Norwegian School of Economics
Bergen, Spring 2016

NHH

# Freight rate determinants in the offshore market

*Does energy efficiency pay?*

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Master thesis in Finance

NORWEGIAN SCHOOL OF ECONOMICS

# Abstract

There is a growing interest in the dynamics of freight rates in the offshore market, yet, the research within the field of microeconomic freight rate determinants is limited. This paper is an attempt to fill this gap by investigating microeconomic determinants of time-charter freight rates for Offshore Support Vessels (OSVs) in the global offshore market.

We utilize a comprehensive panel data set of 40,537 individual fixtures for Platform Supply Vessels (PSV) and Anchor Handling Tug Supply (AHTS) vessels between 1984 and 2015. Through a division into spot and term charter rates, we pursue to verify to what extent there exists a relationship between realized freight rates for individual fixtures and macro-, contract- and ship-specific variables. Our findings suggest that the market proxy for a standardised vessel dominates in terms of explanatory power, typically explaining around 80% of the rate for individual fixtures. Additionally, we find operating region, build country, vessel size, vessel age and other ship-specific properties, e.g. dynamic positioning system 2 (DP2) and ice class, as significant determinants of OSV freight rates.

Moreover, we examine the presence of a freight rate premium for energy-efficient OSVs using four different definitions of efficiency. The time-charter market represents a classical principal-agent problem, where shipowners should, in a competitive market, obtain a premium reflecting the fuel savings that accrue to charterers. We suggest a two-tier market where energy efficiency pays off in the AHTS term market, whereas the PSV market is subject to an apparent market failure.

# Preface

This master thesis is written as a concluding part of our Master of Science in Economics and Business Administration at Norwegian School of Economics (NHH). The thesis is written within the field of our major in Finance.

Our choice of topic is based on our interest in the maritime industry. The research within the offshore freight rate market is limited, which has encouraged us to shed some further light on this field. After discussions with our supervisor and several market participants, we believe to have found a relevant and forward-looking subject. Writing this thesis has been a challenging and demanding process, yet exciting and rewarding experience. Knowledge acquired through several courses at NHH has been useful, and, finally, we are left with a greater understanding of the offshore market.

As we now are about to finish our master degree at NHH, there are some who deserves our attention. First and foremost, we would like to thank our supervisor, Roar Os Adland, for sharing his extensive knowledge and providing constructive feedbacks throughout the writing process. Furthermore, we would like to thank Ulstein Group for access to their comprehensive and detailed data set, and Per Olaf Brett and André Keane for meaningful and inspiring discussions regarding the offshore market. Finally, we are grateful to receive grants from The Norwegian Ship Owners´ Association´s Fund at NHH. Hopefully, our work will be of relevance.

Bergen, June 2016

Aleksander Dahle

Daniel Jøsok Kvalsvik

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# 1. Introduction

A growing interest in the dynamics of freight rates in the offshore market has been discernible over the past few years. As the nature of the offshore industry is highly volatile and cyclical due to constant changes in the balance of supply and demand, separate research apart from deep-sea shipping is required. Gaining a deeper knowledge of freight rate determinants will be of great interest to market participants such as shipowners, charterers and shipbrokers.

The purpose of this thesis is to investigate determinants of time-charter freight rates for PSV and AHTS vessels from the mid 1980´s until today. Through a division into spot and term charter rates, we pursue to verify to what extent it exists a relationship between realized freight rates for individual fixtures and macro-, contract- and ship-specific variables. Specifically, we examine the presence of a freight rate premium for energy efficiency. In order to uncover changing market dynamics and potential non-linear effects, we perform a separate analysis ranging from 2010 to 2015 and quantile regressions, respectively.

All these issues are important for various reasons. Firstly, increased understanding of freight rate determinants could create opportunities for foresighted shipowners and charterers regarding investments and operational activities with respect to design of OSVs. Secondly, a potential energy efficiency premium in the time-charter market induces shipowners to build environmentally friendly ships. Conversely, energy-efficient ships not being rewarded by charterers suggest a market failure in the offshore market, which in turn will inhibit innovation and the take-up of fuel saving technologies. Hence, we wish to contribute with an extension of research related to offshore freight rate determinants, and, hopefully, this will inspire to further research within the field.

The thesis is structured as follows. Section 2 reviews existing literature on microeconomic determinants of shipping and offshore freight rates. A brief introduction to the offshore market is presented in section 3, including an explanation of energy efficiency for OSVs. In section 4, we present our methodical framework with choice of variables and regression model. The data is presented and described in section 5. Section 6 contains results and discussions from our analyses. Finally, a conclusion with criticism to our findings and suggestions to further research are presented in section 7.

# 2. Literature review

Macroeconomic determinants of shipping freight rates have to a large degree been established, however, the microeconomic field is limited but expanding. Literature on microeconomic determinants of freight rates is typically looking at freight rate data for individual contracts, trying to establish certain effects in the price data. Tamvakis and Thanopoulou (2000) investigate the existence of a two-tier spot freight market for dry bulk carriers of differing age, finding no significant age premium in freight rates paid to younger tonnage. This is in line with Strandenes (1999) arguing that demand for quality tankers has to increase by 30% for a two-tier tanker market to emerge. However, in a more recent study, Köhn and Thanopoulou (2011) find strong evidence for the existence of a quality premium in the dry bulk time-charter market during the freight market boom years of 2003-2007, when controlling for contract-specific effects such as place of delivery, charter length and number of days forward to delivery, as well as vessel size and fuel consumption.

Furthermore, Alizadeh and Talley (2011a, b) broaden the research of microeconomic determinants of spot freight rates in the dry bulk and tanker market, respectively. By investigating the contract time between fixture and start date, as well as macroeconomic and microeconomic proxies, the results from both shipping segments suggest that the contract lead time is an important determinant of the freight rates, and *vice versa*. As an extension of previous microeconomic studies, Agnolucci et al (2014) present a model for time-charter rates in the Panamax dry bulk market in the years 2007-2012, focusing on whether there exists a rate premium for fuel efficiency. Their findings show a significant fuel consumption variable, where only 40% of financial savings from energy-efficient vessels accrue to the owners. However, according to Adland et al (2015), both Köhn and Thanopoulou (2011) and Agnolucci et al (2014) do not properly account for the impact of the underlying market. By ignoring the changing relationship between contract duration and the “market rate”, their results ascribe higher statistical significance to the other variables, such as energy efficiency proxies. When properly accounting for the dynamic term structure of freight rates, Adland et al (2015) find market rate, vessel age, fuel prices, place of delivery and DWT as significant determinants. Moreover, they suggest a market failure in the dry bulk time-charter market where the market is not willing to pay a premium for energy-efficient ships.

Whereas all the studies above consider conventional shipping freight rates, the research within offshore freight rates is limited. Bjørkelund (2014) proposes a two-regime mean reverting jump diffusion model to analyze the characteristics of spot freight rates for PSV and AHTS vessels in the North Sea market. Moreover, Døsen and Langeland (2015) investigate term charter freight rates in the PSV market from 2004 to 2015. They find deck area, operating region, oil price and monthly average spot freight rate as the most significant determinants in fixtures from Brazil and the North Sea.

To our knowledge, it has been no attempt to empirically analyze both spot and term charter freight rates over a substantial time period for the global PSV and AHTS market, and neither has an energy efficiency premium in offshore freight rates been investigated. Thus, the contribution of this thesis to existing literature is threefold. Firstly, we expand previous research and examine freight rate determinants in the OSV market between 1984 and 2015, including spot and term charter contracts for PSV and AHTS vessels. A wider empirical research both in terms of time and segments able us to ensure robustness of any conclusions. Secondly, we investigate the presence of an energy efficiency premium in offshore freight rates using four definitions of efficiency. In order to identify a potential freight rate premium, we consider different market conditions by using interaction dummies and a separate analysis ranging from 2010 to 2015. Thirdly, we perform quantile regression analyses to uncover non-linear effects and thus determine the impact for a vessel being in the upper or lower quantile with respect to ship specifications.

# 3. The offshore market

## 3.1 Overview

Platform Supply Vessels (PSV) and Anchor Handling Tug Supply (AHTS) vessels represent two important components operating in the worldwide offshore market. As part of the Offshore Support Vessel (OSV) market, both segments are essential in the upstream logistical chain development of offshore oil and gas fields. Generally, OSVs provide support services to offshore rigs, pipe laying and oil producing assets utilised in exploration and production activities. More specifically, PSVs and AHTSs are designed for individually purposes:

**PSVs** transport supplies and equipment to and from offshore installations in deck containers or under-deck bulk. Typically supplying rigs with drilling mud, drilling risers, water and other liquids. The most important property is carrying capacity, measured by deck area (M2) and under-deck tanks (DWT).

**AHTSs** tow offshore installations and position their anchors from one location to another. Can be used as substitutes for PSVs when carrying under-deck cargoes and personnel. The most important properties are bollard pull (BP) and brake horsepower (BHP).

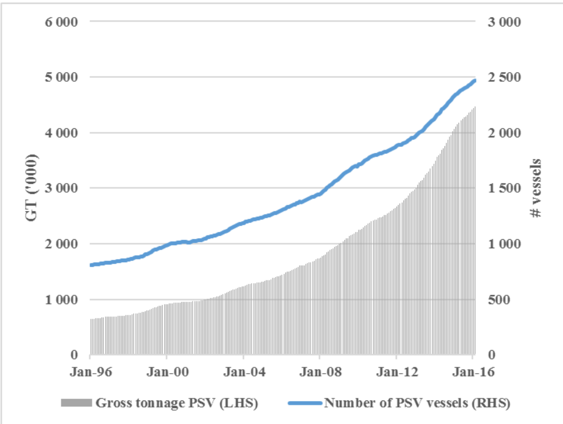



*Figure 1: PSV fleet development*

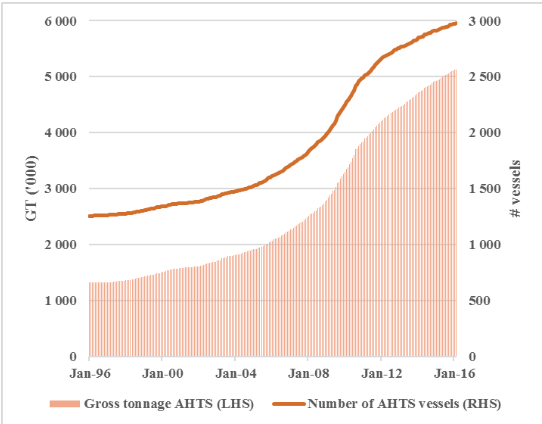



*Figure 2: AHTS fleet development*

Even though PSVs and AHTSs may be concerned with different operations, they both operate in the same offshore market. Figure 1 and 2 present the fleet development over the last decade, which show increasing size of OSVs measured in gross tonnage (Clarkson Research, 2016a). In February 2016, the PSV and AHTS fleet is estimated to 2,466 and

2,980 vessels, respectively. The same fleet counted 1,196 and 1,479 vessels in February 2004, having more than doubled the last 12 years. Today, the rapid fleet expansion followed by a sustained period of low oil prices, has created an OSV surplus in the market. However, the OSV market is not a single global market, but a series of regional markets (ICS, 2011). This has led to a variety of specialised OSVs, where the determination of the design is a compromise between technological complexity and operational flexibility. With more sophisticated vessels suited to support charterer´s operations, shipowners may receive premium freight rates from the charterer and achieve better utilisation.

## 3.2 Freight rates – linking supply and demand

By linking supply and demand, freight rates are constantly adjusting in response to changes in their balance. Such a market mechanism makes freight rate cycles appear, with the characteristic pattern of irregular peaks and troughs. According to Alizadeh and Nomikos (2011), the demand is considered inelastic in the dry bulk shipping market, whereas the supply has a convex shape due to the limitation of supply at any point in time. Related to the offshore market, the overall supply of OSVs are determined by the size of available fleet, influenced by the number of vessels laid up or being scrapped (ICS, 2011). The demand side is stimulated largely by the level of activity from the oil companies, either directly through production and drilling support, or indirectly in other scope of work.

In reality, the interaction between supply and demand in the offshore market is more complex, with three aspects we would like to point out. Firstly, additional supply increase in the short run is only possible by vessels moving from other markets in the world or reducing days in port. Overall, the time-lag in shipbuilding will be reflected in the long-term equilibrium. Secondly, the biggest single factor affecting the supply-demand equation in the offshore market is the oil price (ICS, 2011). Ringlund et al (2008) states that oil price changes can induce significant changes in oilrig activity, and thus affect demand for vessels. However, the consequences of any movement in the oil price may not be felt immediately in the supply chain. In the case of a price drop, demand will be sustained if cancellation costs exceed the cost of continuing. On the other hand, a rising oil price will not necessarily translate into immediate demand for OSVs as big projects involve a long lead-time. Thirdly, the limitation of OSVs to deliver services in bad weather represents the most significant bottleneck in the upstream offshore chain (Aas et al, 2009). Affecting both carrying capacity and sailing capability for OSVs, the “bad weather bottleneck” often leads to larger demand peaks in front of and immediately after bad weather, and therefore often are predictable a day or two ahead of time.

Hence, freight rate cycles occur as a result of volatile demand and a significant time-lag before supply adjusts to demand. Whereas the above-mentioned relationships are due to macro determinants, the dynamic interaction between demand and supply could suggest different pricing of micro determinants, such as contract- and ship specifications, throughout the cycle. Through a further examination in chapter 6, we attempt to investigate this relationship under different market conditions.

## 3.3 Spot and term charter contracts

Under a time-charter contract, fuel costs are payable by the charterer, whereas other costs, such as lube oil and crew, are covered by the shipowner. The duration of a fixture determines whether the contract is a spot, medium or long-term charter (ICS, 2011)[1]. Compared to conventional shipping, OSV contracts may differ substantially in terms of duration. An OSV is a small part in a complex supply operation, where the participating risk preferences are important due to large consequences of incidents. Generally, the OSV market is considered to be more short-sighted than conventional shipping. The spot contracts have typically 10-14 days duration and are fixed only a few days ahead of commencement. Due to high liquidity of spot fixtures, the spot rate today may vary greatly from tomorrow´s spot rate. Such characteristics result in extreme volatility in the spot freight rate market for both PSVs and AHTSs, as shown in figure 3 and 4.

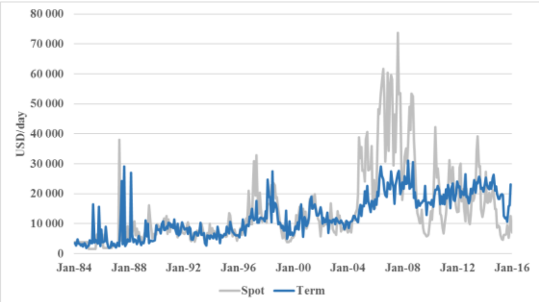



*Figure 3: PSV average monthly freight rates*

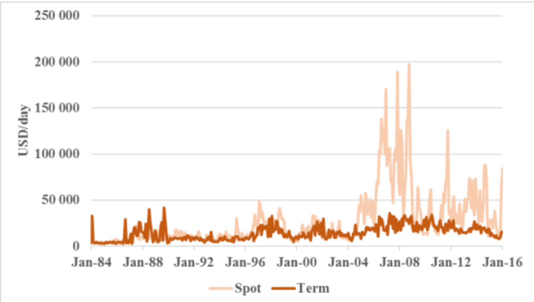



*Figure 4: AHTS average monthly freight rates*

[1] We consider fixtures with duration of less than 30 days as spot charter and fixtures with more than 30 days as term charter.

Furthermore, spot and term charter freight rates may differ between regions. The North Sea is considered as the only well-functioning spot market in the world today, however, in recent years spot markets have materialised in West Africa, Brazil and South-East Asia (ICS, 2011). Depending on activity level and differences in the spot freight rates, tonnage may move between regional spot markets. Moreover, the operating cost varies significantly from region to region, to the extent that it becomes complex to define a unified worldwide rate level for a particular class of OSVs. With regard to our analyses, we find it interesting to examine whether duration and activity region of the fixtures are related to freight rate levels. Additionally, we attempt to account for the underlying relationship between freight rates and contract region in our heterogeneous data. Therefore, we construct a market proxy based on contractual regions and vessel size and implement it in our analyses in chapter 6.

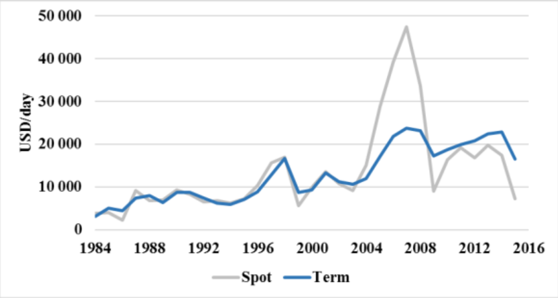
## 3.4 Term structure

The relationship between freight rate level and duration of the charter party is referred to as the term structure (Veenstra, 1999). In the general literature on term structure for shipping freight rates[2], short-term freight rates are thought to be determined by current supply and demand for shipping services, whereas long-term charter rates are believed to be determined through shipowner´s and charterer´s expectations about future short-term rates. If the shipowner expects rates to increase in the future, he usually prefers spot chartering since it leaves him free to negotiate a more favourable contract next time. On the other hand, a charterer usually tries to obtain long-term contracts at current rates if he expects rates to increase in the future. Hence, one can assume that term charter freight rates in fact are a form of forward freight rates. Depending on the shape of the forward curve, the OSV market can be characterised as contango or backwardated[3]. A forward curve is constructed from our data set by comparing yearly spot and term charter freight rates in figure 5 and 6. Until 2003, we find the spot freight rate relatively equal to the term charter freight rate for both PSVs and AHTSs. Thereafter, the AHTS market changed to backwardation, implying a downward sloping forward curve from 2003 to 2016. The PSV market was in backwardation from 2003

[2] See e.g. Zannetos (1966), Strandenes (1984), Veenstra (1999) and Kavussanos and Alizadeh (2002).

[3] Contango occurs when the spot freight rate is below the term charter freight rate, and, conversely, backwardation occurs when the spot freight rate is above the term charter freight rate.

and throughout 2008, before it shifted to contango in the aftermath of the financial crisis, implying an upward sloping term structure from 2009 to 2016.



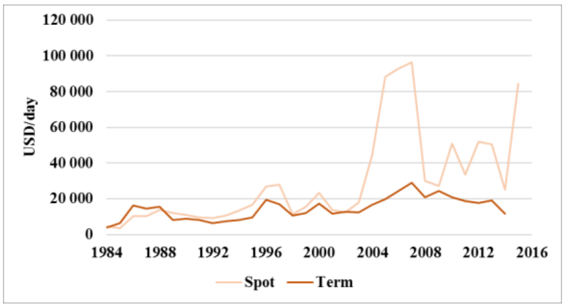




***Figure 5: PSV yearly average freight rates*** ***Figure 6: AHTS yearly average freight rates***

Based on the forward curve in figure 5 and 6, we attempt to examine the impact of contract length (duration) and length of the period from fixture date to start date (forward). Followed by the discussion above, an average downward sloping term structure is expected to yield a declining freight rate further out on the forward curve, and *vice versa*. By using interaction dummies we investigate whether duration and forward are significant determinants of OSV freight rates.

## 3.5 Energy efficiency

Energy efficiency is described as doing the same amount of useful work, while consuming less energy (IMO, 2009). Consequently, less fuel is burned and emissions of exhaust gases are reduced. To improve the energy efficiency in the OSV market, we consider two options: technological and operational measures. Through new building or retrofitting processes, technological measures may improve the energy efficiency by customizing OSVs´ capability, design speed, hull design or propulsion systems. According to Norlund and Gribkovskaia (2013), fuel consumption is reduced by 25% when optimizing sailing speed in supply vessel operations. Operational measures, such as fleet management, technological incentives, voyage optimization and energy management, may also improve the energy efficiency. Halvorsen-Weare et al (2012) optimize fleet composition and periodic routing of OSVs in the North Sea, estimating the annual cost saving for Statoil to be USD 3 million.

As energy efficiency turns out to be one of the most profitable opportunities for reducing emissions, being green is often equivalent to being more profitable (ABB, 2012). However, the time-charter market represents a classical principal-agent problem where the shipowner (agent) determines the level of technological energy efficiency, while the charterer (principal) bears the costs associated with that level of energy efficiency (Rehmatulla and Smith, 2015). The problem is thus related to what extent fuel cost savings are recouped by the shipowner through higher charter rates or better utilization, i.e. whether increased CAPEX is compensated by a freight rate premium or fewer idle days. Such an intrinsic split-incentive barrier is similar to the tenant-landlord problem in the buildings sector (see e.g. Gillingham et al, 2012), and may result in an economic market failure where efficiency measures are not implemented despite substantial cost savings potential. If a charterer picks an energy-efficient vessel, i.e. consumption cost below consumption cost for a standard vessel, he should be willing to pay a higher rate compared to all standard vessels in an efficient market. This rate premium equals the difference in consumption costs, and the charterer pays freight rate plus bunkers cost in total. However, the literature on energy efficiency in the shipping market suggests that fuel cost savings are not fully recouped by shipowners (see e.g. Agnolucci et al, 2014 and Adland et al, 2015).

Moreover, the OSV fleet can be divided into two categories, i.e. OSVs with conventional mechanical propulsion system and OSVs with diesel-electric propulsion system and other hybrid solutions. Through hybrid technology fuel savings often reach 15-25% in typical operating profiles and 40-50% in pure DP operations (ABB, 2012). With increased awareness of operational costs and environmental emissions, a large part of charterers request OSVs equipped with hybrid propulsion system. Hence, one can argue that a two-tier market has emerged within the OSV fleet if the hybrid solutions in fact attract a rate premium. In order to examine whether energy efficiency is priced in the offshore market, we hypothesize energy-efficient OSVs to obtain a freight rate premium in an efficient market. Conversely, signs of a market failure occur if shipowners do not get paid for building energy-efficient vessels. We are aware that market conditions and the perceived importance of energy efficiency may have changed during our time period, which is handled through a separate analysis of the period from 2010 to 2015.

# 4. Method

## 4.1 Choice of variables

In order to investigate freight rates determinants in the OSV market, we include variables believed to be crucial indicators. Our choice of variables is largely based on literature on macro- and microeconomic determinants of freight rates, as explained in chapter 2. In addition, we include some new variables inspired particular to the offshore market by discussions with market participants. To structure our multiple regression models, determinants are grouped into macro-, contract- and ship-specific variables. Table 1 summarizes the independent variables with expected sign of the coefficients and interpretation in our study.

| Variables | Unit | PSV | | AHTS | | Interpretation |
|---|---|---|---|---|---|---|
| | | Included | Exp. sign | Included | Exp. sign | |
| ***Macro:*** | | | | | | |
| Market proxy | $/day | X | + | X | + | Regional market rate for a standardised vessel (w/ Kernel smoothing) |
| ***Contract:*** | | | | | | |
| Duration_BW | Days | X | - | X | - | Interaction dummy for contract lenght during backwardation periods |
| Forward_BW | Days | X | - | X | - | Interaction dummy for forward length during backwardation periods |
| Production_D | | X | - | | | Whether the scope of work is production support or not |
| Drilling_D | | | | X | + | Whether the scope of work is drilling support or not |
| US Gulf_D | | X | - | | | Dummy for activity in US Gulf |
| Brazil_D | | X | + | | | Dummy for activity in Brazil |
| Asia_D | | | | X | - | Dummy for activity in Southeast Asia |
| Middle_East_D | | | | X | - | Dummy for activity in Middle East |
| ***Ship:*** | | | | | | |
| DWT | Tonnes | X | + | X | + | Deadweight carrying capacity of a ship |
| BHP | | X | + | | | Brake horse power of a ship |
| BP | Tonnes | | | X | + | Bollard pull, measure of pulling power of a ship |
| Age | Years | X | - | X | - | Age of ship on fixture date |
| Age2 | | X | - | X | - | Squared age to capture non-linear effects |
| DP2_D | | X | + | X | + | Dummy for presence of Dynamic Positioning 2 system |
| Helideck_D | | X | + | X | + | Dummy for presence of Helideck |
| ROV_D | | X | + | X | + | Dummy for presence of Remotely Operated Vehicle support |
| Ice Class_D | | X | + | X | + | Whether the ship has ice classification or not |
| Build Far East_D | | X | - | X | - | Dummy for builder region Far East |
| Build NW Europe_D | | X | + | X | + | Dummy for builder region NW Europe |
| Speed | Knots | X | ? | X | ? | Vessel design speed |
| Consumption | Tonnes/day | X | - | X | - | Fuel consumption at design speed |
| FEI (DWT) | | X | - | | | Consumption/(DWT x Speed x 24) |
| FEI (BHP) | | | | X | - | Consumption/(BHP x Speed x 24) |
| DAF | | X | - | X | - | (Consumption - Average fleet consumption) x Bunkerprice |
| Conventional_D | | X | - | X | - | Dummy for conventional diesel as propulsion type |
| Boom_Cons | | X | + | X | + | Interaction dummy for Consumption during 87-90, 96-98, 05-09 |
| Boom_FEI (DWT) | | X | + | | | Interaction dummy for FEI (DWT) during 87-90, 96-98, 05-09 |
| Boom_FEI (BHP) | | | | X | + | Interaction dummy for FEI (BHP) during 87-90, 96-98, 05-09 |
| Boom_DAF | | X | + | X | + | Interaction dummy for DAF during 87-90, 96-98, 05-09 |
| Boom_Conventional | | X | + | X | + | Interaction dummy for Conventional diesel during 87-90, 96-98, 05-09 |

***Table 1: List of variables***

### 4.1.1 Macro-specific variable

A *market proxy* is included in order to account for the underlying market in our model. We estimate daily averages for spot rates as this market tends to be highly volatile, while we use weekly averages for term rates given lower volatility and fewer observations. Hence, we construct our own index by differentiating between vessel size[4] for spot rates and both vessel size and operating region[5] for term rates. The potential effects of differentiated variables, i.e. M2, BHP and operating regions, are embedded in the proxy and consequently rejected as micro variables. Furthermore, a Kernel smoothing is applied with inspiration from Adland and Strandenes (2006) to construct the final indexes. The selected bandwidth parameter, h, were set to five days for spot rates and three weeks for term rates in order to consider the volatility dynamics for each segment. Unlike Adland and Strandenes (2006), our smoothed freight rate function is symmetric, i.e. based on both historical and future dates. Thus, the kernel approach able us to compute a representable weighted average of the underlying freight rate market.

As an alternative to our own index representing the market, we could availed indexes provided by Clarkson Research. However, such indexes do not fully account for regional differences and are usually limited to monthly data, considered as too low frequency to capture the large but short spikes in the highly volatile spot market. Compared to the Clarkson index, we find our market proxy as a satisfying approximation to the underlying market. Appendix 4 shows two examples per segment of how our market proxy tracks the monthly Clarkson spot and term charter index. Obviously, we expect our market proxy and fixture rates to be highly positively correlated and dominate in terms of explanatory power. However, the intention behind the market proxy is not about explanatory power *per se*, but that a failure to account for the underlying market would ascribe unreliable significance to the remaining micro determinants. As an example, figure 7 shows our smoothed market

[4] PSVs divided into three categories: PSV1 = 500-749 m2, PSV2 = 750-900 m2, PSV3 = 900+ m2.
AHTSs divided into four categories: AHTS1 = 8,000-10,999 bhp, AHTS2 = 11,000-15,999 bhp, AHTS3 = 16,000-19,999 bhp, AHTS4 = 20,000+ bhp.

[5] PSV term is divided into four regions: Northwest Europe, U.S. Gulf, South America and Other.
AHTS term is divided into four regions: Northwest Europe, Middle East, Southeast Asia and Other.
For all spot rates we do *not* divide into regions as the majority is operating in Northwest Europe.

proxy compared to realized freight rates for PSV term charters operating in the Northwest Europe with size category 3 (900+m2).

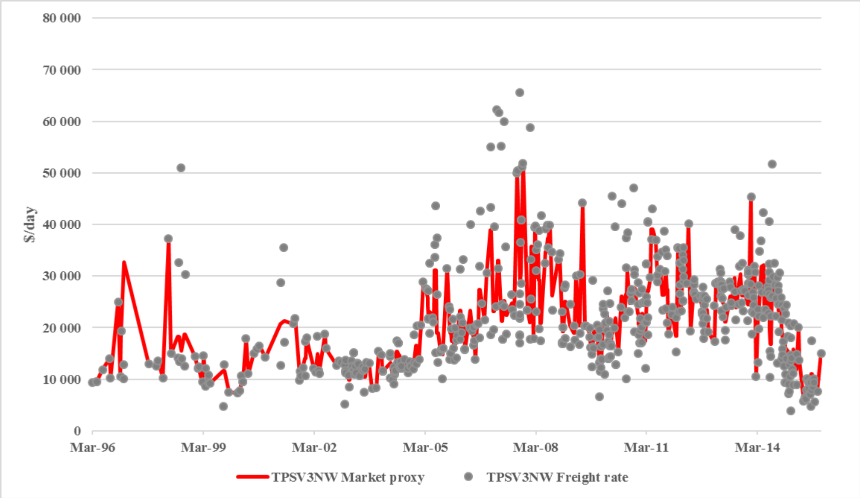



***Figure 7: Freight rate vs. Market proxy: Term PSV 900+m2 NW Europe***

### 4.1.2 Contract-specific variables

In order to investigate the impact of duration[6] and forward[7] variables, we construct interaction dummies based on the forward curve in chapter 3.4, i.e. *Duration_BW* and *Forward_BW*. Both duration and forward of the fixtures are expected to be negatively related to freight rates if, on average, the term structure is downward sloping. Conversely, with an upward sloping term structure the coefficients are expectedly positive. Naturally, we expect most effects to be picked up by the term analyses. We choose to analyze backwardation periods in our sample, however, we examine contango market in the PSV 2010-2015 analysis due to prevailing market conditions. Note that we exclude the forward variable in the spot analyses for both PSV and AHTS as spot fixtures usually are executed within one day.

The scope of work dummies for production support (*Production_D*) and drilling support (*Drilling_D*) is affected by the predictability for the charterer. Whereas production support is an ongoing requirement, drilling support is a function of many factors, e.g. number of wells being drilled and number of rig moves (ICS, 2011). Therefore, PSVs on production support

[6] Duration is defined as the number of days from fixture start date to fixture end date with options.

[7] Forward is defined as the number of days from fixture date to fixture start date.

is expected to receive significantly lower freight rates than other scopes of work, such as AHTSs on drilling support. On the other hand, the underlying trend of increased pre-lay activity and more efficient rig moves implies a negatively growth in AHTSs demand and decreased freight rates (RS Platou, 2015). In general, we expect the spot market to be less significant for both production support and drilling support, as a result of the predictability aspect in the term charter market.

Two region dummies per segment are included in order to investigate geographical differences in the OSV spot market. Our sample consists to a large degree of fixtures in Northwest Europe, apart from the AHTS term charter market[8], which encourage us to use this area as a base dummy for both PSVs and AHTSs. In the PSV market, we include dummies for the *U.S. Gulf* and *Brazil*[9]. Whereas the U.S. Gulf is characterized as a matured market with smaller PSVs, lower specifications and less costly operations, the Brazilian market is more specialized and characterized by cabotage regime with strict local content and crewing requirements. Thus, PSVs operating in the U.S. Gulf and Brazil is expected to receive significantly lower and higher freight rates, respectively, compared to Northwest Europe. Turning to the AHTS market, we include dummies for *Asia* and the *Middle East*[10]. Both these AHTS markets are characterized as low-cost area, dominated by small AHTSs operating in benign waters. Consequently, we expect significantly lower freight rates in Asia and the Middle East compared to the Northwest Europe market.

### 4.1.3 Ship-specific variables

In order to measure operational capability for OSVs, there are some standard specifications that need consideration. Dead weight tonnes (DWT) and the size of the deck area (M2) are the most important properties for PSVs' carrying capacity, measuring both outside deck area and "inner" tanks. We expect vessels with larger capacity to obtain higher freight rates due to economies-of-scale effects for both charterer and shipowner, i.e. lower transport unit costs. A larger engine size influences the capability of performing more complex duties, and

[8] The number of PSVs on term charter in the Northwest Europe is far more than the number of AHTSs, with demand for AHTS being met from the spot market (ICS, 2011).

[9] The largest PSV fleets next to Northwest Europe pr. september 2014 (IHS Petrodata, 2014).

[10] The largest AHTS fleets pr. september 2014 (IHS Petrodata, 2014).

thus we expect BHP to have positive influence on the freight rate for PSVs. Moreover, BHP and BP are the most important properties for AHTSs, measuring the vessel´s engine power and pulling power, respectively. As AHTSs can be used as substitutes for PSVs when carrying cargo, we expect DWT to impact freight rate levels as well. From a charterer´s perspective, we believe greater performance capability in complex operations will add significant value for AHTSs. As we embed vessel size in our market proxy, M2 and BHP is omitted in our regression analyses for PSVs and AHTSs, respectively. In addition, the correlation between these standard specifications is substantially high (Appendix 2), and could potentially bias our results. Therefore, we include *DWT* and *BHP* for the PSV analyses, and *DWT* and *BP* for the AHTS analyses.

Furthermore, we check whether freight rate levels are sensitive to vessel age **(***Age*). Alizadeh and Talley (2011b) and Adland et al (2016) found a non-linear relationship between vessel age and shipping freight rates, which inspire us to measure squared age (*Age2*) as well. We believe newer OSVs with greater operational performance will be compensated through higher rates, and thus expect a negative coefficient for vessel age. A dummy for dynamic positioning class 2 (*DP2_D*) is also included as charterers request this feature. Discussions with market participants confirm that lack of DP2 system could have negative impact on freight rates, indicating a positive coefficient to be expected in the presence of DP2 system.

Moreover, we check whether *helideck*, *ROV* (Remotely Operated Vehicle) and *ice class* are significant determinants in the offshore market. As part of the technological development of OSVs, increased demand from charters for these features is expected to be compensated through higher freight rates. The vessel´s build country is often seen as a quality indicator in terms of modernity, innovation and environmental friendliness, e.g. Norwegian yards are believed to provide greater quality compared to Chinese yards. With greater quality charterers should be willing to pay premium freight rates, and by including dummies for OSVs built in Northwest Europe[11] (*Build NW Europe_D*) and Far East[12] (*Build Far East_D*) we attempt to examine this myth. Furthermore, vessel *speed*, here referring to the nominal design speed that a vessel is optimized for in normal conditions, is included in order to investigate whether greater sailing capability is rewarded through higher freight rates. We do

[11] Our observations from NW Europe consist of 566 OSVs built in Norway and 162 OSVs built in Netherlands.

[12] Our observations from Far East consist of 1,452 OSVs built in China and 167 OSVs built in Japan.

not expect speed to influence freight rates in the same manner as in the conventional shipping market due to high degree of weather sensitivity, however, lack of economic theory related to speed of OSVs make us eager to analyze this variable.

Finally, we include four variables reflecting each vessel´s energy efficiency in order to investigate the presence of a premium in offshore freight rates. Firstly, we consider fuel *consumption* (tonne/day) at the design speed. It is worth mentioning that this variable represents nominal fuel consumption in idealized conditions, which may differ substantially from consumption in real-life seaway conditions. Secondly, inspired by Adland et al (2015), we define a Fuel Efficiency Index (*FEI*) for PSVs and AHTS, respectively:

$$FEI_{PSV} = \frac{Consumption}{DWT*Speed*24} * 10^6 \quad (1) \qquad FEI_{AHTS} = \frac{Consumption}{BHP*Speed*24} * 10^6 \quad (2)$$

The FEIs measure effective fuel consumption (grams/tonnemile) relative to its operational capability of OSVs, however, we are aware that the indexes do not capture all ship-specific effects. Thirdly, we calculate the difference from average fleet consumption (*DAF*) for each specific OSV with equation 3:

$$DAF = \left(Consumption - Average\ fleet\ consumption^{13}\right) * Bunker\ price^{14} \quad (3)$$

With increased fuel prices we expect fuel-efficient ships becoming more attractive, which in an efficient market should be rewarded through a freight rate premium. Fourthly, we use a dummy for conventional mechanical propulsion type (*Conventional_D*). As discussed in chapter 3.5, electric propulsion system and hybrid solutions have demonstrated substantial fuel reduction for OSVs, making us eager to investigate a potential freight rate discount for conventional propulsion systems. For all four energy efficiency variables, a higher reading denotes lower energy efficiency. Hence, we expect negative coefficients with regards to the freight rate in the presence of an efficient market.

Because of the changing market conditions in the years covered by the sample, we allow for an interaction dummy between the energy efficiency variables and boom periods in the

[13] Average fleet consumption is defined as yearly average at that point in time, assuming no vessels being scrapped or laid-up. To date, scrapping activity in the offshore fleet has been limited (ICS, 2011).

[14] Historical bunker prices are daily 3.5%/380cst HFO Rotterdam (PEUR35RF Index), obtained from Bloomberg (2016).

offshore freight rate market[15], i.e. *Boom_Cons*, *Boom_FEI (DWT)*, *Boom_FEI (BHP)*, *Boom_DAF* and *Boom_Conventional*. Our a priori expectation is that energy efficiency will matter less during very strong markets, where there is a potential shortage of vessels, than during times of low earnings and focus on cost reduction. Therefore, we expect a positive coefficient for the interaction dummies, suggesting a market failure where energy-efficient ships obtain a reduced premium during strong markets compared to normal market conditions.

## 4.2 Regression model

The variables in our multiple regression model are grouped into macro-, contract- and ship-specific variables. In order to explain the determinants of the period time-charter rate *F* for fixture *i*, we have implemented the following model:

$$F_i = \propto_0 + \propto_1 I_t + \sum_j \theta_j R_{i,j} + \sum_j \omega_j S_{i,k} + \varepsilon_i \qquad (4)$$

where $F_i$ is the observed freight rate of the *i*th fixture signed at date *t*. $\propto_0$ represents the unobserved effect. The macro variable is represented by the calculated market proxy $I_t$ at fixture date. $R_{i,j}$ is the set of *j* contract-specific variables, while $S_{i,k}$ is the set of ship-specific variables. Lastly, $\varepsilon_i$ is a random perturbation, known as the error term, such that E($\varepsilon_i$) = 0 and V($\varepsilon_i$) = $\sigma^2$. When incorporating the market proxy in the model, the coefficients of contract- and ship-specifications will be statistically insignificant where the specifications do not matter as freight rate determinants.

To perform our analysis, we use panel data estimation techniques[16]. An alternative would be to use pooled ordinary least squares, but these techniques will lead to biased and inconsistent coefficients, as this method does not take into account the individual heterogeneity in ships that is constant over time (Verbeek, 2012). In a panel dataset we have both a cross-sectional and a time series dimension, which able us to follow the same individual vessel across time.

[15] After studying our observations, we define the boom periods as 1987-1990, 1996-1998 and 2005-2009. This is confirmed by discussions with market participants.

[16] We have used the statistical software package Stata to execute our panel data regressions.

There are mainly two types of panel data models, i.e. random effects and fixed effects (Wooldridge, 2015). A random effect, or variance components model, assumes unique, time constant attributes of groups that are the results of random variation. However, a random effect model assumes that the unobserved effect is uncorrelated with each explanatory variable. A fixed effect model allows for this correlation between the explanatory variable and the unobserved individual specific effect, and uses a transformation to eliminate the unobserved heterogeneity by demeaning the variables prior to estimation. Consequently, the fixed effects model will be less efficient than the random effects model. The Hausman test reveals whether one should use fixed or random effects model by testing a null hypothesis where the coefficients from the fixed effects model and the random effects model corresponds with each other (Hausman, 1978). Our Hausman test rejects the null hypothesis and thereby encouraging us to use the random effects model, which we expected a priori due to a strongly unbalanced dataset with variables that both vary and are constant over time.

We control for potential heteroscedasticity and serial correlation in the error term by using the cluster-robust standard errors. Heteroscedasticity does not invalidate the analysis, but it weakens the efficiency of the results as it impacts the standard errors. We test for multicollinearity by creating a correlation matrix between each individual variable (Appendix 2). In cases of high degree of multicollinearity, Stata will omit the unreliable variables. Additionally, we test for multicollinearity by using the variance inflation factor (VIF), even though the test is not optimized for panel data analysis (Appendix 3). In general, a score above ten will indicate a high degree of multicollinearity.

In order to robustness test our results, we perform a quantile regression for a range of variables. The analyses evaluate the upper and lower ten percentages by value for all the ship-specific variables excluded dummies. Hence, we are able to capture non-linear effects and determine whether vessels, with e.g. the highest fuel consumption or DWT, are being rewarded or penalized in terms of freight rates. Compared to standard linear regression techniques that summarizes the average relationship between the variables, the quantile regression provides the capability of investigating the conditional distribution of the freight rate for a given ship specification. Note that we perform the quantile regressions by values, implying that the upper ten percentages of for instance consumption are the most polluting vessels in terms of tonne per day, and not necessarily the best scoring fuel-efficient vessels.

# 5. Data

## 5.1 Data preparation

Our dataset provided by Ulstein Group contains of 73,156 observations before data cleansing. The sample covers fixture information between 1967 and early 2016 for PSVs and AHTSs. In total, 5,948 freight rates expressed in EUR, GBP or NOK are converted to USD with exchange rate on fixture date[17]. In addition, we supplement the dataset with our choice of variables. In cases of missing data for ship-specific variables, complementary information is gathered from Clarkson Research (2016b). Furthermore, missing fuel consumption is handled through implied consumption (equation 5) based on individually kW specifications, and, finally, we are able to add 11,407 fixtures with specific consumption[18].

$$Implied\ consumption: \quad kW * \frac{g}{kWh} * \frac{24}{1''} = tonnes/day \qquad (5)$$

To prepare our sample for the analysis process, we have excluded duplicates and fixtures without IMO number and USD rate. The filtering reduces the dataset to 40,750 fixtures, however, we do not expect it will bias our results as the omitted fixtures are evenly spread out through the analysis period. Having taken into account outliers in our sample, we finally utilize a comprehensive data set of 40,537 individual fixtures between January 31$^{th}$ 1984 and January 5$^{th}$ 2016[19]. We note that Stata conducts a listwise deletion of missing data in our sample, i.e. eliminates those fixtures from the analysis (Acock, 2008). Even though this may reduce the statistical power in our model, we believe alternative methods to have even greater shortcomings.

[17] Exchange rates are obtained from Federal Reserve (2016).

[18] After discussions with Ulstein Group, we assume fuel consumption to be 170 g/kWh for diesel-mechanical propulsion system and 200 g/kWh for diesel-electric propulsion system.

[19] Outliers are defined as illogical values and removed manually. A detailed data cleansing can be found in Appendix 1.

## 5.2 Data description

In order to describe our data sample, table 2 shows descriptive statistics for both OSV segment. In addition, correlation matrices for PSV spot, PSV term, AHTS spot and AHTS term are presented in Appendix 2.

| Variables | PSV SPOT | | | PSV TERM | | | AHTS SPOT | | | AHTS TERM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Obs | Mean | Std. Dev. | Obs | Mean | Std. Dev. | Obs | Mean | Std. Dev. | Obs |
| ***Dependent:*** | | | | | | | | | | | | |
| Freight rate | 14220 | 12481 | 12919 | 17482 | 10830 | 4092 | 28999 | 36670 | 19148 | 17616 | 15002 | 4378 |
| ***Macro:*** | | | | | | | | | | | | |
| Market proxy | 13551 | 11289 | 12919 | 16903 | 9431 | 4092 | 26525 | 32168 | 19148 | 17025 | 13557 | 4378 |
| ***Contract:*** | | | | | | | | | | | | |
| Duration | 4.5 | 21.7 | 12919 | 522.7 | 661.0 | 4092 | 4.1 | 16.1 | 19148 | 462.3 | 616.9 | 4378 |
| Forward | | | 12919 | 32.5 | 131.2 | 4092 | | | 19148 | 19.4 | 88.8 | 4378 |
| Production_D | 0.6% | | 12919 | 42.7% | | 4092 | | | | | | |
| Drilling_D | | | | | | | 0.4% | | 19148 | 43.7% | | 4378 |
| U.S. Gulf_D | 1.1% | | 12919 | | | | | | | | | |
| Brazil_D | 0.2% | | 12919 | | | | | | | | | |
| Asia_D | | | | | | | 0.4% | | 19148 | | | |
| Middle East_D | | | | | | | 0.2% | | 19148 | | | |
| ***Ship:*** | | | | | | | | | | | | |
| DWT | 3242 | 1042 | 12919 | 3066 | 1303 | 4092 | 2694 | 1083 | 19148 | 1963 | 915 | 4378 |
| BHP | 6183 | 2094 | 12916 | 5927 | 2464 | 4087 | | | | | | |
| BP | | | | | | | 177 | 62 | 19106 | 116 | 56 | 4340 |
| Age | 10.5 | 8.4 | 12919 | 9.1 | 9.3 | 4092 | 7.8 | 6.1 | 19148 | 8.1 | 8.6 | 4378 |
| DP2_D | 42.1% | | 12919 | 47.1% | | 4092 | 44.5% | | 19148 | 29.5% | | 4378 |
| Helideck_D | 0.9% | | 12919 | 0.3% | | 4092 | 0.6% | | 19148 | 0.2% | | 4378 |
| ROV_D | 10.2% | | 12919 | 4.3% | | 4092 | 5.9% | | 19148 | 1.5% | | 4378 |
| Ice class_D | 10.0% | | 12919 | 6.9% | | 4092 | 45.4% | | 19148 | 15.2% | | 4378 |
| Build Far East_D | 4.5% | | 12919 | 7.6% | | 4092 | 8.0% | | 19148 | 30.7% | | 4378 |
| Build NW Europe_D | 75.8.% | | 12919 | 43.7% | | 4092 | 68.8% | | 19148 | 30.3% | | 4378 |
| Speed | 13.5 | 1.6 | 12876 | 13.3 | 1.7 | 3948 | 15.5 | 2.0 | 19117 | 13.9 | 1.9 | 4269 |
| Consumption | 11.4 | 3.7 | 10436 | 10.6 | 4.4 | 2656 | 21.7 | 12.2 | 15660 | 16.2 | 9.1 | 2970 |
| FEI (DWT) | 12.5 | 6.1 | 10399 | 13.0 | 8.4 | 2607 | | | | | | |
| FEI (BHP) | | | | | | | 4.3 | 2.6 | 15658 | 5.3 | 2.6 | 2926 |
| DAF | 106 | 1271 | 10436 | -243 | 1874 | 2656 | 748 | 3934 | 15660 | -1567 | 3753 | 2970 |
| Conventional_D | 33.7% | | 12919 | 34.3% | | 4092 | 42.3% | | 19148 | 35.4% | | 4378 |

***Table 2: Descriptive statistics***

We find the USD freight rate and our calculated market proxy highly correlated, i.e. above 85% in all analyses, suggesting how individual contract- and ship-specific factors are not likely to add much explanatory power. Regarding contract specifications, PSVs tend to be fixed further ahead (Forward) and for longer time periods (Duration) than AHTSs. Positive correlations between duration and forward for both segments suggest that fixtures with longer duration are planned ahead to cover basis services. Furthermore, we note a clear distinction regarding share of contracts in production support for PSV spot (0.6%) and PSV term (42.7%), as well as share of contracts in drilling support for AHTS spot (0.4%) and AHTS term (43.7%). This confirms the predictability aspect discussed in chapter 4.1.2, where the spot market in a larger degree absorbs unpredictable work for OSVs. Vessel age is weak negatively correlated with number of days forward and contract duration, indicating that younger vessels have longer forward period and duration than older vessels. Moreover, we observe age to be negative correlated with all standard ship specifications, i.e. DWT, M2, BHP and BP. We note that also DP2 are strongly negative correlated with age, implying this feature to become more common. Overall, it indicates increasing operational capability for newer OSVs in order to perform operations in more demanding environments. The descriptive statistics show greatly variance in OSV size, however, we find strong correlation between standard specifications which support us in our choice to omit BHP from the AHTS analyses.

| **PSV** | | **AHTS** | |
|---|---|---|---|
| *Region:* | *Days:* | *Region:* | *Days:* |
| NW Europe | 57 | NW Europe | 20 |
| U.S. Gulf | 312 | Asia | 368 |
| Brazil | 1216 | Middle East | 666 |

***Table 3: Average contract durations - PSV and AHTS***

Regarding region variables, Northwest Europe dominates as the place of activity in the spot market, i.e. above 95% for both PSVs and AHTSs. The term charter market consists of 48.7% PSV fixtures in Northwest Europe, whereas 33.7% of AHTS fixtures are present in Asia. In general, we note that standard ship specifications only are positive correlated with activity in Northwest Europe, indicating higher operational requirements in the North Sea compared to other regions. Moreover, table 3 shows that average contract duration is substantial higher in other OSV regions compared to Northwest Europe, suggesting that Northwest Europe consolidates its reputation as a shortsighted market. Even more interestingly, we find a high correlation between activity- and build dummies for Northwest Europe in the term charter market. The interpretation is that vessels expected to operate in this region on longer duration, tend to be built at Northwest European yards. Looking finally on our chosen energy efficiency measures, we find AHTSs as more energy demanding compared to PSVs, likely due to larger vessel size. Moreover, consumption is positive correlated with speed in all analyses.

# 6. Results

## 6.1 Results 1984-2015

### 6.1.1 PSV spot

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Market proxy | 1.009$^{***}$ | 1.018$^{***}$ | 1.018$^{***}$ | 1.018$^{***}$ | 1.014$^{***}$ | 1.016$^{***}$ | 1.016$^{***}$ | 1.018$^{***}$ | 1.013$^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Duration_BW | | -0.446 | -0.350 | -0.338 | -2.618 | -0.928 | -0.953 | -0.351 | -2.968 |
| | | (0.815) | (0.853) | (0.861) | (0.388) | (0.643) | (0.644) | (0.856) | (0.326) |
| Production_D | | -42.05 | -56.69 | -32.22 | -382.6 | -41.52 | -55.01 | -29.71 | -381.0 |
| | | (0.954) | (0.939) | (0.965) | (0.543) | (0.955) | (0.940) | (0.968) | (0.543) |
| U.S. Gulf_D | | -252.8 | -239.7 | -137.7 | -969.4 | -239.3 | -175.7 | -139.8 | -965.4 |
| | | (0.779) | (0.791) | (0.882) | (0.191) | (0.790) | (0.845) | (0.880) | (0.193) |
| Brazil_D | | 20079.1$^{***}$ | 20119.6$^{***}$ | 20014.8$^{***}$ | 18416.4$^{***}$ | 20118.0$^{***}$ | 20150.1$^{***}$ | 20016.0$^{***}$ | 18461.7$^{***}$ |
| | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| DWT | | -0.262 | -0.371 | -0.250 | -0.0621 | -0.244 | -0.366 | -0.248 | -0.0554 |
| | | (0.124) | (0.100) | (0.145) | (0.732) | (0.149) | (0.103) | (0.151) | (0.759) |
| BHP | | -0.00537 | 0.0105 | -0.0130 | -0.116 | -0.00271 | 0.0138 | -0.0129 | -0.114 |
| | | (0.944) | (0.889) | (0.865) | (0.176) | (0.972) | (0.855) | (0.866) | (0.183) |
| Age | | -54.90 | -54.01 | -57.12 | -57.25 | -49.14 | -48.48 | -55.95 | -54.52 |
| | | (0.136) | (0.142) | (0.111) | (0.095) | (0.159) | (0.159) | (0.119) | (0.111) |
| Age2 | | -0.190 | -0.197 | -0.180 | -0.139 | -0.256 | -0.250 | -0.208 | -0.153 |
| | | (0.856) | (0.851) | (0.864) | (0.886) | (0.801) | (0.805) | (0.843) | (0.876) |
| DP2_D | | 370.4 | 339.1 | 364.9 | 779.3$^{*}$ | 407.6 | 371.0 | 369.4 | 796.9$^{*}$ |
| | | (0.180) | (0.216) | (0.190) | (0.037) | (0.138) | (0.174) | (0.186) | (0.033) |
| Helideck_D | | -2286.0 | -2165.2 | -2323.5 | -2245.1 | -2222.5 | -2127.7 | -2316.5 | -2246.9 |
| | | (0.377) | (0.421) | (0.361) | (0.267) | (0.388) | (0.427) | (0.362) | (0.265) |
| ROV_D | | 317.9 | 351.4 | 345.7 | 1134.7 | 290.5 | 331.6 | 329.8 | 1132.6 |
| | | (0.344) | (0.307) | (0.310) | (0.130) | (0.384) | (0.332) | (0.332) | (0.132) |
| Ice class_D | | 1517.4$^{***}$ | 1504.8$^{***}$ | 1534.8$^{***}$ | 914.6$^{**}$ | 1518.6$^{***}$ | 1505.2$^{***}$ | 1528.9$^{***}$ | 918.8$^{**}$ |
| | | (0.000) | (0.000) | (0.000) | (0.005) | (0.000) | (0.000) | (0.000) | (0.005) |
| Build Far East_D | | -54.36 | -33.30 | -81.01 | 588.0 | -57.11 | -47.55 | -87.67 | 595.0 |
| | | (0.938) | (0.962) | (0.910) | (0.420) | (0.935) | (0.946) | (0.902) | (0.415) |
| Build NW Europe_D | | 213.1 | 227.7 | 231.1 | 504.9 | 195.8 | 210.7 | 229.3 | 491.2 |
| | | (0.432) | (0.409) | (0.391) | (0.071) | (0.470) | (0.445) | (0.395) | (0.080) |
| Speed | | 69.84 | 61.50 | 69.46 | 147.7 | 70.31 | 61.24 | 67.50 | 146.4 |
| | | (0.344) | (0.452) | (0.364) | (0.068) | (0.342) | (0.454) | (0.379) | (0.071) |
| Consumption | | 22.75 | | | | 16.04 | | | |
| | | (0.467) | | | | (0.612) | | | |
| FEI (DWT) | | | -23.41 | | | | -30.96 | | |
| | | | (0.346) | | | | (0.237) | | |
| DAF | | | | 0.117 | | | | 0.112 | |
| | | | | (0.452) | | | | (0.482) | |
| Conventional_D | | | | | -160.3 | | | | -229.6 |
| | | | | | (0.537) | | | | (0.384) |
| Boom_Cons | | | | | | 16.00 | | | |
| | | | | | | (0.254) | | | |
| Boom_FEI (DWT) | | | | | | | 14.70 | | |
| | | | | | | | (0.325) | | |
| Boom_DAF | | | | | | | | 0.0862 | |
| | | | | | | | | (0.574) | |
| Boom_Conventional | | | | | | | | | 327.8 |
| | | | | | | | | | (0.133) |
| Constant | 552.3$^{***}$ | 83.53 | 988.6 | 356.3 | -792.1 | 14.20 | 975.8 | 373.5 | -813.0 |
| | (0.000) | (0.946) | (0.533) | (0.755) | (0.494) | (0.991) | (0.537) | (0.744) | (0.483) |
| N | 12919 | 10397 | 10397 | 10397 | 12873 | 10397 | 10397 | 10397 | 12873 |
| Overall R2 | 0.860 | 0.872 | 0.872 | 0.872 | 0.868 | 0.872 | 0.872 | 0.871 | 0.868 |

*p*-values in parentheses

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

***Table 4: Results PSV spot 1984-2015***

As expected, the market proxy representing the underlying market dominates in terms of explanatory power with an overall R2 of 86.0% (1), and is significant at the 99.9% level of confidence in all nine analyses. The overall R2 is stable at 87.2%, but after adding the dummy for conventional diesel as propulsion type, we notice a slight decrease in terms of explanatory power.

Neither duration nor the scope of work for production support show significant results, indicating them to be of no relevance in the PSV spot market. The U.S. Gulf as operating region has no impact on the level of freight rates, however, the Brazilian premium of about $20,000/day is clearly present in the data with significance on a confidence level of 99.9% in all analyses. Such a large premium might be related to less mature spot market in Brazil compared to Northwest Europe, causing higher start-up costs and incentivizing higher level of freight rates, an observation that is confirmed after speaking with shipowners. Standard specifications such as DWT and BHP do not prove any significance at all, which could indicate that charterers in the spot market takes these specs for granted. Neither the vessel age proves significance, implying no age premium where short-term duties are suitable for most vessels. The presence of DP2, helideck and ROV support seems not to be rewarded in the PSV spot market. On the other hand, an ice class premium of about $1,500/day is clearly present in the data with confidence level of at least 99% for all nine models. There is no evidence that build region and sailing capability (speed) are determinants of spot freight rates.

Regarding energy efficiency, none of the variables prove significance at all, not even during boom periods. In other words, energy efficiency is not of significant value for PSVs operating in the spot market.

## 6.1.2 PSV term

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Market proxy | 0.867$^{***}$ | 0.910$^{***}$ | 0.909$^{***}$ | 0.910$^{***}$ | 0.876$^{***}$ | 0.903$^{***}$ | 0.905$^{***}$ | 0.910$^{***}$ | 0.874$^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Duration_BW | | -0.508$^{**}$ | -0.484$^{**}$ | -0.514$^{**}$ | -0.495$^{**}$ | -0.770$^{***}$ | -0.691$^{***}$ | -0.514$^{**}$ | -0.561$^{***}$ |
| | | (0.005) | (0.009) | (0.005) | (0.001) | (0.000) | (0.000) | (0.005) | (0.001) |
| Forward_BW | | 0.968 | 1.028 | 0.962 | 1.016 | 0.361 | 1.028 | 0.979 | 1.045 |
| | | (0.539) | (0.536) | (0.543) | (0.537) | (0.812) | (0.530) | (0.524) | (0.524) |
| Production_D | | -677.6$^{**}$ | -687.3$^{**}$ | -677.9$^{**}$ | -667.1$^{***}$ | -685.0$^{**}$ | -681.8$^{**}$ | -678.4$^{**}$ | -673.1$^{***}$ |
| | | (0.006) | (0.005) | (0.006) | (0.001) | (0.006) | (0.006) | (0.005) | (0.001) |
| DWT | | 0.130 | -0.0562 | 0.132 | 0.478$^{**}$ | 0.172 | -0.0458 | 0.133 | 0.483$^{**}$ |
| | | (0.449) | (0.769) | (0.443) | (0.004) | (0.311) | (0.809) | (0.444) | (0.004) |
| BHP | | 0.135 | 0.199$^{*}$ | 0.124 | 0.0343 | 0.158 | 0.214$^{**}$ | 0.124 | 0.0383 |
| | | (0.112) | (0.016) | (0.152) | (0.674) | (0.061) | (0.009) | (0.152) | (0.637) |
| Age | | 48.75 | 50.80 | 47.17 | 93.72$^{*}$ | 59.36 | 54.16 | 47.10 | 98.19$^{*}$ |
| | | (0.310) | (0.292) | (0.319) | (0.020) | (0.219) | (0.264) | (0.321) | (0.015) |
| Age2 | | -4.039$^{**}$ | -3.839$^{**}$ | -3.986$^{**}$ | -5.461$^{***}$ | -4.192$^{**}$ | -3.818$^{**}$ | -3.984$^{**}$ | -5.537$^{***}$ |
| | | (0.003) | (0.007) | (0.003) | (0.000) | (0.002) | (0.008) | (0.003) | (0.000) |
| DP2_D | | 1832.0$^{***}$ | 1709.0$^{***}$ | 1865.2$^{***}$ | 2192.5$^{***}$ | 1931.6$^{***}$ | 1779.6$^{***}$ | 1863.8$^{***}$ | 2209.1$^{***}$ |
| | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Helideck_D | | 4480.9$^{***}$ | 4965.3$^{***}$ | 4306.4$^{***}$ | 1892.6 | 4527.0$^{***}$ | 4984.2$^{***}$ | 4304.8$^{***}$ | 1875.0 |
| | | (0.000) | (0.000) | (0.000) | (0.171) | (0.000) | (0.000) | (0.000) | (0.174) |
| ROV_D | | 1095.7 | 1185.1 | 1115.3 | 1273.7 | 975.4 | 1122.1 | 1117.9 | 1259.2 |
| | | (0.170) | (0.130) | (0.158) | (0.116) | (0.219) | (0.150) | (0.161) | (0.116) |
| Ice class_D | | 83.71 | 119.8 | 101.0 | -535.8 | 101.5 | 135.6 | 100.2 | -527.0 |
| | | (0.852) | (0.794) | (0.824) | (0.200) | (0.821) | (0.767) | (0.826) | (0.207) |
| Build Far East_D | | -1637.0$^{***}$ | -1513.3$^{***}$ | -1654.2$^{***}$ | -1356.6$^{***}$ | -1547.9$^{***}$ | -1469.0$^{***}$ | -1652.9$^{***}$ | -1339.5$^{***}$ |
| | | (0.000) | (0.001) | (0.000) | (0.001) | (0.001) | (0.001) | (0.000) | (0.001) |
| Build NW Europe_D | | -791.9$^{*}$ | -737.5$^{*}$ | -794.7$^{*}$ | -851.1$^{**}$ | -888.5$^{**}$ | -814.8$^{*}$ | -794.2$^{*}$ | -874.6$^{**}$ |
| | | (0.023) | (0.034) | (0.023) | (0.006) | (0.009) | (0.018) | (0.023) | (0.004) |
| Speed | | 115.4 | 95.01 | 116.4 | 101.7 | 98.00 | 80.73 | 116.2 | 100.7 |
| | | (0.243) | (0.339) | (0.238) | (0.201) | (0.315) | (0.416) | (0.238) | (0.205) |
| Consumption | | 39.36 | | | | 11.67 | | | |
| | | (0.204) | | | | (0.720) | | | |
| FEI (DWT) | | | -40.89$^{*}$ | | | | -56.65$^{*}$ | | |
| | | | (0.047) | | | | (0.011) | | |
| DAF | | | | 0.120 | | | | 0.122 | |
| | | | | (0.099) | | | | (0.083) | |
| Conventional_D | | | | | -194.7 | | | | -335.5 |
| | | | | | (0.407) | | | | (0.156) |
| Boom_Cons | | | | | | 72.02$^{**}$ | | | |
| | | | | | | (0.002) | | | |
| Boom_FEI (DWT) | | | | | | | 47.42$^{***}$ | | |
| | | | | | | | (0.000) | | |
| Boom_DAF | | | | | | | | -0.0133 | |
| | | | | | | | | (0.942) | |
| Boom_Conventional | | | | | | | | | 549.2 |
| | | | | | | | | | (0.092) |
| Constant | 2833.8$^{***}$ | -1032.0 | 355.8 | -541.3 | -431.2 | -903.5 | 511.5 | -540.7 | -439.8 |
| | (0.000) | (0.375) | (0.784) | (0.658) | (0.661) | (0.433) | (0.695) | (0.658) | (0.655) |
| N | 4092 | 2603 | 2603 | 2603 | 3944 | 2603 | 2603 | 2603 | 3944 |
| Overall R2 | 0.759 | 0.789 | 0.789 | 0.790 | 0.786 | 0.791 | 0.790 | 0.790 | 0.786 |

*p*-values in parentheses

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

***Table 5: Results PSV term 1984-2015***

The market proxy separately performs a R2 of 75.9% (1). When including contract- and ship- specific variables the overall explanatory power stabilize around 79%, implying those variables to add value in the PSV term market.

As expected a priori, the interaction dummy related to duration in backwardated markets proves significance with negative coefficients, implying that a downward sloping term structure yields declining freight rates as duration increases. On the other side, the length of the forward period does not take on any significance. Overall, there is evidence that production support contributes with a discount of about $600/day, as the degree of predictability usually is high for the charterer. DWT yields mostly insignificant results, however, when including the dummy for diesel propulsion system (5), a slightly premium appears. The same can be said about BHP, which proves insignificance in all but two cases. Vessel age does not take on any significance *per se*, however, the non-linear effect captures a discount for older vessels as squared age has negative coefficients with at least 99% certainty. In other words, there exists no evidence of a premium for a 1-year-old vessel, but, for instance, a 10-year-old vessel is exposed to a discount of about $400/day. As opposed to the PSV spot analysis, DP2 and helideck are of importance in the PSV term market. DP2 contributes with a premium of about $1,800/day, while helideck proves a substantial premium of about $4,500/day for all analysis but (5). Surprisingly, the presence of ice class premium in the spot market has disappeared in the PSV term analysis. Looking at the dummies for build region, the results suggest a discount in both Far East and Northwest Europe. However, vessels built in the Far East obtain a discount of about $1600/day – twice as big as the Northwest Europe discount.

Focusing on our chosen energy efficiency measures, we observe a slight discount for vessels with higher fuel consumption relative to its operational capability (3). By itself, this indicates that energy efficiency matter in the PSV term market, however, we notice that the remaining variables prove insignificant results. By controlling for market conditions via our interaction dummies we can measure whether energy efficiency matters during good times, which it seem to do in this case. Our result for the FEI variable shows a negative aggregated coefficient (7), implying that less energy-efficient vessels are being penalized. Hence, energy-efficient PSVs could get rewarded in the term market, however, the evidence for an energy efficiency premium is weak.

## 6.1.3 AHTS spot

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Market proxy | 1.032*** | 1.042*** | 1.042*** | 1.042*** | 1.038*** | 1.032*** | 1.035*** | 1.043*** | 1.027*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Duration_BW | | 15.70 | 15.84 | 16.05 | 9.569 | 34.90 | 28.52 | 14.76 | 19.85 |
| | | (0.441) | (0.438) | (0.434) | (0.404) | (0.111) | (0.189) | (0.479) | (0.151) |
| Drilling_D | | 1583.4 | 1587.0 | 1566.4 | 1200.6 | 1173.7 | 1180.0 | 1579.6 | 940.2 |
| | | (0.350) | (0.349) | (0.356) | (0.372) | (0.484) | (0.483) | (0.352) | (0.479) |
| Asia_D | | -1151.7 | -1114.7 | -1151.7 | -679.0 | -977.4 | -677.6 | -1120.7 | -489.0 |
| | | (0.418) | (0.433) | (0.418) | (0.503) | (0.487) | (0.633) | (0.432) | (0.625) |
| Middle East_D | | 140.4 | 198.7 | 76.78 | -312.7 | 493.5 | 1044.8 | 160.3 | 127.5 |
| | | (0.938) | (0.912) | (0.966) | (0.799) | (0.780) | (0.564) | (0.929) | (0.915) |
| DWT | | 0.508 | 0.493 | 0.494 | 0.629 | 0.595 | 0.589 | 0.503 | 0.850 |
| | | (0.423) | (0.442) | (0.437) | (0.261) | (0.345) | (0.353) | (0.426) | (0.115) |
| BP | | 8.673 | 8.082 | 9.023 | 3.140 | 11.58 | 9.948 | 8.857 | 1.054 |
| | | (0.600) | (0.620) | (0.589) | (0.808) | (0.483) | (0.533) | (0.595) | (0.934) |
| Age | | 311.9** | 313.1** | 310.6** | 251.6** | 280.6** | 288.2** | 313.7** | 216.1* |
| | | (0.003) | (0.003) | (0.003) | (0.007) | (0.007) | (0.006) | (0.003) | (0.013) |
| Age2 | | -15.81*** | -15.90*** | -15.73*** | -13.21*** | -14.45*** | -14.62*** | -15.76*** | -11.42*** |
| | | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.000) | (0.001) |
| DP2_D | | -132.6 | -103.2 | -130.6 | -34.72 | 17.95 | 6.244 | -155.8 | 191.7 |
| | | (0.857) | (0.889) | (0.857) | (0.961) | (0.980) | (0.993) | (0.830) | (0.788) |
| Helideck_D | | -6197.8** | -6283.5*** | -6234.7*** | -5687.7*** | -6354.4*** | -6368.4*** | -6191.3** | -5156.5** |
| | | (0.001) | (0.001) | (0.001) | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) |
| ROV_D | | 1361.6 | 1418.5 | 1354.2 | 1290.0 | 1358.2 | 1260.3 | 1355.1 | 1036.6 |
| | | (0.506) | (0.484) | (0.510) | (0.440) | (0.505) | (0.532) | (0.510) | (0.539) |
| Ice class_D | | 843.9 | 848.9 | 856.5 | 469.5 | 864.9 | 868.1 | 832.2 | 527.6 |
| | | (0.169) | (0.169) | (0.161) | (0.419) | (0.159) | (0.155) | (0.172) | (0.354) |
| Build Far East_D | | -2085.8* | -2081.0* | -2085.9* | -1397.2 | -2108.6* | -2199.0** | -2108.4* | -1450.1 |
| | | (0.013) | (0.013) | (0.012) | (0.105) | (0.011) | (0.009) | (0.012) | (0.080) |
| Build NW Europe_D | | 833.7 | 864.4 | 854.1 | 781.9 | 953.7 | 895.8 | 804.5 | 821.3 |
| | | (0.234) | (0.212) | (0.211) | (0.180) | (0.177) | (0.196) | (0.250) | (0.156) |
| Speed | | -143.2 | -143.0 | -142.1 | -85.40 | -160.7 | -154.5 | -135.6 | -91.44 |
| | | (0.180) | (0.186) | (0.185) | (0.338) | (0.155) | (0.167) | (0.210) | (0.316) |
| Consumption | | -8.672 | | | | -34.76* | | | |
| | | (0.615) | | | | (0.033) | | | |
| FEI (BHP) | | | -5.230 | | | | -133.7 | | |
| | | | (0.944) | | | | (0.075) | | |
| DAF | | | | -0.0315 | | | | -0.0139 | |
| | | | | (0.586) | | | | (0.810) | |
| Conventional_D | | | | | 590.0 | | | | -792.6 |
| | | | | | (0.247) | | | | (0.078) |
| Boom_Cons | | | | | | 93.42*** | | | |
| | | | | | | (0.000) | | | |
| Boom_FEI (BHP) | | | | | | | 376.6*** | | |
| | | | | | | | (0.000) | | |
| Boom_DAF | | | | | | | | -0.103 | |
| | | | | | | | | (0.496) | |
| Boom_Conventional | | | | | | | | | 3837.8*** |
| | | | | | | | | | (0.000) |
| Constant | 1612.7*** | -512.6 | -581.3 | -737.9 | -1089.1 | -901.0 | -856.4 | -804.9 | -1022.8 |
| | (0.000) | (0.806) | (0.798) | (0.738) | (0.549) | (0.679) | (0.707) | (0.716) | (0.577) |
| N | 19148 | 15630 | 15630 | 15630 | 19075 | 15630 | 15630 | 15630 | 19075 |
| Overall R2 | 0.845 | 0.848 | 0.848 | 0.848 | 0.850 | 0.849 | 0.849 | 0.848 | 0.851 |

*p* -values in parentheses

$^{*}$ $p$ < 0.05, $^{**}$ $p$ < 0.01, $^{***}$ $p$ < 0.001

***Table 6: Results AHTS spot 1984-2015***

The market proxy clearly dominates in terms of explanatory power with an overall R2 of 84.5% (1), followed by a marginal increase when adding contract- and ship-specific variables.

Our a priori expectations related to a discount for operating in Asia or Middle East does not prove any statistical evidence. Neither DWT nor BP prove any significance as determinants of freight rate levels, suggesting that duties in the spot market involves low degree of complexity. Regarding vessel age, we find a non-linear relationship such that, all else equal, a brand new vessel will pick up a slight premium of about $300/day, declining to a $1,300/day discount for a 10-year old vessel. DP2, ROV and ice class does not prove any evidence, while the presence of helideck actually is penalized. With at least 99% certainty, AHTSs with helideck receive a substantial discount of about $6,000/day. Moreover, there is some evidence regarding Far East build vessels obtaining a discount of about $2,000/day. We note that the significance disappears when adding the dummy for vessel with conventional diesel as propulsion system, suggesting that the penalty is mainly related to Far East build vessels not being able to adapt into alternative propulsion systems, an observation that is confirmed by our discussions with market participants. As for the PSV spot market, greater sailing capability in terms of speed is not rewarded in the AHTS spot market.

None of our chosen energy efficiency measures prove significance before considering interaction dummies, indicating that energy efficiency does not matter during normal market conditions. When controlling for market conditions, however, some interesting inferences can be made from the results. A positive aggregated coefficient related to consumption (6) implies that higher consumption yields higher freight rates during boom periods. Hence, as expected a priori, energy efficiency will matter less during strong markets, where there is a potential shortage of vessels, compared to normal market conditions.

## 6.1.4 AHTS term

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Market proxy | 0.912*** | 0.897*** | 0.897*** | 0.897*** | 0.900*** | 0.881*** | 0.889*** | 0.896*** | 0.893*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Duration_BW | | -0.115 | -0.114 | -0.117 | 0.150 | -0.192 | -0.216 | -0.0781 | 0.110 |
| | | (0.606) | (0.608) | (0.598) | (0.309) | (0.389) | (0.336) | (0.728) | (0.454) |
| Forward_BW | | 2.354 | 2.315 | 2.377 | 2.792 | 2.713 | 2.723 | 2.344 | 3.088* |
| | | (0.208) | (0.215) | (0.202) | (0.051) | (0.144) | (0.146) | (0.207) | (0.035) |
| Drilling_D | | 447.0 | 447.1 | 446.4 | 550.9** | 297.9 | 296.4 | 480.7* | 469.9* |
| | | (0.060) | (0.060) | (0.061) | (0.003) | (0.215) | (0.210) | (0.040) | (0.014) |
| DWT | | 1.087** | 1.056** | 1.089** | 0.721** | 1.163*** | 1.100** | 1.090** | 0.754** |
| | | (0.001) | (0.002) | (0.001) | (0.007) | (0.001) | (0.001) | (0.001) | (0.005) |
| BP | | 12.96* | 11.30 | 12.56* | 16.54*** | 15.97* | 12.31* | 12.52* | 17.09*** |
| | | (0.040) | (0.053) | (0.045) | (0.001) | (0.013) | (0.037) | (0.045) | (0.001) |
| Age | | 82.33 | 83.98 | 81.95 | 75.93* | 88.71 | 86.83 | 78.39 | 74.29 |
| | | (0.078) | (0.072) | (0.083) | (0.048) | (0.055) | (0.060) | (0.097) | (0.052) |
| Age2 | | -3.164* | -3.018* | -3.169* | -3.155** | -3.344* | -3.217* | -2.972* | -3.099** |
| | | (0.021) | (0.026) | (0.022) | (0.005) | (0.013) | (0.016) | (0.033) | (0.005) |
| DP2_D | | 1668.0*** | 1664.7*** | 1670.7*** | 1998.3*** | 1900.9*** | 1796.4*** | 1698.5*** | 2087.3*** |
| | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Helideck_D | | -4970.7 | -4942.8 | -4989.7 | -5347.7 | -4846.6 | -4830.0 | -5123.6 | -5201.5 |
| | | (0.180) | (0.176) | (0.180) | (0.116) | (0.199) | (0.188) | (0.174) | (0.136) |
| ROV_D | | 2480.8 | 2535.8 | 2494.3 | 3232.6* | 2243.0 | 2375.7 | 2527.3 | 3088.7 |
| | | (0.185) | (0.165) | (0.186) | (0.046) | (0.227) | (0.190) | (0.180) | (0.058) |
| Ice class_D | | -253.9 | -285.1 | -248.6 | -693.3 | -269.6 | -320.9 | -222.7 | -666.2 |
| | | (0.602) | (0.558) | (0.612) | (0.135) | (0.585) | (0.514) | (0.650) | (0.152) |
| Build Far East_D | | -869.6* | -897.5* | -869.4* | -997.7*** | -769.4* | -802.0* | -905.9* | -913.5*** |
| | | (0.015) | (0.012) | (0.015) | (0.000) | (0.029) | (0.023) | (0.012) | (0.000) |
| Build NW Europe_D | | -356.3 | -386.4 | -352.2 | -670.3 | -517.3 | -477.2 | -318.3 | -794.8* |
| | | (0.344) | (0.303) | (0.350) | (0.059) | (0.172) | (0.202) | (0.400) | (0.027) |
| Speed | | -61.67 | -108.1 | -62.50 | -12.21 | -78.32 | -128.7 | -59.26 | -15.56 |
| | | (0.533) | (0.288) | (0.526) | (0.885) | (0.433) | (0.209) | (0.547) | (0.854) |
| Consumption | | -6.152 | | | | -32.67 | | | |
| | | (0.696) | | | | (0.057) | | | |
| FEI (BHP) | | | -122.6* | | | | -189.6*** | | |
| | | | (0.019) | | | | (0.000) | | |
| DAF | | | | -0.00434 | | | | -0.0280 | |
| | | | | (0.919) | | | | (0.494) | |
| Conventional_D | | | | | -260.6 | | | | -701.3** |
| | | | | | (0.263) | | | | (0.002) |
| Boom_Cons | | | | | | 75.42*** | | | |
| | | | | | | (0.000) | | | |
| Boom_FEI (BHP) | | | | | | | 178.7*** | | |
| | | | | | | | (0.000) | | |
| Boom_DAF | | | | | | | | 0.163 | |
| | | | | | | | | (0.107) | |
| Boom_Conventional | | | | | | | | | 1934.0*** |
| | | | | | | | | | (0.000) |
| Constant | 2095.2*** | -1010.0 | 451.9 | -1058.5 | -1386.5 | -884.0 | 865.3 | -1128.0 | -1308.9 |
| | (0.000) | (0.410) | (0.743) | (0.404) | (0.187) | (0.472) | (0.532) | (0.372) | (0.212) |
| N | 4378 | 2902 | 2902 | 2902 | 4235 | 2902 | 2902 | 2902 | 4235 |
| Overall R2 | 0.853 | 0.864 | 0.864 | 0.864 | 0.869 | 0.865 | 0.865 | 0.864 | 0.870 |

*p*-values in parentheses

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

***Table 7: Results AHTS term 1984-2015***

As the previous analyses, the market proxy proves a high degree of explanatory power, yielding an overall R2 of 85.3%. We note a 1% increase in R2 when adding contract- and ship-specific variables.

Contrary to our expectations, duration and forward lenght during backwardated periods are not significant determinants of freight rates in the AHTS term market. Neither duties related to drilling activity are off any importance, however, a slightly premium of about $550/day appear when including conventional diesel as propulsion system (5). As opposed to the spot analyses, standard specifications such as DWT and BP impact freight rate levels in the AHTS term market. The importance of good specifications for fixtures with longer duration suggest a higher degree of complexity and predictability in the term market, incentivizing economies of scale effects by using larger and more powerful vessels. DP2 is the only ship-specific feature that generates statistical evidence, providing a premium of about $1,700/day with 99.9% certainty. Vessel age shows little evidence of a new build premium, but a non-linear relationship through a slight discount for older AHTS vessels is present. In accordance with our expectations, vessels build in the Far East region obtain a discount of about $900/day, however, there is no premium for vessels build in Northwest Europe.

From an energy efficiency perspective, we find some interesting inferences. Whereas daily fuel consumption, DAF and our dummy for conventional diesel all show insignificant, the FEI suggest that AHTSs with higher fuel consumption relative to its operational capability are getting penalized (3). As for the PSV term market, this indicates that energy efficiency measured by FEI is rewarded with 95% certainty. If we control for strong market conditions via our interaction dummies, the aggregated FEI coefficient shows negative with strong significance (7). In other words, energy efficiency could matter during good times as well in the AHTS term market.

## 6.2 Results 2010-2015

Several market participants we have spoken to, mention an increasing importance of fuel efficiency over the last decade as several oil majors are constantly putting environmental restrictions into account. Innovations and technological improvements among the shipyard industry continuously gain attention, and we suspect features to have stronger influence on the freight rates in past time. Furthermore, the latest boom period was ranging between 2006 and 2009, making us eager to investigate the following period with normal and bad market conditions. Therefore, we have supplemented our original analysis with a separate analysis containing the period from 2010 to 2015. The implemented variables are basically the same, but obviously we do not implement interaction dummies for boom periods.

### 6.2.1 PSV

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | SPOT | SPOT | SPOT | SPOT | SPOT | TERM | TERM | TERM | TERM | TERM |
| Market proxy | 0.981$^{***}$ | 1.004$^{***}$ | 1.004$^{***}$ | 1.004$^{***}$ | 0.985$^{***}$ | 0.834$^{***}$ | 0.860$^{***}$ | 0.862$^{***}$ | 0.860$^{***}$ | 0.803$^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Duration_Con | | 70.72$^{***}$ | 70.31$^{***}$ | 70.28$^{***}$ | 47.75$^{***}$ | | 0.425 | 0.438 | 0.428 | 0.407 |
| | | (0.000) | (0.000) | (0.000) | (0.001) | | (0.160) | (0.137) | (0.157) | (0.062) |
| Forward_Con | | | | | | | -0.341 | -0.464 | -0.335 | -0.00552 |
| | | | | | | | (0.794) | (0.722) | (0.797) | (0.995) |
| Production_D | | 1466.8 | 1563.7 | 1465.4 | 154.6 | | -1038.9$^{**}$ | -1020.8$^{**}$ | -1040.2$^{**}$ | -846.6$^{***}$ |
| | | (0.315) | (0.287) | (0.319) | (0.867) | | (0.002) | (0.002) | (0.001) | (0.001) |
| U.S. Gulf_D | | -1764.1 | -2116.6 | -1810.4 | -1546.4 | | | | | |
| | | (0.160) | (0.094) | (0.154) | (0.124) | | | | | |
| Brazil_D | | 19903.3$^{***}$ | 19888.5$^{***}$ | 19915.8$^{***}$ | 18087.1$^{***}$ | | | | | |
| | | (0.000) | (0.000) | (0.000) | (0.000) | | | | | |
| DWT | | -0.857$^{***}$ | -0.729$^{**}$ | -0.872$^{***}$ | -0.324 | | 0.302 | 0.0571 | 0.300 | 0.673$^{**}$ |
| | | (0.000) | (0.001) | (0.000) | (0.288) | | (0.211) | (0.836) | (0.213) | (0.002) |
| BHP | | 0.104 | 0.101 | 0.117 | 0.0564 | | 0.209$^{*}$ | 0.286$^{**}$ | 0.200$^{*}$ | 0.103 |
| | | (0.174) | (0.163) | (0.115) | (0.608) | | (0.036) | (0.002) | (0.045) | (0.313) |
| Age | | -81.48 | -69.69 | -77.69 | -120.1 | | 73.24 | 77.34 | 70.71 | 113.6 |
| | | (0.196) | (0.258) | (0.209) | (0.068) | | (0.300) | (0.287) | (0.315) | (0.063) |
| Age2 | | -0.486 | -1.060 | -0.551 | 0.245 | | -5.217$^{**}$ | -4.788$^{*}$ | -5.158$^{**}$ | -6.458$^{***}$ |
| | | (0.790) | (0.565) | (0.760) | (0.897) | | (0.009) | (0.024) | (0.009) | (0.000) |
| DP2_D | | -141.9 | -121.8 | -145.5 | 371.8 | | 2442.9$^{***}$ | 2339.2$^{***}$ | 2447.3$^{***}$ | 2482.4$^{***}$ |
| | | (0.755) | (0.788) | (0.749) | (0.448) | | (0.000) | (0.000) | (0.000) | (0.000) |
| Helideck_D | | 3245.6 | 3312.3 | 3327.3 | 1824.5 | | 5540.1$^{***}$ | 6163.2$^{***}$ | 5481.3$^{***}$ | 2326.9 |
| | | (0.324) | (0.314) | (0.318) | (0.273) | | (0.000) | (0.000) | (0.000) | (0.225) |
| ROV_D | | 1550.6$^{*}$ | 1544.8$^{*}$ | 1565.9$^{*}$ | 2521.4$^{**}$ | | 1587.0 | 1625.1 | 1574.9 | 2598.7 |
| | | (0.039) | (0.040) | (0.036) | (0.009) | | (0.125) | (0.112) | (0.129) | (0.107) |
| Ice class_D | | 1375.5$^{**}$ | 1338.7$^{**}$ | 1334.6$^{**}$ | 480.8 | | -416.8 | -343.9 | -392.8 | -958.1 |
| | | (0.002) | (0.003) | (0.003) | (0.301) | | (0.454) | (0.539) | (0.484) | (0.098) |
| Build Far East_D | | 227.8 | 206.2 | 217.7 | 855.0 | | -1824.2$^{**}$ | -1653.4$^{**}$ | -1832.5$^{**}$ | -1497.6$^{**}$ |
| | | (0.797) | (0.815) | (0.805) | (0.385) | | (0.002) | (0.005) | (0.002) | (0.002) |
| Build NW | | 823.5$^{*}$ | 859.9$^{*}$ | 805.4$^{*}$ | 764.3 | | -1100.3$^{*}$ | -1171.2$^{*}$ | -1094.3$^{*}$ | -1013.8$^{*}$ |
| | | (0.016) | (0.012) | (0.019) | (0.087) | | (0.020) | (0.013) | (0.020) | (0.013) |
| Speed | | 182.7$^{*}$ | 218.9$^{*}$ | 183.4$^{*}$ | 250.8$^{*}$ | | 209.3 | 171.7 | 206.5 | 118.4 |
| | | (0.047) | (0.026) | (0.046) | (0.028) | | (0.122) | (0.193) | (0.128) | (0.262) |
| Consumption | | 53.46 | | | | | 29.18 | | | |
| | | (0.196) | | | | | (0.503) | | | |
| FEI (DWT) | | | 59.82 | | | | | -62.67 | | |
| | | | (0.146) | | | | | (0.078) | | |
| DAF | | | | 0.0545 | | | | | 0.0793 | |
| | | | | (0.574) | | | | | (0.360) | |
| Conventional_D | | | | | 256.9 | | | | | -268.4 |
| | | | | | (0.495) | | | | | (0.390) |
| Constant | 1137.3$^{***}$ | -380.8 | -1363.4 | 159.2 | -2056.4 | 3911.8$^{***}$ | -2720.2 | -985.0 | -2271.9 | -519.1 |
| | (0.000) | (0.777) | (0.399) | (0.900) | (0.230) | (0.000) | (0.114) | (0.587) | (0.226) | (0.706) |
| N | 4331 | 3527 | 3527 | 3527 | 4289 | 2031 | 1107 | 1107 | 1107 | 1926 |
| Overall R2 | 0.745 | 0.799 | 0.798 | 0.799 | 0.776 | 0.708 | 0.759 | 0.758 | 0.759 | 0.769 |

*p*-values in parentheses

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

***Table 8: Results PSV 2010-2015***

In general, the analysis based on PSV fixtures from 2010 to 2015 yields robust results, but several deviations are present. Compared to the original PSV analyses, both spot and term analysis have decreased explanatory power in terms of overall R2. Surprisingly to our expectations, duration shows strongly significant in the spot market whereas the contract length yields no evidence as determinants of term charter freight rates in the contango period. The scope of work is robust with regard to our separate analysis, where the term market provides a discount of about $10,00/day for production support during 2010-2015. Moreover, the substantial premium for operating in the Brazilian spot market is still present in recent years. Looking at standard ship specifications, a slightly increased premium related to BHP is observed in the term market. On the other hand, a greater operational capability in terms of DWT is actually penalized in the spot market. Vessel age only proves significant in the term market, which shows an increased discount of about $100/day for a 10-year-old PSV. Regarding ship-specific features, the premium related to DP2 and helideck in the term market has increased with 20% during 2010-2015. In addition, ROV has become a significant determinant of spot freight rates, yielding a premium of about $1,500/day. Overall, the results confirm our expectations where increased demand for these features is reflected in higher freight rates. The dummies for build country show evidence for a spot charter premium to PSVs build in Northwest Europe, however, a discount is still present for both Far East and Northwest Europe in the term charter market. We note significant coefficients for speed in the spot market, implying an increased willingness to pay for sailing capability during 2010-2015.

Turning over to energy efficiency, none of our chosen measures prove significance. Hence, the slight penalty related to high-fuel consuming PSVs in the original analysis is no longer present, suggesting that energy efficiency is actually of less importance in normal market conditions during recent years.

## 6.2.2 AHTS

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | SPOT | SPOT | SPOT | SPOT | SPOT | TERM | TERM | TERM | TERM | TERM |
| Market proxy | 1.038$^{***}$ | 1.029$^{***}$ | 1.029$^{***}$ | 1.030$^{***}$ | 1.030$^{***}$ | 0.646$^{***}$ | 0.709$^{***}$ | 0.709$^{***}$ | 0.707$^{***}$ | 0.747$^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Duration_BW | | 108.5$^{**}$ | 108.5$^{**}$ | 108.8$^{**}$ | 106.3$^{***}$ | | 0.674 | 0.656 | 0.641 | 0.637$^{**}$ |
| | | (0.005) | (0.005) | (0.005) | (0.001) | | (0.065) | (0.071) | (0.077) | (0.007) |
| Forward_BW | | | | | | | 2.956 | 3.114 | 3.091 | 5.271$^{*}$ |
| | | | | | | | (0.202) | (0.178) | (0.183) | (0.021) |
| Drilling_D | | -1572.3 | -1556.4 | -1594.9 | -1629.0 | | -138.0 | -133.5 | -163.1 | -3.666 |
| | | (0.576) | (0.581) | (0.571) | (0.425) | | (0.621) | (0.632) | (0.561) | (0.986) |
| Asia_D | | -488.7 | -490.7 | -491.2 | -1109.2 | | | | | |
| | | (0.827) | (0.827) | (0.826) | (0.529) | | | | | |
| Middle East_D | | 1514.7 | 1607.7 | 1490.6 | 87.97 | | | | | |
| | | (0.603) | (0.583) | (0.609) | (0.968) | | | | | |
| DWT | | 1.019 | 1.047 | 1.023 | 1.339 | | 1.900$^{***}$ | 1.868$^{***}$ | 1.901$^{***}$ | 1.422$^{***}$ |
| | | (0.429) | (0.423) | (0.429) | (0.203) | | (0.001) | (0.001) | (0.001) | (0.000) |
| BP | | 21.67 | 19.60 | 21.22 | 6.392 | | 40.64$^{***}$ | 35.43$^{**}$ | 41.86$^{***}$ | 35.45$^{***}$ |
| | | (0.374) | (0.418) | (0.387) | (0.746) | | (0.001) | (0.001) | (0.000) | (0.000) |
| Age | | 205.7 | 227.4 | 211.1 | 161.7 | | 209.2$^{**}$ | 211.6$^{**}$ | 214.2$^{**}$ | 165.3$^{**}$ |
| | | (0.385) | (0.349) | (0.374) | (0.398) | | (0.002) | (0.002) | (0.002) | (0.004) |
| Age2 | | -9.240 | -10.05 | -9.439 | -7.947 | | -7.407$^{***}$ | -7.164$^{***}$ | -7.510$^{***}$ | -6.470$^{***}$ |
| | | (0.259) | (0.241) | (0.251) | (0.204) | | (0.000) | (0.000) | (0.000) | (0.000) |
| DP2_D | | -1831.5 | -1885.5 | -1846.0 | -2288.6 | | 1969.7$^{**}$ | 1957.9$^{**}$ | 2008.4$^{**}$ | 1734.4$^{***}$ |
| | | (0.250) | (0.235) | (0.247) | (0.124) | | (0.002) | (0.002) | (0.001) | (0.000) |
| Helideck_D | | -6978.6$^{**}$ | -7227.8$^{**}$ | -7039.8$^{**}$ | -5925.2$^{*}$ | | -6345.7 | -6578.4 | -6315.0 | -7089.6 |
| | | (0.007) | (0.005) | (0.006) | (0.019) | | (0.418) | (0.404) | (0.414) | (0.377) |
| ROV_D | | 1762.1 | 1909.4 | 1810.7 | 2399.0 | | -1561.0 | -1230.5 | -1679.4 | 1499.5 |
| | | (0.452) | (0.407) | (0.437) | (0.246) | | (0.401) | (0.486) | (0.366) | (0.580) |
| Ice class_D | | 1219.0 | 1107.8 | 1175.4 | 110.5 | | 1974.9 | 1920.9 | 2035.0 | -89.28 |
| | | (0.344) | (0.387) | (0.359) | (0.927) | | (0.117) | (0.120) | (0.107) | (0.930) |
| Build Far East_D | | -3568.9 | -3562.3 | -3573.6 | -3034.5 | | -698.1 | -708.9$^{*}$ | -690.3 | -1024.8$^{***}$ |
| | | (0.229) | (0.227) | (0.228) | (0.190) | | (0.053) | (0.048) | (0.056) | (0.000) |
| Build NW | | 1725.3 | 1624.0 | 1692.4 | 1451.0 | | 567.7 | 481.6 | 580.8 | -63.89 |
| | | (0.340) | (0.371) | (0.347) | (0.288) | | (0.504) | (0.567) | (0.494) | (0.934) |
| Speed | | -383.2 | -382.2 | -382.5 | -228.9 | | -314.5 | -399.5 | -318.2 | -94.57 |
| | | (0.216) | (0.225) | (0.216) | (0.258) | | (0.152) | (0.089) | (0.149) | (0.534) |
| Consumption | | -25.72 | | | | | -41.96 | | | |
| | | (0.470) | | | | | (0.193) | | | |
| FEI (BHP) | | | -30.20 | | | | | -202.7$^{*}$ | | |
| | | | (0.904) | | | | | (0.025) | | |
| DAF | | | | -0.0388 | | | | | -0.106 | |
| | | | | (0.580) | | | | | (0.055) | |
| Conventional | | | | | -789.3 | | | | | -320.7 |
| | | | | | (0.477) | | | | | (0.280) |
| Constant | 1869.8$^{**}$ | -758.8 | -852.4 | -1202.5 | -454.5 | 6854.5$^{***}$ | 745.7 | 2998.1 | -258.1 | -1381.6 |
| | (0.004) | (0.900) | (0.893) | (0.843) | (0.919) | (0.000) | (0.774) | (0.334) | (0.918) | (0.450) |
| N | 4750 | 3730 | 3730 | 3730 | 4743 | 2555 | 1533 | 1533 | 1533 | 2454 |
| Overall R2 | 0.785 | 0.780 | 0.779 | 0.779 | 0.790 | 0.844 | 0.875 | 0.876 | 0.875 | 0.876 |

*p*-values in parentheses

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

***Table 9: Results AHTS 2010-2015***

The AHTS analysis ranging between 2010 and 2015 provides largely the same results as the original analysis. Regarding the spot analysis for 2010-2015, we note a slight decrease in explanatory power when adding contract- and ship-specific variables, predominantly related to a sample decrease due to missing consumption data.

Moreover, some deviations are present. The premium related to drilling activity is no longer present in recent years, likely due to an underlying trend of increased pre-lay activity and more efficient rig moves. Standard ship specifications prove an increased premium in the term market, implying that operations for AHTSs on longer duration are becoming more demanding. As for the 2010-2015 PSV analysis, vessel age has a non-linear relationship to term charter freight rates, however, a brand-new AHTS have obtained a slight premium of about $200/day in recent years. The presence of DP2 is rewarded through a premium of about $2,000/day in the term market – a 15% increase from the original analysis and thus confirming our expectations *a priori*. Furthermore, we note that the substantial discount related to helideck still is present in the spot analysis, while none of the other ship-specific features are significant determinants of AHTS freight rates. As opposed to the term market, there is no longer evidence of a Far East build vessel discount in the spot market. From discussions with market participants, this is expectedly due to decreased quality difference between Northwest Europe and Far East new buildings, in addition to an equalized exchange rate development.

Looking at energy efficiency measures, all but one variable proves insignificant results. We observe a discount of about $200/day when measuring fuel consumption relative to its operational capability (FEI) in the 2010-2015 analysis (8). Compared to the original analysis it equals a 65% increase, implying that the AHTS term market is more sensitive to energy efficiency in recent years.

# 6.3 Results quantile regression

| | PSV Spot U10% | PSV Spot L10% | PSV Term U10% | PSV Term L10% | AHTS Spot U10% | AHTS Spot L10% | AHTS Term U10% | AHTS Term L10% |
|---|---|---|---|---|---|---|---|---|
| ***Quantile regression DWT*** | | | | | | | | |
| DWT | -0.311 | 0.531 | -0.129 | 2.152 | 25.71*** | -0.178 | 3.897* | 0.113 |
| P-values | (0.551) | (0.869) | (0.824) | (0.257) | (0.000) | (0.903) | (0.027) | (0.905) |
| N | 1083 | 1115 | 236 | 208 | 1692 | 1653 | 292 | 223 |
| Overall R2 | 0.885 | 0.347 | 0.695 | 0.591 | 0.813 | 0.500 | 0.861 | 0.630 |
| ***Quantile regression BHP*** | | | | | | | | |
| BHP | -0.180 | 1.576 | 0.289 | 1.080 | | | | |
| P-values | (0.332) | (0.088) | (0.208) | (0.150) | | | | |
| N | 1066 | 1574 | 341 | 139 | | | | |
| Overall R2 | 0.900 | 0.706 | 0.727 | 0.824 | | | | |
| ***Quantile regression BP*** | | | | | | | | |
| BP | | | | | 20.87 | 81.42*** | -21.89 | 74.95 |
| P-values | | | | | (0.569) | (0.000) | (0.488) | (0.105) |
| N | | | | | 1276 | 1637 | 320 | 318 |
| Overall R2 | | | | | 0.803 | 0.567 | 0.794 | 0.465 |
| ***Quantile regression Speed*** | | | | | | | | |
| Speed | 64.05 | -444.2 | 920.4 | -970.3 | 1407.4 | 252.9 | 2779.5 | 340.0 |
| P-values | (0.852) | (0.657) | (0.248) | (0.172) | (0.562) | (0.509) | (0.055) | (0.246) |
| N | 1044 | 1216 | 319 | 287 | 1218 | 1781 | 370 | 566 |
| Overall R2 | 0.899 | 0.785 | 0.624 | 0.865 | 0.776 | 0.886 | 0.900 | 0.871 |
| ***Quantile regression Consumption*** | | | | | | | | |
| Consumption | 3.526 | -837.6 | 159.7* | -583.6 | 82.67*** | 793.7 | 39.76 | 8.500 |
| P-values | (0.971) | (0.064) | (0.022) | (0.067) | (0.000) | (0.130) | (0.192) | (0.975) |
| N | 1225 | 1222 | 265 | 268 | 1698 | 1631 | 352 | 305 |
| Overall R2 | 0.880 | 0.878 | 0.728 | 0.815 | 0.833 | 0.714 | 0.911 | 0.780 |
| ***Quantile regression FEI (DWT)*** | | | | | | | | |
| FEI (DWT) | -33.23 | 292.9 | 69.12* | -198.7 | | | | |
| P-values | (0.550) | (0.344) | (0.021) | (0.640) | | | | |
| N | 1110 | 1044 | 262 | 259 | | | | |
| Overall R2 | 0.370 | 0.872 | 0.679 | 0.706 | | | | |
| ***Quantile regression FEI (BHP)*** | | | | | | | | |
| FEI (BHP) | | | | | 355.1 | 2410.5 | -155.9 | 3179.9 |
| P-values | | | | | (0.165) | (0.575) | (0.425) | (0.123) |
| N | | | | | 1694 | 1627 | 282 | 300 |
| Overall R2 | | | | | 0.824 | 0.788 | 0.745 | 0.875 |
| ***Quantile regression DAF*** | | | | | | | | |
| DAF | 0.221 | -0.161 | 0.491*** | -0.652 | 0.0698 | 0.554 | 0.0901 | -0.278 |
| P-values | (0.261) | (0.624) | (0.000) | (0.149) | (0.427) | (0.253) | (0.151) | (0.229) |
| N | 1043 | 1041 | 265 | 250 | 1567 | 1563 | 296 | 283 |
| Overall R2 | 0.877 | 0.834 | 0.744 | 0.813 | 0.847 | 0.830 | 0.886 | 0.789 |

*This is an excerption of the regressions. All other base variables were included in the analyses.*
*U10%/L10%: Upper/Lower ten percentage by value of the selected variable*
$p$-values in parentheses
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

***Table 10: Results quantile regression***

The quantile regression for the PSV spot market shows insignificant coefficients for all variables, including energy efficiency measures. In other words, we cannot prove a non-linear relationship between ship-specification and spot freight rates in the PSV market.

In the PSV term market, vessels in the upper ten percentage of consumption are actually rewarded with higher freight rates on a 95% confidence level. This is in accordance with DAF, which is significant on a 99.9% confidence level, implying that the most polluting vessels are rewarded in the PSV term market. Moreover, the FEI variable shows weak significance for a premium in the upper quantile. These results are counter-intuitive with regards to our original PSV term analysis, where FEI proved a penalty, implying a non-linear relationship for fuel efficiency. Consequently, our findings from previous PSV term analyses cannot be said to be robust in terms of an energy efficiency premium.

Regarding the AHTS spot market, some interesting findings are made in the quantile regressions. The results show a non-linear relationship, where the upper quantile for DWT and the lower quantile of BP are being rewarded. Both variables prove strong statistical evidence, suggesting that duties related to non-core demand, such as under-deck cargo capacity, are rewarded in the AHTS spot market. In addition, we note a premium from vessels with the ten percentage highest consumption on a 99.9% confidence level, implying that AHTSs with the highest consumption actually obtained higher spot freight rates.

In the AHTS term market, DWT prove significance for the upper ten percentages of vessels with 95% certainty. Hence, the findings from the AHTS spot market are present in the term market as well, implying that size matter for longer duration as well. On the other hand, we cannot prove a penalty to vessels in the lower ten percentages with regard to DWT.

Overall, a non-linear relationship is proved between AHTS freight rate levels and vessel size, where DWT shows significance in both the spot and term market on at least 95% confidence level for the upper quantile analyses. Moreover, we find no evidence that fuel efficiency matters in our quantile regression. On the contrary, the highest fuel-consuming vessels are actually being rewarded in the PSV term and AHTS spot market.

# 7. Concluding remarks

The purpose of this thesis has been to investigate microeconomic determinants of time-charter freight rates in the global offshore market. Specifically, we examine the presence of a freight rate premium for energy-efficient ships using four different definitions of efficiency. A separate analysis ranging from 2010 to 2015 and quantile regressions have been performed to capture changing market dynamics and non-linear effects, respectively.

The empirical results reveal some important takeaways. We have shown that the market rate will dominate any contract- and ship-specific variables in the determination of the freight rate for an individual fixture in both the PSV and AHTS market. Neither duration nor forward length seem to be significant determinants of freight rates in the OSV market, contrary to our *a priori* expectations. In general, a trend towards stronger significance for standard ship specifications is present on term fixtures, suggesting the predictability aspect to become more important on longer duration. Vessel age yields a non-linear relationship to freight rate levels, however, age of OSVs has in recent years been of less importance in the spot market – indicating a homogeneous market where operational capability often is regardless of age, an observation confirmed by our discussions with market participants.

In regards of energy efficiency, our results show no evidence of an energy efficiency premium in the PSV and AHTS spot markets. On the other hand, we find weak evidences of an energy efficiency premium in our term analyses based on FEI. The results are robust if we control for boom periods, which imply that PSVs and AHTSs received a penalty in the term market under different market conditions. Intuitively, there seem to be increased willingness for charterers to pay for fuel efficiency when there exists savings over time or when planning for longer duties, compared to a short spot trip. However, our findings deviate in robustness as our supplemented analyses actually reward less efficient PSVs, while the AHTS market has become more sensitive to energy efficiency in recent years. Consequently, we suggest a two-tier market where energy efficiency pays off in the AHTS term market, whereas the PSV market is subject to an apparent market failure. In accordance with the literature, measuring energy efficiency is a difficult aspect. Energy efficiency receives increased attention as stricter environmental legislation are being developed in the offshore market through more sophisticated emission indexes, such as Environmental Ship Index (ESI), and thus we expect the energy efficiency premium to pose greater distinction in the future.

There are some noteworthy limitations in our study. Firstly, we have utilized a data sample consisting of fixtures predominantly in the Northwest Europe. This could indicate that results are not representative for the worldwide offshore market, yet, we see it as a data limitation problem followed by the given market characteristics. Secondly, we have relied on nominal values regarding fuel consumption and speed, which may differ substantially from values in real-life seaway conditions. As real-life values are missing during our sample period, this is a choice based on data availability. Thirdly, and most important, we are prone to a failure of representing the underlying market by incorporating a market proxy based on our own fixtures. By using a relatively low smoothing parameter, the exposure of overfitting our market proxy is present, which potentially could lead to biased results for our micro determinants. As this issue is familiar to us, we have ensured that a higher smoothing parameter for both the spot and term analyses, e.g. nine days for spot and five weeks for term, do not radical influence our conclusions. In addition, we are susceptible to systematic errors in the model estimations when not implementing the underlying relationship of the term structure in our market proxy, as mentioned by Adland et al (2015). Instead we consider the relationship between region and contractual freight rates for standardized vessels through a Kernel smoothed market proxy. However, we should be aware that such a constrained regression might influence our results. The decision to interpret a self-made index can by itself be of questionable matter. However, as the offshore market tends to be highly volatile on a daily basis, we consider alternative methods to have greater shortcomings in order to fully capture the actual market dynamics.

Finally, we acknowledge that further research in the field of offshore freight rate determinants is required. One possible way is to examine the impact of charterers with regard to OSV freight rates. In a perfect world, an extra cent should have the same effect wherever it used. In practice, however, the oil companies have to a large extent the opportunity to obtain benefits, because of their significant power in the supply chain. Another interesting avenue of future research is related to the utilization of energy efficient vessels – it does not matter if the emission rate is low if the utilization of the vessel is low as well. Energy-efficient OSVs might be rewarded through other channels than a freight rate premium, and by achieving better utilization the shipowners have less idle time for their vessels and higher average earnings. We find this as a very interesting and natural next step with regard to energy efficiency determinants in the offshore market.

# References

Aas, B., Halskau Sr, Ø. and Wallace S.W. 2009. The role of supply vessels in offshore logistics. Maritime Economics & Logistics, 11, 302-325.

ABB, 2012. Generations magazine. Issue 1 – 2012. ABB Marine and Cranes.

Acock, A. C. 2008. A gentle introduction to Stata. Stata press.

Adland R., Alger, H. and Banyte, J. 2015. Does fuel efficiency pay? Empirical evidence from the drybulk timecharter market revisited. Working paper.

Adland, R. and Strandenes, S. 2006. Market efficiency in the bulk freight market revisited. Maritime Policy and Management. 33 (2), 107-117.

Adland, R., Cariou, P. and Wolff F. C. 2016. The influence of charterers and owners on bulk shipping freight rates. Transportation Research Part E, 86, 69-82.

Agnolucci, P., Smith, T. and Rehmatullah, N. 2014. Energy efficiency and time charter rates: Energy efficiency savings recovered by ship owners in the Panamax market. Transportation Research Part A, 66, 173-184.

Alizadeh, A. H. and Talley, W. K. 2011b. Vessel and voyage determinants of tanker freight rates and contract times. Transport Policy, 18(5), 665-675.

Alizadeh, A. H. and Nomikos, N. K. 2011. Dynamics of the Term Structure and Volatility of Shipping Freight Rates. Journal of Transport Economics and Policy, 45(1), 105-128.

Alizadeh, A. H., and Talley, W. K. 2011a. Microeconomic determinants of dry bulk shipping freight rates and contract times. Transportation, 38(3), 561-579.

Bloomberg. 2016. Platts – Historical Bunker Prices. Obtained April 6, 2016. Bloomberg Terminal

Bjørkelund, A. M. 2014. Pricing in Offshore Shipping Markets. A Two-Regime Mean Reverting Jump Diffusion Model with Seasonality. Master thesis, Norwegian School of Economics.

Clarkson Research. 2016a. Shipping Intelligence Network database. Obtained February 22, 2016. https://sin.clarksons.net/

Clarkson Research. 2016b. World Fleet Register. Obtained March 14, 2016. http://wfr.clarksons.net/

Døsen, H. C and Langeland, J. 2015. Offshore freight rate determinants. A study of PSV term charter freight rates from 2004-2015. Master thesis, Norwegian School of Economics.

Federal Reserve, 2016. G.5/H.10 – Foreign Exchange Rates. Obtained March 14, 2016. http://www.federalreserve.gov/

Gillingham, K., Harding, M. and Rapson, D. 2012. Split Incentives in Residential Energy Consumption. Energy Journal 33 (2), 37-62.

Halvorsen-Weare, E. E, Fagerholt K., Nonås, L. M. and Asbjørnslett, B. E. 2012. Optimal fleet composition and periodic routing of offshore supply vessels. European Journal of Operational Research, 223, 508-517.

Hausman, J. A., 1978. Specification Tests in Econometrics. Econometrica: Journal of the Econometric Society, 46(6), 1251-1271.

ICS, 2011. Institute of Chartered Shipbrokers. Offshore Support Industry, Chapter 4: Chartering, 47-68.

IHS, 2014. IHS Petrodata. Obtained April 7, 2016. https://login.ods-petrodata.com/

IMO, 2009. Prevention of air pollution from ships. Second IMO GHG Study 2009. Paper MEPC 59/INF. 10. Annex. International Maritime Organization, London, UK.

Kavussanos, M.G. and Alizadeh, A. 2002. The expectation hypothesis of the term structure and premiums in dry bulk shipping freight markets. Journal of Transport Economics and Policy 36 (2), 267–304.

Köhn, S. and Thanopolou, H. 2011. A GAM Assessment of quality premia in the drybulk timecharter market. Transportation Research Part E, 47(5), 709-721.

Norlund, E. K. and Gribkovskaia, I. 2013. Reducing emissions through speed optimization in supply vessel operations. Transportation Research Part D, 23, 105-113.

Rehmatullah, N. and Smith, T. 2015. Barriers to entry energy efficiency in shipping: A triangulated approach to investigate the principal agent problem. Energy Policy, 84, 44-57.

Ringlund, G. B., Rosendahl K.E. and Skjerpen T. 2008. Does oilrig activity react to oil price changes? An empirical investigation. Energy Economics, 30, 371-396.

RS Platou, 2015. The Platou Report 2015.

Strandenes, S. P. 1984. Price Determination in the Time Charter and Second Hand Markets. Center for Applied Research, Norwegian School of Economics, Working Paper MU 06.

Strandenes, S. P. 1999. Is there potential for a two-tier tanker market? Maritime Policy and Management 26 (3): 249-264.

Tamvakis, M. N. and Thanopolou, H. A. 2000. Does quality pay? The case of the dry bulk market, Transportation Research Part E 36 (4): 297-307.

Veenstra, A.W. 1999. The term structure of ocean freight rates. Maritime Policy & Management, 26:3, 279-293.

Verbeek, Marno. 2012. A Guide to Modern Econometrics. 4th ed. UK: John Wiley & Sons, Ltd.

Wooldridge, Jeffrey M. 2015. Introduction to Econometrics. 3rd edition. China: RR Donnelley.

Zannetos, Z. S. 1966. The theory of oil tankship rates. Cambridge, Mass: MIT Press.

# Appendices

## Appendix 1 – Detailed data cleansing

Starting with 73 156 fixtures

- Removal of non-IMO (32 fixtures)
- Removal of non-USD Rate (31 001 fixtures)
- Removal of duplicates (1 373 fixtures)
- Excluding 213 outliers (#VERDI: 26, IMODUP: 37, AGE: 149, CONS: 1)
    - Ending up with 40 537 fixtures

Divided into:

- PSV (17 011 fixtures)
    - PSV Spot → In total 12 919 fixtures
    - PSV Term → In total 4 092 fixtures
- AHTS (23 526 fixtures)
    - AHTS Spot → In total 19 148 fixtures
    - AHTS Term → In total 4 378 fixtures

# Appendix 2 – Correlation matrices

## PSV spot

| | Freightrate | Market proxy | Duration | Production_D | U.S. Gulf_D | Brazil_D | DWT | BHP | Age | DP2_D | Helideck_D | ROV_D | Ice class_D | Build Far East_D | Build NW Europe_D | Speed | Consumption | FEI (DWT) | DAF | Conventional_D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Freightrate** | 1.00 | | | | | | | | | | | | | | | | | | | |
| **Market proxy** | 0.93 | 1.00 | | | | | | | | | | | | | | | | | | |
| **Duration** | -0.01 | -0.02 | 1.00 | | | | | | | | | | | | | | | | | |
| **Production_D** | 0.02 | 0.02 | 0.06 | 1.00 | | | | | | | | | | | | | | | | |
| **U.S. Gulf_D** | -0.01 | 0.00 | 0.04 | 0.25 | 1.00 | | | | | | | | | | | | | | | |
| **Brazil_D** | 0.07 | 0.01 | 0.01 | 0.00 | 0.00 | 1.00 | | | | | | | | | | | | | | |
| **DWT** | 0.30 | 0.30 | 0.01 | -0.01 | -0.08 | 0.00 | 1.00 | | | | | | | | | | | | | |
| **BHP** | 0.28 | 0.27 | 0.02 | 0.00 | -0.06 | -0.01 | 0.75 | 1.00 | | | | | | | | | | | | |
| **Age** | -0.06 | -0.01 | -0.05 | -0.02 | 0.03 | -0.02 | -0.39 | -0.45 | 1.00 | | | | | | | | | | | |
| **DP2_D** | 0.25 | 0.22 | 0.03 | 0.01 | 0.01 | 0.05 | 0.55 | 0.56 | -0.48 | 1.00 | | | | | | | | | | |
| **Helideck_D** | 0.04 | 0.04 | 0.00 | 0.02 | 0.00 | 0.00 | 0.18 | 0.17 | -0.07 | 0.07 | 1.00 | | | | | | | | | |
| **ROV_D** | 0.05 | 0.03 | 0.00 | -0.01 | -0.02 | -0.01 | 0.08 | 0.11 | -0.07 | 0.31 | 0.16 | 1.00 | | | | | | | | |
| **Ice class_D** | 0.05 | 0.01 | 0.05 | 0.00 | -0.02 | -0.01 | 0.16 | 0.21 | -0.18 | 0.16 | 0.00 | 0.05 | 1.00 | | | | | | | |
| **Build Far East_D** | -0.07 | -0.06 | 0.00 | 0.00 | -0.01 | -0.01 | -0.04 | -0.03 | -0.02 | -0.07 | -0.01 | -0.08 | -0.07 | 1.00 | | | | | | |
| **Build NW Europe_D** | 0.00 | 0.00 | 0.00 | -0.04 | -0.12 | -0.07 | -0.01 | -0.07 | 0.17 | -0.05 | 0.03 | 0.10 | 0.11 | -0.43 | 1.00 | | | | | |
| **Speed** | 0.13 | 0.12 | 0.01 | -0.01 | -0.04 | 0.03 | 0.46 | 0.51 | -0.31 | 0.39 | 0.09 | 0.07 | 0.04 | -0.05 | -0.11 | 1.00 | | | | |
| **Consumption** | 0.04 | 0.03 | -0.01 | -0.01 | -0.04 | 0.02 | 0.15 | 0.19 | 0.02 | 0.11 | 0.12 | 0.08 | -0.01 | -0.05 | 0.04 | 0.20 | 1.00 | | | |
| **FEI (DWT)** | -0.24 | -0.24 | -0.01 | 0.00 | 0.07 | -0.01 | -0.74 | -0.53 | 0.32 | -0.41 | -0.05 | -0.07 | -0.05 | 0.01 | 0.10 | -0.45 | 0.39 | 1.00 | | |
| **DAF** | 0.07 | 0.07 | -0.01 | -0.02 | -0.06 | 0.04 | 0.07 | 0.14 | 0.06 | 0.07 | 0.08 | -0.02 | -0.02 | 0.05 | -0.06 | 0.14 | 0.77 | 0.30 | 1.00 | |
| **Conventional_D** | 0.00 | 0.00 | -0.01 | 0.01 | 0.04 | 0.04 | -0.01 | -0.07 | 0.00 | -0.06 | -0.05 | -0.17 | -0.17 | 0.11 | -0.14 | 0.11 | -0.16 | -0.19 | -0.05 | 1.00 |

## PSV term

| | Freightrate | Market proxy | Duration | Forward | Production_D | DWT | BHP | Age | DP2_D | Helideck_D | ROV_D | Ice class_D | Build Far East_D | Build NW Europe_D | Speed | Consumption | FEI (DWT) | DAF | Conventional_D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Freightrate** | 1.00 | | | | | | | | | | | | | | | | | | |
| **Market proxy** | 0.88 | 1.00 | | | | | | | | | | | | | | | | | |
| **Duration** | 0.12 | 0.16 | 1.00 | | | | | | | | | | | | | | | | |
| **Forward** | 0.23 | 0.26 | 0.47 | 1.00 | | | | | | | | | | | | | | | |
| **Production_D** | -0.07 | -0.05 | 0.15 | -0.03 | 1.00 | | | | | | | | | | | | | | |
| **DWT** | 0.55 | 0.55 | 0.07 | 0.19 | 0.09 | 1.00 | | | | | | | | | | | | | |
| **BHP** | 0.51 | 0.49 | 0.10 | 0.19 | 0.10 | 0.79 | 1.00 | | | | | | | | | | | | |
| **Age** | -0.30 | -0.23 | -0.11 | -0.14 | 0.01 | -0.45 | -0.41 | 1.00 | | | | | | | | | | | |
| **DP2_D** | 0.50 | 0.46 | 0.07 | 0.15 | -0.03 | 0.51 | 0.50 | -0.49 | 1.00 | | | | | | | | | | |
| **Helideck_D** | 0.08 | 0.06 | -0.02 | 0.00 | -0.02 | 0.11 | 0.10 | 0.00 | 0.04 | 1.00 | | | | | | | | | |
| **ROV_D** | 0.11 | 0.06 | -0.02 | 0.00 | -0.07 | 0.09 | 0.16 | -0.04 | 0.21 | 0.17 | 1.00 | | | | | | | | |
| **Ice class_D** | 0.11 | 0.09 | -0.05 | 0.03 | 0.02 | 0.20 | 0.19 | -0.08 | 0.14 | -0.01 | 0.00 | 1.00 | | | | | | | |
| **Build Far East_D** | 0.05 | 0.09 | 0.07 | 0.00 | -0.06 | -0.06 | -0.01 | -0.15 | 0.08 | -0.01 | -0.07 | -0.09 | 1.00 | | | | | | |
| **Build NW Europe_D** | -0.12 | -0.14 | -0.12 | -0.07 | 0.14 | 0.21 | 0.15 | 0.07 | -0.11 | 0.03 | 0.09 | 0.14 | -0.35 | 1.00 | | | | | |
| **Speed** | 0.33 | 0.30 | 0.01 | 0.05 | 0.10 | 0.55 | 0.55 | -0.31 | 0.39 | 0.06 | 0.09 | 0.11 | -0.06 | 0.09 | 1.00 | | | | |
| **Consumption** | 0.11 | 0.09 | 0.01 | 0.02 | 0.04 | 0.25 | 0.33 | -0.01 | 0.06 | 0.08 | 0.15 | 0.04 | -0.02 | 0.19 | 0.22 | 1.00 | | | |
| **FEI (DWT)** | -0.41 | -0.38 | -0.03 | -0.12 | -0.06 | -0.68 | -0.46 | 0.49 | -0.42 | -0.02 | -0.04 | -0.06 | 0.06 | -0.08 | -0.47 | 0.30 | 1.00 | | |
| **DAF** | 0.10 | 0.08 | 0.01 | 0.02 | 0.04 | 0.22 | 0.31 | -0.02 | 0.01 | 0.10 | 0.09 | 0.02 | 0.00 | 0.17 | 0.18 | 0.89 | 0.27 | 1.00 | |
| **Conventional_D** | -0.09 | -0.07 | -0.03 | -0.05 | 0.01 | -0.13 | -0.19 | 0.07 | -0.11 | -0.03 | -0.11 | -0.13 | -0.01 | -0.09 | -0.10 | -0.09 | 0.03 | -0.05 | 1.00 |

## AHTS spot

| | Freightrate | Market proxy | Duration | Drilling_D | Asia_D | Middle East_D | DWT | BP | Age | DP2_D | Helideck_D | ROV_D | Ice class_D | Build Far East_D | Build NW Europe_D | Speed | Consumption | FEI (BHP) | DAF | Conventional_D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Freightrate** | 1.00 | | | | | | | | | | | | | | | | | | | |
| **Market proxy** | 0.92 | 1.00 | | | | | | | | | | | | | | | | | | |
| **Duration** | 0.00 | -0.01 | 1.00 | | | | | | | | | | | | | | | | | |
| **Drilling_D** | 0.00 | 0.00 | 0.10 | 1.00 | | | | | | | | | | | | | | | | |
| **Asia_D** | -0.02 | -0.02 | 0.09 | 0.29 | 1.00 | | | | | | | | | | | | | | | |
| **Middle East_D** | -0.02 | -0.02 | 0.03 | 0.00 | 0.00 | 1.00 | | | | | | | | | | | | | | |
| **DWT** | 0.32 | 0.32 | 0.03 | -0.02 | -0.02 | -0.05 | 1.00 | | | | | | | | | | | | | |
| **BP** | 0.34 | 0.34 | 0.01 | -0.03 | -0.04 | -0.06 | 0.91 | 1.00 | | | | | | | | | | | | |
| **Age** | -0.11 | -0.10 | -0.02 | 0.01 | -0.02 | 0.01 | -0.48 | -0.50 | 1.00 | | | | | | | | | | | |
| **DP2_D** | 0.36 | 0.37 | 0.00 | -0.01 | 0.01 | -0.02 | 0.64 | 0.68 | -0.44 | 1.00 | | | | | | | | | | |
| **Helideck_D** | 0.01 | 0.02 | -0.01 | -0.01 | -0.01 | 0.00 | 0.18 | 0.17 | -0.05 | 0.10 | 1.00 | | | | | | | | | |
| **ROV_D** | 0.14 | 0.14 | 0.02 | -0.01 | -0.01 | -0.01 | 0.46 | 0.42 | -0.14 | 0.29 | 0.35 | 1.00 | | | | | | | | |
| **Ice class_D** | 0.07 | 0.06 | 0.01 | -0.02 | -0.04 | -0.03 | 0.11 | 0.17 | -0.04 | 0.13 | 0.10 | 0.15 | 1.00 | | | | | | | |
| **Build Far East_D** | -0.10 | -0.08 | 0.02 | 0.02 | 0.06 | 0.08 | -0.16 | -0.19 | 0.04 | -0.17 | -0.03 | -0.07 | 0.15 | 1.00 | | | | | | |
| **Build NW Europe_D** | 0.04 | 0.02 | -0.01 | -0.02 | -0.07 | -0.05 | -0.06 | 0.06 | 0.03 | 0.12 | 0.06 | -0.03 | 0.06 | -0.43 | 1.00 | | | | | |
| **Speed** | 0.14 | 0.14 | 0.01 | -0.03 | -0.04 | -0.04 | 0.38 | 0.40 | -0.24 | 0.32 | 0.03 | 0.20 | 0.14 | -0.10 | 0.16 | 1.00 | | | | |
| **Consumption** | 0.06 | 0.07 | -0.01 | -0.01 | -0.03 | -0.03 | 0.27 | 0.26 | -0.10 | 0.08 | 0.08 | 0.04 | -0.01 | -0.01 | -0.15 | 0.03 | 1.00 | | | |
| **FEI (BHP)** | -0.16 | -0.16 | -0.01 | 0.01 | 0.01 | 0.03 | -0.31 | -0.36 | 0.24 | -0.37 | -0.04 | -0.18 | -0.17 | 0.09 | -0.20 | -0.43 | 0.71 | 1.00 | | |
| **DAF** | 0.10 | 0.11 | 0.01 | -0.02 | -0.03 | -0.05 | 0.26 | 0.29 | -0.09 | 0.13 | 0.05 | 0.04 | 0.06 | -0.05 | -0.02 | 0.08 | 0.79 | 0.43 | 1.00 | |
| **Conventional_D** | 0.03 | 0.03 | -0.01 | -0.01 | 0.01 | 0.00 | 0.01 | -0.04 | -0.04 | 0.02 | 0.09 | -0.11 | -0.09 | 0.05 | -0.18 | -0.07 | 0.07 | 0.05 | 0.00 | 1.00 |

## AHTS term

| | Freightrate | Market proxy | Duration | Forward | Drilling_D | DWT | BP | Age | DP2_D | Helideck_D | ROV_D | Ice class_D | Build Far East_D | Build NW Europe_D | Speed | Consumption | FEI (BHP) | DAF | Conventional_D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Freightrate** | 1.00 | | | | | | | | | | | | | | | | | | |
| **Market proxy** | 0.92 | 1.00 | | | | | | | | | | | | | | | | | |
| **Duration** | 0.04 | 0.05 | 1.00 | | | | | | | | | | | | | | | | |
| **Forward** | 0.20 | 0.21 | 0.26 | 1.00 | | | | | | | | | | | | | | | |
| **Drilling_D** | 0.16 | 0.14 | -0.06 | 0.01 | 1.00 | | | | | | | | | | | | | | |
| **DWT** | 0.68 | 0.67 | 0.03 | 0.15 | 0.17 | 1.00 | | | | | | | | | | | | | |
| **BP** | 0.71 | 0.71 | 0.00 | 0.13 | 0.15 | 0.86 | 1.00 | | | | | | | | | | | | |
| **Age** | -0.09 | -0.06 | 0.01 | -0.04 | -0.06 | -0.23 | -0.13 | 1.00 | | | | | | | | | | | |
| **DP2_D** | 0.48 | 0.44 | 0.00 | 0.14 | 0.07 | 0.54 | 0.48 | -0.28 | 1.00 | | | | | | | | | | |
| **Helideck_D** | 0.11 | 0.12 | 0.00 | 0.02 | -0.03 | 0.13 | 0.15 | 0.00 | 0.08 | 1.00 | | | | | | | | | |
| **ROV_D** | 0.19 | 0.18 | -0.02 | 0.01 | -0.07 | 0.18 | 0.14 | -0.04 | 0.20 | 0.41 | 1.00 | | | | | | | | |
| **Ice class_D** | 0.17 | 0.18 | 0.03 | 0.02 | -0.02 | 0.23 | 0.34 | 0.08 | -0.01 | 0.11 | 0.10 | 1.00 | | | | | | | |
| **Build Far East_D** | -0.17 | -0.15 | -0.02 | 0.00 | -0.06 | -0.22 | -0.32 | -0.27 | -0.03 | -0.03 | -0.08 | -0.16 | 1.00 | | | | | | |
| **Build NW Europe_D** | 0.06 | 0.06 | -0.02 | -0.02 | 0.04 | 0.08 | 0.29 | 0.30 | -0.12 | 0.07 | 0.02 | 0.32 | -0.48 | 1.00 | | | | | |
| **Speed** | 0.37 | 0.37 | 0.01 | 0.10 | 0.07 | 0.47 | 0.55 | -0.02 | 0.21 | 0.04 | 0.03 | 0.33 | -0.20 | 0.30 | 1.00 | | | | |
| **Consumption** | 0.34 | 0.34 | 0.02 | 0.03 | 0.08 | 0.39 | 0.49 | 0.07 | 0.18 | 0.07 | 0.02 | 0.15 | -0.22 | 0.17 | 0.30 | 1.00 | | | |
| **FEI (BHP)** | -0.34 | -0.32 | 0.01 | -0.09 | -0.08 | -0.45 | -0.48 | 0.24 | -0.25 | -0.05 | -0.05 | -0.23 | 0.09 | -0.16 | -0.46 | 0.35 | 1.00 | | |
| **DAF** | 0.34 | 0.34 | 0.00 | 0.02 | 0.08 | 0.39 | 0.53 | 0.11 | 0.17 | 0.07 | 0.01 | 0.24 | -0.31 | 0.30 | 0.33 | 0.83 | 0.18 | 1.00 | |
| **Conventional_D** | -0.01 | -0.01 | -0.02 | 0.00 | 0.01 | 0.06 | 0.01 | -0.22 | 0.05 | 0.06 | -0.04 | -0.11 | 0.08 | -0.18 | -0.06 | -0.06 | -0.11 | -0.11 | 1.00 |

# Appendix 3 – VIF-tests

**PSV spot**

| Variable | VIF | 1/VIF |
|---|---|---|
| Age | 11.91 | 0.083967 |
| Age2 | 10.27 | 0.097365 |
| BHP | 2.88 | 0.346956 |
| DWT | 2.58 | 0.386848 |
| DP2_D | 1.99 | 0.502134 |
| Speed | 1.46 | 0.687062 |
| Build NW Europe_D | 1.37 | 0.728159 |
| Build Far East_D | 1.27 | 0.789377 |
| ROV_D | 1.19 | 0.838409 |
| Market proxy | 1.16 | 0.864685 |
| U.S. Gulf_D | 1.12 | 0.890161 |
| Consumption | 1.10 | 0.911083 |
| Ice class_D | 1.09 | 0.915713 |
| Production_D | 1.08 | 0.927198 |
| Helideck_D | 1.08 | 0.927244 |
| Duration_BW | 1.02 | 0.984429 |
| Brazil_D | 1.01 | 0.986641 |
| **Mean VIF** | **2.56** | |

**PSV term**

| Variable | VIF | 1/VIF |
|---|---|---|
| Age | 10.15 | 0.098488 |
| Age2 | 8.90 | 0.112404 |
| DWT | 3.67 | 0.272409 |
| BHP | 3.13 | 0.319211 |
| DP2_D | 1.92 | 0.519995 |
| Market proxy | 1.76 | 0.569590 |
| Speed | 1.59 | 0.629138 |
| Build NW Europe_D | 1.48 | 0.675637 |
| Duration_BW | 1.26 | 0.793342 |
| Forward_BW | 1.24 | 0.808585 |
| Consumption | 1.21 | 0.824619 |
| Build Far East_D | 1.19 | 0.842004 |
| ROV_D | 1.15 | 0.872744 |
| Production_D | 1.08 | 0.921776 |
| Ice class_D | 1.07 | 0.936101 |
| Helideck_D | 1.05 | 0.956029 |
| **Mean VIF** | **2.62** | |

**AHTS spot**

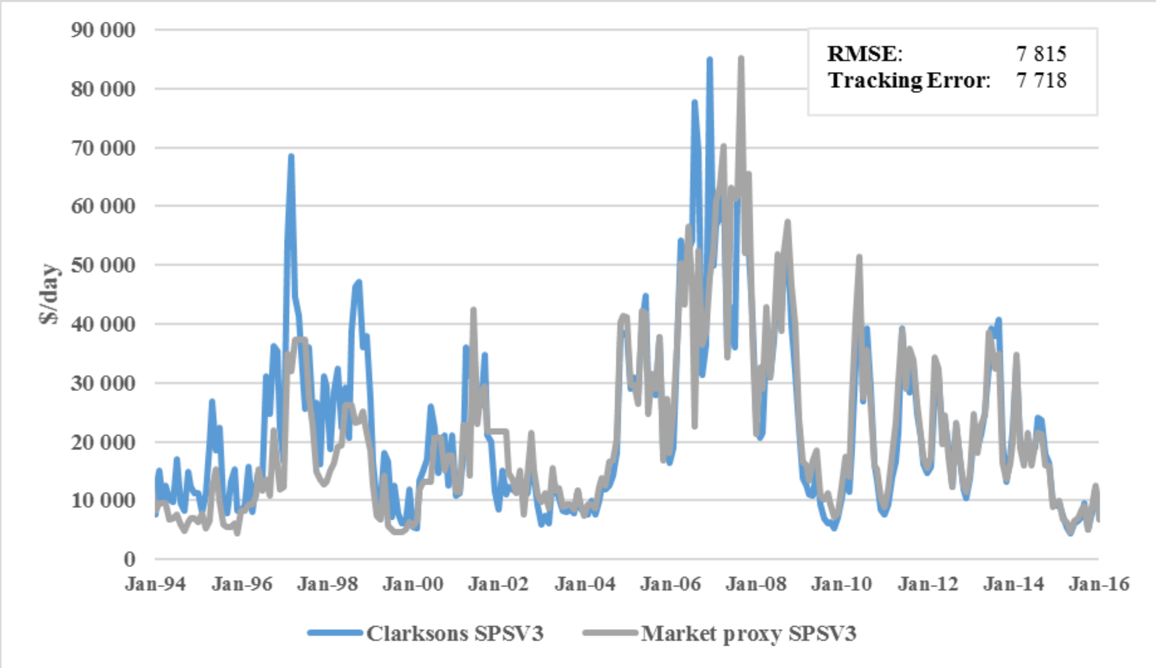
| Variable | VIF | 1/VIF |
|---|---|---|
| Age | 10.13 | 0.098680 |
| Age2 | 9.08 | 0.110091 |
| BP | 7.01 | 0.142630 |
| DWT | 6.63 | 0.150772 |
| DP2_D | 2.11 | 0.474920 |
| Build NW Europe_D | 1.47 | 0.682468 |
| ROV_D | 1.46 | 0.686406 |
| Build Far East_D | 1.37 | 0.728066 |
| Speed | 1.26 | 0.790778 |
| Market proxy | 1.21 | 0.827299 |
| Helideck_D | 1.17 | 0.852719 |
| Consumption | 1.15 | 0.866864 |
| Asia_D | 1.14 | 0.877436 |
| Drilling_D | 1.13 | 0.882851 |
| Ice class_D | 1.13 | 0.886273 |
| Duration_BW | 1.11 | 0.898306 |
| Middle East_D | 1.03 | 0.973009 |
| **Mean VIF** | **2.92** | |

**AHTS term**

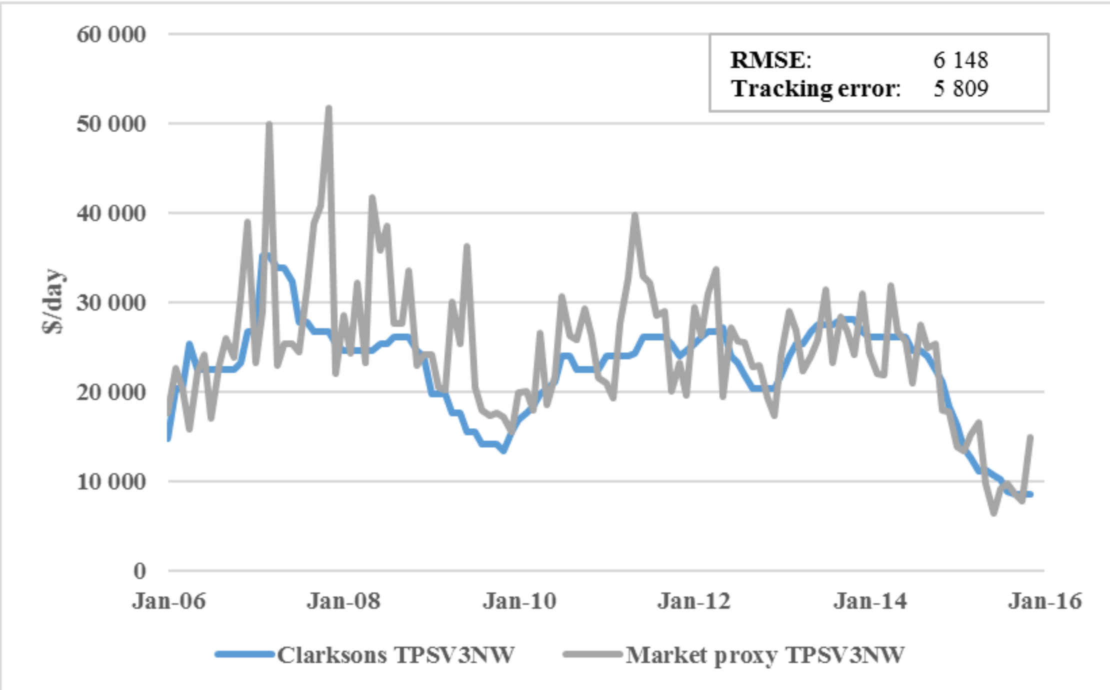
| Variable | VIF | 1/VIF |
|---|---|---|
| Age | 10.62 | 0.094125 |
| Age2 | 10.04 | 0.099605 |
| BP | 6.81 | 0.146871 |
| DWT | 4.69 | 0.213325 |
| Market proxy | 2.32 | 0.431448 |
| Build NW Europe_D | 1.75 | 0.571500 |
| DP2_D | 1.64 | 0.611542 |
| Speed | 1.54 | 0.648426 |
| Build Far East_D | 1.48 | 0.675199 |
| Consumption | 1.37 | 0.729803 |
| ROV_D | 1.30 | 0.769824 |
| Ice class_D | 1.28 | 0.780265 |
| Helideck_D | 1.23 | 0.811723 |
| Forward_BW | 1.16 | 0.861392 |
| Duration_BW | 1.14 | 0.878313 |
| Drilling_D | 1.06 | 0.943883 |
| **Mean VIF** | **3.09** | |

# Appendix 4 – Clarkson index tracking

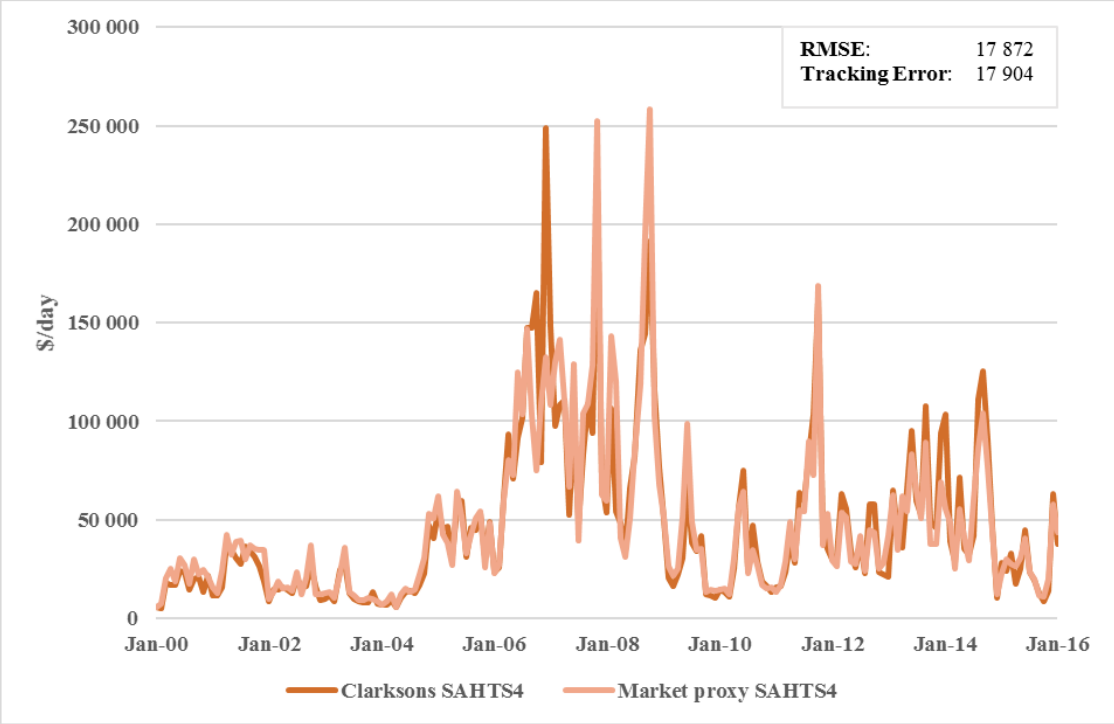
**PSV, Spot, 900+m2:**




**PSV, Term, 900+m2, Northwest Europe:**



**AHTS, Spot, 20,000+ bhp:**




**AHTS, Term, 16,000-19,999 bhp, Northwest Europe:**