this dissertation hold variables constant over the lifetime of the vessel, and do not consider the correlation between the variables when assessing the impact of variable changes. As previously stated, this choice was based on simplicity of calculations, and with the purpose of measuring isolated changes in order to assess the impact and importance of each variable change over the investment horizon. Moreover, the simplicity allowed us to cover a large area of analysis, rather than narrowing down the analysis to a small specific area.

In order to evaluate the impact of change in each fuel type in the assessment of ship design importance for the product tanker investment decision, our findings illustrate sensitivities of design profitability to fuel price volatility based on the assumption of an isolated fluctuation in each type of fuel.

However, holding variables constant over an investment horizon of 20 years is not a realistic assumption. The shipping industry is known to be both volatile and complex, and several key variables influence each other. Moreover, the operational performance of a ship will typically weaken over time, with the consequence of operational costs increasing (Bertram & Schneekluth 1998). Although our intention was not to measure exact profitability, the constant variable values and neglected correlations could mean that certain effects are over- or undervalued. For instance, the negative relation of bunker prices and freight rates in the tanker market (BIMCO 2015) implies that lower bunker costs would in fact have a larger impact than measured by the model, as freight rates would be strengthened as a consequence.

An interesting aspect related to correlation of variables which was not captured by our model, is the relation between HFO, LSMGO and LNG prices in the assessment of ECA abatement strategies. A more comprehensive econometric analysis of the price dynamics between the three could potentially provide more robust evidence of the uncertainties facing ship owners as a consequence of ECA regulation.

It has also been strongly highlighted that large uncertainties lie in the implementation date of a global sulphur cap and future fuel price levels. A more comprehensive understanding of the impact of the lack in infrastructure to deliver low-sulphur distillates, and the subsequent price dynamics, would have strengthened our suggestions on the impact on the investment decision. To our knowledge, there is an absence in maritime economics literature of a more comprehensive study which quantifies the impact of the timing of the enforcement of the global sulphur cap with regard to the ship owner’s investment decision. A real option valuation analysis considering the alternatives of the global sulphur cap entering into force in 2020, and in 2025, on different compliance alternatives could be an important contribution to both maritime literature and of interest for ship owners. The same holds true for a more comprehensive analysis of the price dynamics of LNG and compliant fuels such as marine gas oil (MGO).

6.3.2 Operating in the time-charter market

The difference in the level of risk between the spot- and time charter market is an important aspect to highlight. As a time charter means that shipping rates are fixed for a certain period of time, these types of contracts act as a type of hedging strategy, with more predictable future cash flows and greater opportunity to achieve a high fleet utilization by organizing the shipping schedule in advance. A spot charter hence involves a higher level of uncertainty, but also increases the opportunity to take advantage of improving rates (Mao 2014).

The calculations on the impact of increasing oil price volatility on the ship owner's investment would have been less potent if the analysis had assumed a vessel operating in the time charter market. As it is the charterer who bears the bunker cost under a time charter contract, the ship owner would be affected to a lesser extent. In theory, the dynamics of fuel price volatility should instead be expressed through time charter rates, where fuel savings due to a more efficient vessel would be expressed through higher rates to the ship owner. However, in practice this is not the case. Any premium is affected by the negotiation power between the ship owner and the charterer, and could potentially range from anywhere between zero and 75 per cent of the value of the fuel saving (Agnolucci et al. 2014; Sand 2015, Appendix B.2).

The research on impact of fuel differences on time charter rates is sparse, and consequently the differences in effects from operating in the spot or time charter market is difficult to assess for our calculations. In order to assess whether our results indicating a substantial impact of oil price volatility on the ship owner's investment decision is transferrable to a ship owner operating in the time charter market, further research on the relationship between time charter rates and fuel efficiency in relation to oil price volatility would be necessary.

7. Conclusion

The shipping industry has faced an increase in environmental awareness, and maritime regulations have become more stringent as a consequence. In 2006, the Baltic Sea became the first fully implemented SOx ECA, and since then three other ECAs have come into effect (IMO n.d.*f*). In 2011, the EEDI was introduced, and the first reports on ECO ship design started to surface (IMO n.d.*a*; Poten & Partners 2014). Since then, the enforcement of the EEDI has taken place, and the concept of ECO ship design has become the standard for all newbuildings ordered today.

The regulatory implementation of ECAs, the upcoming global sulphur cap and the enforcement of the EEDI present the possibility of a more prevalent role of ship design issues in the ship owner's investment decision. The growing interest in design efficiency and the recent collapse in the oil price, suggests that potential changes in oil price volatility could also present ship owners with greater uncertainty going forward. The contribution of this study therefore lies in addressing the impact of recent and future environmental regulations and oil price volatility, and assessing whether these issues constitute any fundamental change in the product tanker investment decision. Specifically, the purpose of this thesis was to quantitatively evaluate the key factors for determining the profitability of an investment in a product tanker newbuilding, and if and how ship design issues and recent oil price volatilities have become more important for such investments.

These regulatory and industry-wide influences, together with the increasing oil price volatility over the past decade (Ebrahim et. al 2014), comprise the foundation and outset of the research objective of this dissertation. As such, the analysis considered changes since 2006 and going forward in order to fully incorporate the impact of ship design issues, environmental regulations and oil price volatility on the ship owner's investment decision.

Through defining and measuring sensitivities to current and future environmental regulations and oil price volatility, our main contribution to the maritime economic literature has been to quantitatively illustrate how a ship owner faces greater uncertainty in the product tanker investment decision going forward than prior to 2006.

Our research question was answered through a mixed methods approach, using both quantitative and qualitative data. The analysis comprised four main sections. An investment model firstly calculated the effects on profitability of fluctuations in key factors highlighted in previous maritime economic literature. Findings showed that, the key factors determining the profitability of an investment in a product tanker newbuilding are still the same as prior to 2006. Freight rates have the largest impact from operations on profitability and the effects of newbuilding prices can be crucial through the dynamics of timing of investments.

In order to evaluate whether design issues and oil price volatilities have become more important for the product tanker investment decision, the crude oil price volatility between 1987 and 2015 was assessed and econometric analysis was applied to forecast future oil price volatility. The effects of ECAs were then assessed through calculating the minimum amount of days spent within such regulated areas for profitability of different abatement strategies. These results were also used to assess the impact of a future global sulphur cap. The impact of the EEDI and ECO ship design were lastly discussed and calculated in terms of effects of different fuel consumption levels on profitability and on the additional capital expenditure that a ship owner could pay under different oil price scenarios.

Our findings show that ship design issues *have* become more important to the profitability of an investment in a product tanker newbuilding through the increased uncertainty from current and future sulphur target regulations. In terms of profitability, the implementation of ECAs has made the choice of design more sensitive to oil price volatilities than prior to 2006. This is due to the fact that the choice between different abatement strategies also implies a choice between different compliant fuels. Relative fluctuations in fuel prices will therefore have effects on investment profitability through the chosen type of design. Findings also show that more time spent within an ECA will affect the investment decision through a larger sensitivity to oil price volatility.

The scenario of a global sulphur cap being enforced in 2020 rather than 2025 will imply that a larger fraction of the purchased vessel’s commercial life will be spent under global sulphur restrictions. This aspect, in combination with greater challenges in unavailability of compliant fuel, will imply higher fuel prices and a larger sensitivity to such fuel prices. The implementation date of the global sulphur cap is therefore an additional factor making the choice of design more important for the product tanker decision.

In addition, recent oil price volatilities have increased the uncertainty in the investment decision. Our findings in Section 5.2 suggest that the oil price volatility is higher than it was prior to 2006, and that it is increasing over the long-term horizon. The forecast of an increased oil price volatility going forward strengthens the already established role of bunker price risk in shipping operations.

We do not suggest that the oil price volatility itself has fundamentally changed the product tanker investment decision. As illustrated in Section 5.1, the isolated impact of fluctuations in bunker fuel prices does not appear to alter the established dynamics of investment profitability. Instead, we suggest that the recent oil price volatilities impact uncertainty in the investment decision as an exogenous factor. That is, the increased importance of ship design caused by sulphur regulations has in turn amplified the impact of oil price volatility on investment uncertainty.

According to our findings, the most substantial effect of the increased oil price volatility is that it implies that ship owners will be faced with more vigorous effects on the relative profitability for the choice of design to adhere to ECA regulations. The analysis in this dissertation illustrates how the optimal choice of design and equipment is highly sensitive to fluctuations in fuel prices. Consequently, through the effects of ECA regulations and the future sulphur cap, recent oil price volatilities further increases the uncertainty in the investment decision.

The combined effects of ECA regulations, the uncertainty and implementation of the global sulphur cap, and increased oil price volatility have large influence on the ship owner’s margins for profit and loss. Our analysis does not provide an answer for which design and equipment is optimal for the investment in a product tanker newbuild, but rather quantifies the potential impact of these considerations for the ship owner’s investment decision. Although freight levels and asset values are still key factors for the product tanker investment decision, our results show that misjudging the direction of the different fuel price markets can lead to less profitable design choices. As the ship owner faces new uncertainties, the impact of his ability to predict the direction of shipping markets appears to be even stronger on the profitability of investment. For good financial performance, the successful ship owner also needs to consider, and accurately predict, the relative fluctuations in different fuel prices in relation to capital expenditure in order to reap the full benefits from the optimal choice of design.

8. References

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