Norwegian School of Economics
Bergen, Fall 2017

NHH

Revenue determinants in the Offshore Support Vessel market

A study of North Sea fixtures

Asmund Wiig & Marius Vik Tvedte

Supervisor: Roar Os Ådland

Master thesis in Finance

NORWEGIAN SCHOOL OF ECONOMICS

Abstract

The purpose of this thesis is to investigate the vessel-specific determinants of commercial success, measured by vessel revenue, in the North Sea Offshore Support Vessels (OSV) market. By studying the characteristics and technical specifications of individual vessels, we aim to determine which attributes contribute to vessel revenue generation over time and across market conditions.

Through a quantitative approach, we analyze comprehensive North Sea fixture data and apply statistical methods to make inferences about how vessels' specifications influence their revenue. Revenue is a function of dayrates and vessels' ability to obtain contracts (i.e. utilization).

In accordance with previous research, we find that large vessels with increased carrying capacity earn revenue premiums in the North Sea OSV market. Our results further suggest a non-linear relationship between vessel age and vessel revenue. Other specifications such as build region, fuel-efficiency and propulsion system also have significant effects on revenue within the various vessel segments. Studying the period after the oil price decline of 2014 in isolation, we find that preferences have changed, and different specifications earn revenue premiums in the recent weak market.

Missing data and possible omitted variable bias are important limitations of our study. For speed and fuel consumption, missing values have been imputed and these estimates might deviate from their true values. Further, our models might not be able to control for all variables that affect revenue.

Our results are of interest to market participants, and are particularly useful for shipowners in determining their optimal fleet composition and deployment.

While previous research has focused on the determinants of either dayrates or utilization ratios, we argue that these variables should not be studied in isolation. By combining dayrates and utilization for individual vessels, our thesis is the first to study the determinants of actual revenue generation for OSVs.

Preface

This thesis is written as a concluding part of our Master of Science in Economics and Business Administration, within our Major in Finance, at NHH – Norwegian School of Economics.

We would like to thank our supervisor, Roar Os Adland, for interesting discussions and constructive feedback throughout the process. We would also like to thank Haying Jia at the Norwegian School of Economics for guidelines regarding imputation and regression methodology, as well as Clarksons Platou Offshore for access to supplementary data. Finally, we would like to thank Ulstein International for providing the main dataset and Jose Jorge Garcia Agis, Per Olaf Brett and André Keane for valuable input on the offshore markets.

We hope our thesis proves to be valuable, both as input for market participants and as inspiration for further research.

Bergen, December 2017

Asmund Wiig

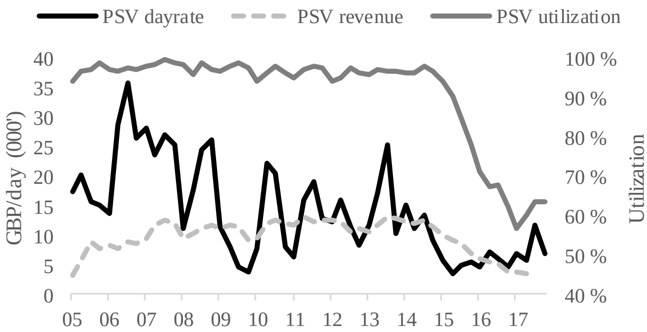
Marius Vik Tvedte

Table of contents

1. Introduction

The market for offshore support vessels in the North Sea is characterized by high volatility and fierce competition. Driven by volatile commodity prices, changing weather conditions and slow supply side adjustment, both freight rates and utilization ratios have fluctuated widely over time.

Traditionally, either the prevailing dayrate or current utilization ratio has served as the established indicator of the market condition. Viewed in separation however, these indicators do not provide a complete picture. This thesis argues that studying freight rates and utilization in combination is a more accurate way of measuring both the market condition and the commercial attractiveness of individual vessels. This point is demonstrated in Figure 1, comparing revenue with dayrates and utilization ratios respectively.



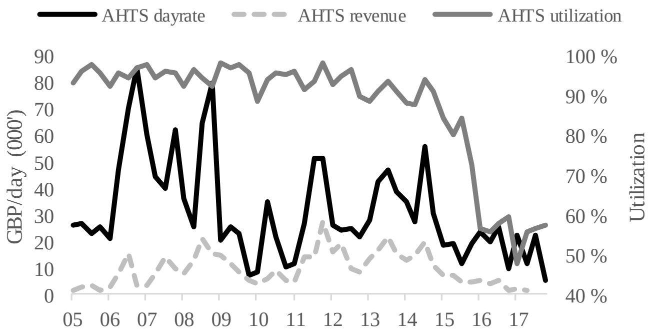


Figure 1 *– Historical spot dayrates, utilization and revenue in the North Sea (PSV > 900m^2 and AHTS > 20k BHP)*
Source: Clarksons, Ulstein, authors' calculations

Revenue clearly deviates from dayrates and utilization, and this provides the motivation for our thesis. Our objective is to determine how shipowners may improve revenue, by studying how revenue is affected by differences in vessel specifications. We study this for the main vessel types and size segments in the North Sea OSV market.

We argue that choosing the right set of specifications is of crucial importance in order to stay competitive in the North Sea OSV market. Due to a fragmented supply side with little pricing power, shipowners are vulnerable to changes in market conditions. In order to survive and remain competitive over time, shipowners must ensure that their vessels are suited to the changing requirements of their clients. Previous research on the determinants of freight rates and utilization, suggests that shipowners are able to differentiate themselves from competing vessels based on their specifications (Tvedte & Sterud, 2016; Dahle & Kvalsvik, 2016; Adland et al, 2016; Adland et al 2017a; Adland et al, 2017b; Adland et al, 2017c).

However, vessels that earn freight rate premiums might suffer on utilization as a direct consequence. Conversely, highly utilized vessels might not be earning high dayrates. Thus, there may even be a negative relationship between the two variables. Some shipowners might pursue fewer high-paying contracts, while others may be willing to accept lower dayrates in order to keep their vessels in operation. Hence, separate analysis of freight rates and utilization may be misleading with regards to revenue generation. This serves as an important motivation for our thesis where we combine freight rates and utilization to provide a complete picture of the determinants of the actual revenue stream to shipowners.

Since late 2014, the OSV market has been marked by low demand and significant oversupply of tonnage. This has resulted in a persistent situation of historically low rates and utilization, making it an interesting point of study. In such conditions, differentiation becomes even more important as competition intensifies. We will therefore also study how specifications affect revenue during the recent weak market in detail.

Using regression models, we are able to study the distinctive value-add in terms of revenue for each vessel specification, while controlling for the general market condition. We study vessel age and other relevant specifications such as size, power, build region and fuel-efficiency, to determine how these specifications affect revenue over time. Moreover, as vessel design preferences are likely to change during different market conditions, we also compare results from before and after the oil price decline of 2014.

Our thesis is primarily of interest to shipowners in determining their fleet composition. Our models could be of use when deciding which vessels to acquire, divest or modify in order to improve revenue by developing more accurate revenue predictions and investment cases. For newbuild orders, our findings are of interest to both owners and yards in determining a vessel's optimal design specifications. Our findings are also of relevance to shipbrokers and analysts who will be interested in the revenue potential of specific vessels for valuation purposes. Our thesis fills an important gap in the literature, and lays the foundation for further research on determinants of vessel revenue over time.

The remainder of this thesis is structured in five sections. First, previous research on the topic will be reviewed. We will thereafter present the North Sea OSV market, before we introduce our data and methodology. In section 5, the results from our regression models are presented and discussed. Finally, we summarize our findings, limitations and suggestions for further research in section 6.

2. Literature review

In this section, we will review relevant literature within the offshore industry, but also present relevant research from deepsea shipping. First, research regarding utilization will be reviewed, before we investigate research on freight rate determinants. We expect the findings of our thesis to be similar to those in the literature on utilization and freight rates. Thus, this section will, together with known characteristics of the North Sea OSV market, form the basis for our hypothesis.

Tvedte and Sterud (2016) use a logistic regression model to study determinants of utilization in the North Sea OSV market. They find that younger, medium complex vessels with large deck area built in Northwest Europe are preferred in the PSV market, and that utilization in the spot market is more sensitive to vessel specifications compared to the term market. Operational capabilities such as DP II, ice-class and fire-fighting increase probability of obtaining a spot contract. In the term market, however, ice-class has no significant effect, while fire-fighting capabilities reduce utilization. For AHTS vessels, younger, complex and more powerful vessels built in Northwest Europe are preferred in the spot market. They identify a two-tier term market, where either less powerful and less complex or more powerful and more complex vessels are preferred. Furthermore, having a DP II system decreases the probability of obtaining contracts in the term market, while fire-fighting capabilities are rewarded. Helideck and moonpool are proven to be rewarded specifications in the term market, but disregarded in the spot market.

The lay-up decision for OSVs has also been thoroughly investigated in recent years. Grøvdal and Tomren (2016) study the decision through interviews, linear regression and logit models. Through interviews, they identify age, efficiency and carrying capacity as the most important determinants. In their quantitative approach, they conclude that for PSVs, larger clear deck area (m^2) reduces probability for lay-up. For AHTS vessels, bollard pull (tons) has a similar effect. Sværen (2017) further investigates these findings, using panel logistic regressions and Cox proportional hazard models to identify determinants for the lay-up decision. She finds that smaller, older and less fuel-efficient PSVs are more likely to be laid-up. Older AHTS vessels also have higher lay-up probability. Also related to utilization, Alizadeh et al (2016) investigate the scrapping decision for dry-bulk vessels. They use a panel logistic model to identify vessel- and market specific determinants for scrapping. Of vessel-specific determinants, age and size have significant impact. Moreover, market forces such as freight rates and bunker prices have significant effect.

Aas et al (2009) investigate the role of PSVs in offshore logistics on the Norwegian continental shelf. Through logistic analysis, they find that carrying capacity, sailing, loading and unloading capabilities are the main features of PSVs. Carrying capacity refers to the capability to carry deck cargo and bulk cargo (Aas et al, 2009). They argue that larger vessels can exploit economies of scale, thus obtaining lower costs per unit. Halvorsen-Weare et al (2012) and Maisiuk and Gribkovskaia (2014) support this view. Furthermore, sailing capabilities refer to a vessel's ability to sail under different conditions. Bad weather may make it necessary to decrease speed, for safety of both cargo and crew. Loading and unloading capabilities refer to a vessel's ability to lift and keep its position (Aas et al, 2009), emphasizing the importance of dynamic positioning systems.

Ringlund et al (2008) show that rig activity is strongly correlated with the oil price. Furthermore, they conclude that increased size and complexity of oilrigs has led to higher demand for larger and more complex OSVs.

Adland et al (2017a) use a hedonic price regression to develop a market index for the North Sea PSV and AHTS spot markets. Unlike common broker indices, they control for heterogeneity in vessel specifications and contract-specific variables. They find that spot rates increase with engine power and carrying capacity of vessels, and reduce non-linearly with age. Vessels built in Northwest Europe, or equipped with dynamic positioning systems, ROV-support or ice-class earn freight rate premiums. Conventional diesel propulsion systems and stronger bollard pull are rewarded for AHTS vessels. By decomposing the variance in freight rates, they also find that time effects contribute approximately 72 % and 57 % of the total variance in freight rates in the PSV and AHTS segments respectively. Moreover, they find that vessel characteristics account for 8 % and 10 % in the respective segments, suggesting that market fluctuations explain a larger proportion of the variance in freight rates than vessel specifications.

Studying the relationship between fuel-efficiency and freight rates, Adland et al (2017b) find that rates are unrelated to fuel-efficiency for PSVs, and negatively related to fuel-efficiency in the AHTS spot market. Thus suggesting that fuel-efficiency is penalized rather than rewarded in the North Sea. They propose three reasons for this result. First, the crude oil price, fuel prices and OSV demand are all positively correlated. Second, there is no physical separation between fuel oil used, and fuel cargo delivered, when PSVs transport fuel oil for delivery. Clients pay a lump sum for the entire volume of oil loaded, and may consider consumption during transportation a sunk cost. Third, downtime in drilling or production can be extremely costly relative to modest savings from fuel-efficiency. Powerful vessels that are able to maintain speed under poor weather conditions are therefore likely to be preferred to more fuel-efficient vessels with higher probability of non-performance.

Dahle and Kvalsvik (2016) also investigate determinants of OSV freight rates in both spot and term markets. They conclude that the market rate, represented by a self-constructed proxy, explains approximately 80 % of the variation in freight rates. Moreover, their findings are generally in line with Adland et al (2017a) as larger, younger vessels with dynamic positioning systems and ice-class are rewarded. They also conclude that a premium exists for Brazil as operating region, while vessels built in the Far East experience lower freight rates.

Døsen and Langeland (2015) have similar findings when investigating the impact of vessel- contract- and macro specific variables on PSV term charter rates. Of vessel specifications, they find that younger, more powerful vessels with large deck area and dynamic positioning system are rewarded with higher rates.

While most research on determinants of freight rates in the offshore segment is quite recent, similar studies have been done in deepsea shipping for some time. Strandenes (1999) investigates the potential for a two-tier tanker market separated by quality. She argues that a two-tier market could exist if demand for quality tankers were to increase sufficiently. Tamvakis and Thanopoulou (2000) investigate the possible existence of a two-tier spot market for dry bulk vessels of differing age. They find that only in very few cases, a premium is paid to younger vessels. More recent studies, such as Köhn and Thanopoulou (2011) and Agnolucci et al (2014), focus on microeconomic determinants for freight rates in the dry bulk time-charter market. Köhn and Thanopoulou (2011) find significant evidence in support of a quality premium. Agnolucci et al (2014) investigate allocation of financial savings from energy efficiency between owners and charterers. They conclude that fuel-efficiency is a significant factor, but that owners only accrue 40 % of the savings. However, Adland et al (2017a; 2017c) argue that market indices used in these papers may capture parts of the heterogeneity they are trying to evaluate, and thus are biased. Moreover, using a hedonic model including macro, vessel- and contract specific variables, Adland et al (2017c) conclude that earlier findings on energy efficiency premiums for dry bulk time charter rates are not robust when increasing sample in time and size. They find that energy efficiency is only rewarded during poor freight market conditions. They also identify age, fuel prices and vessel size as significant determinants. Adland et al (2016) prove that characteristics of owners, charterers and the combination of the two, also have significant impact on bulk freight rates.

In light of the above, the contribution of this thesis is threefold. Unlike other theses, we combine utilization and freight rates, and study revenue instead of the two components separately. Further, we investigate how preferences change across market conditions by separately analyzing the period before and after the oil price decline of 2014. Finally, through variance decomposition, we quantify how much of the revenue variance is attributable to vessel specifications and market fluctuations respectively.

3. The North Sea OSV market

Offshore support vessels form part of the offshore energy upstream value chain, providing rig and construction support to energy companies involved in the offshore exploration and production (E&P) of natural resources. Platform Supply Vessels (PSV) and Anchor Handling and Tug Supply (AHTS) vessels are the dominant vessel types in the OSV segment. PSVs typically provide cargo transportation services to offshore installations throughout the lifecycle of offshore projects. AHTS vessels are mainly used for towing and anchor handling purposes such as rig moves, but may also be used for supply purposes.

Similar to other shipping segments, the OSV market is characterized by a fragmented supply side in which tonnage providers are price takers in a highly competitive market. Frequent changes in demand, which is highly correlated with crude oil prices, coupled with relatively slow supply side adjustment result in volatile utilization ratios and dayrates.

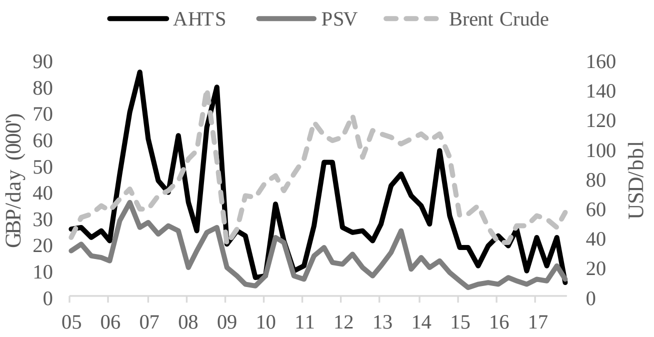


Figure 2 *- PSV and AHTS spot dayrates v. Brent crude oil (PSV > 900 m² and AHTS > 20k BHP)*
Source: Clarksons, Bloomberg

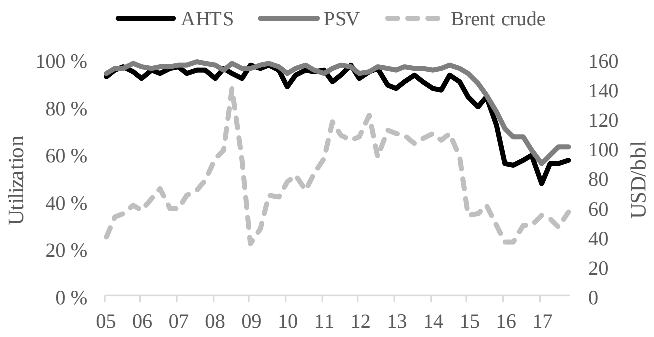


Figure 3 *- PSV and AHTS utilization[1] vs. Brent crude oil (PSV > 900 m² and AHTS > 20k BHP)*
Source: Ulstein, Bloomberg

The volatility in both the AHTS and PSV segments of the North Sea market is evident from Figures 2 and 3 above. Historically, dayrates have been more volatile for AHTS vessels than in the PSV segment. The AHTS market is very vulnerable to short-term pressures such as weather changes, and the whim of E&P companies that dictate the timing of rig moves (Clarksons Research, 2015). Additionally, spot contracts are somewhat more prevalent for AHTS vessels than for PSVs.

[1] Figure 3 shows quarterly utilization (spot and term combined). Data provided by Ulstein.

Utilization in the North Sea is also characterized by high historical volatility. Though to a lesser extent than dayrates, utilization is also correlated with the crude oil price, and changes in the commodity price are quickly reflected in the OSV market. Following the drop in crude oil prices during late 2014, persistent oversupply has kept the OSV market from recovering and both rates and utilization have been consistently low.

The North Sea OSV market is well developed, and the North Sea is one of the most extensively explored offshore oil and gas basins in the world. Thus, much of E&P activity is increasingly focused toward deepwater and harsh environment areas. More deepwater activity has increased demand for floating production units, particularly in weather adverse regions (OECD, 2015). Floating units are typically bigger and more technically complex than conventional Jack-Ups, and require more powerful AHTS vessels and larger size PSVs. Deepwater projects are also more complex and often involve subsea infrastructure that may require subsea functions such as remotely operated vehicle (ROV) support.

Made difficult by the harsh environment, station keeping is important for OSVs that frequently operate in close proximity to offshore installations. This may require sophisticated dynamic positioning (DP) systems that help vessels avoid collisions. The North Sea weather conditions also contribute to the volatility of freight rates, as they may lead to periods of unexpected tightening of the market balance (Clarksons Platou Project Finance, 2016).

Viewed as a pioneer in both technology and industry standards, the North Sea OSV market has an increased focus on safety and environmental protection (OECD, 2015). Thus, safety measures such as fire-fighting capabilities and oil spill recovery functions may be preferred, alongside more modern diesel electric engines.

4. Data and methodology

4.1 Regression model

We consider quarterly revenue as the dependent variable. For each quarter, we measure revenue by multiplying vessels' number of days on contract with the prevailing contractual dayrate.

We apply a longitudinal panel data structure to our dataset, with each line representing quarterly revenue for a given vessel in a given period with vessel specifications as explanatory variables.

With the exception of vessel age, all specifications are time invariant, but are adjusted for any conversions or permanent changes to a vessel's specifications.

Panel data estimation is used instead of pooled OLS, as pooled OLS does not account for the individual time-invariant heterogeneity of vessels. According to Verbeek (2004), this omission leads to biased and inconsistent estimates. The results after conducting a Breusch-Pagan LM-test[2] support this view. As all our independent variables, except age, are time-invariant, a fixed effects model is not appropriate. Thus, we use a random effects specification, although this imposes an assumption that the individual heterogeneity is uncorrelated with the error term. To control for potential heteroscedasticity, which may affect the standard errors, we use cluster-robust standard errors. Some of the independent variables have relatively high correlation, but the variance inflation factors[3] indicate that we may include them in the same model.

We specify the following model:

$$\begin{aligned} Revenue_{it} = {} & \beta_0 + \beta_1 Age_{it} + \beta_2 AgeSq_{it} + \beta_3 DeckArea_i + \beta_4 Bulkcap_i + \beta_5 BHP_i + \beta_6 NWEbuilt_i \\ & + \beta_7 FEI_i + \beta_8 ConvProp_i + \beta_9 DP1_i + \beta_{10} DP2_i + \beta_{11} DP3_i + \beta_{12} ROV_i + \beta_{13} Oilrec_i \\ & + \beta_{14} Ice_i + \beta_{15} Heli_i + \beta_{16} Moonp_i + \beta_{17} Fifi_i + \Sigma\, \delta_t D_t + u_i + \varepsilon_{it} \end{aligned}$$

$Revenue_{it}$ is the revenue for vessel *i* during period *t*. Age_{it} is the number of years since delivery for vessel *i* at the start of period *t*. $AgeSq_{it}$ is the squared term of Age_{it}. $DeckArea_i$ indicates the clear deck area in square meters (m^2), and is our main size variable for PSVs, while BHP_i is the engine break horsepower for vessel *i*, and is the main size variable for AHTS vessels. $Bulkcap_i$ measures the under deck carrying capacity in cubic meters (m^3) for PSVs. Note that $DeckArea_i$ and $Bulkcap_i$ are only included when studying PSVs, while BHP_i is included only in the AHTS regression model.

$NWEbuilt_i$ is a dummy variable equaling one if vessel *i* was built at a yard located in Northwest Europe. $ConvProp_i$, is a dummy variable equaling one if vessel *i* has a conventional diesel mechanical propulsion system, as opposed to diesel electric or hybrid type systems. $DP1\text{-}3_i$ are all dummy variables for the dynamic positioning class for a given vessel, while ROV_i is a dummy that equals one if a given vessel has ROV-support functions in place. Similarly, $Oilrec_i$, Ice_i, $Heli_i$, $Moonp_i$, and $Fifi_i$ are all binary dummy variables equaling one if vessel *i* has the given feature. $Oilrec_i$ indicates whether a vessel has oil-spill recovery capabilities, while Ice_i indicates whether a given vessel has a reinforced hull and is certified with ice-classification by

[2] The Breusch-Pagan Lagrange Multiplier-test tests whether the variance across entities is zero
[3] The variance inflation factor measures levels of collinearity among the independent variables, see appendix 3

a classification society. $Heli_i$ refers to the presence of a helicopter landing deck, and $Moonp_i$ to Moonpool, an opening in the hull of the vessel providing access to calm water. $Fifi_i$ indicates whether the vessel has fire-fighting capabilities.

FEI_i is a fuel-efficiency index based on a given vessel's design speed and design consumption. In accordance with Adland (2017c), the index is calculated using the following formula:

$$FEI_{PSV} = \frac{Consumption}{Speed * DWT * 24}, \qquad FEI_{AHTS} = \frac{Consumption}{Speed * BHP * 24}$$

Note that a decrease in the fuel-efficiency index is equivalent to an improvement in fuel-efficiency and vice versa.

To control for the overall market condition and its fluctuations we include a dummy variable for all but one of the fifty time periods in our sample. The series of dummies allows us to estimate a market index proxy, and is estimated in the same regression model as the effect of vessel specifications. Determining and controlling for the market condition in conjunction with vessel specifications allows us to separate vessel-specific effects from the effect of the market on our dependent variable. Thus, we avoid the issue of a market proxy that is biased by the changes in vessel specifications over time.

Based on previous research and the characteristics of the North Sea market, the hypothesized results of our regression model are summarized in Table 1 below.

Variable name	Specification	Comment	Exp. sign
Age_{it}	Age	Years since delivery from yard	-
$AgeSq_{it}$	Age squared	Years since delivery from yard squared	-
$DeckArea_{i}$	Clear deck area	PSV deck space (m^2) and size variable	+
$Bulkcap_{i}$	Bulk capacity	PSV under deck bulk capacity (m^3)	+
BHP_{i}	Break horsepower	AHTS engine power and size variable	+
$NWEbuilt_{i}$	Build region	Dummy; built in Northwest Europe	+
FEI_{i}	Fuel efficiency	Fuel efficiency index	+
$ConvProp_{i}$	Propulsion system	Dummy; conventional propulsion system	-
$DP1_{i}$	DP I	Dummy; DP class I	+
$DP2_{i}$	DP II	Dummy; DP class II	+
$DP3_{i}$	DP III	Dummy; DP class III	+
ROV_{i}	ROV support	Dummy; ROV support system	+
Ice_{i}	Ice Class	Dummy; Ice class	+
$Oilrec_{i}$	Oilspill recovery	Dummy; Oil-spill recovery capability	+
$Heli_{i}$	Helideck	Dummy; Helicopter landing deck	+
$Moonp_{i}$	Moonpool	Dummy; Moonpool	+
$Fifi_{i}$	Firefighting	Dummy; Firefighting capability	+

Table 1 *– Hypothesis summary: Model variables and expected coefficient sign*

Age is expected to negatively affect vessels revenue. We include a squared term to investigate a possible non-linear relationship between age and revenue. The rationale for this is to investigate a possible revenue discount for vessels with little or no operational track record. Age might then be positively related to operational experience and have a positive effect on revenue during the first years of a vessel's life. Further, we expect age to be associated with an exponential discount for the oldest vessels.

We expect size and carrying capacity, measured in clear deck area and bulk capacity for PSVs, and BHP for AHTS vessels, to positively affect revenue. Similarly, we expect vessels built in Northwest Europe to earn revenue premiums for both vessel types. In line with Adland (2017b), fuel-efficiency is expected to negatively affect revenue for AHTS vessels, i.e. a revenue discount for fuel-efficient vessels. We expect a negative or insignificant effect for PSVs. Conventional propulsion systems are expected to carry a discount to more modern propulsion systems, while DP systems are expected to be rewarded.

Furthermore, we expect ROV-support capabilities and ice-classed vessels to earn revenue premiums in the North Sea. It is less clear whether other auxiliary capabilities such as helideck, moonpool, fire-fighting and oilspill recovery ability will be rewarded, if at all significant.

We expect these results to hold also in the recent weak OSV market. The oil price decline started in the second quarter of 2014, and OSV revenue in the North Sea started falling during Q3 2014. Oversupply of vessels increases the choice and bargaining power of charterers, with more vessels competing for any given contract. As competition among vessels intensifies, vessels with the preferred set of specifications will be the ones winning contracts, while vessels that do not are left unemployed. Thus, we expect coefficients and significance levels of specifications that were preferred before Q3 2014 to increase in magnitude in the weak market that followed.

4.2 Variance decomposition

To quantify the relative contribution of the market- and vessel-specific variables to the total variance in our models, we perform a variance decomposition. The total variance of revenue can be decomposed into the variance of vessel-specific variables $V(X\beta)$, the estimated market index proxy $V(\delta_t)$, and the covariance between them $cov(\delta_t, X\beta)$, in addition to the variance of the combined residual $V(u_i+\varepsilon_{it})$:

$$V(Revenue_{it}) = V(\delta_t) + V(\beta X) + 2cov(\delta_t, \beta X) + V(u_i+\varepsilon_{it})$$

In line with Adland et al (2017a) and Dahle & Kvalsvik (2016) we expect market effects to account for more of the variance than vessel specifications. Further, we expect the total variance of our models to be higher, and the explanatory power lower, compared to previous research that have shorter time increments, and study either freight rates or utilization in isolation.

Studying quarterly vessel revenue, we compare contracts that may have been agreed at widely different time points. Active contracts may therefore have differing terms, and some revenue variation may simply be due to when a vessel’s current contract happened to be signed. Combining freight rates with utilization also increases variation, particularly in bad markets, where observations of idle vessels will be included with zero revenue instead of being omitted from the data. These factors will make vessel revenue more difficult to accurately estimate, increasing the variance attributable to the residual.

4.3 Description of dataset

We utilize a dataset from ODS Petrodata, which consists of 47 245 worldwide OSV fixtures from January 2005 to July 2017, in addition to detailed vessel specifications. This has been complemented by an OSV database from Clarksons Research. Furthermore, we have supplemented our data with a lay-up database from Marine Base. Laid-up vessels in the North Sea are included in our dataset, as we find it appropriate to treat them as part of the supply side. A weakness of this approach is that vessels may be in lay-up for reasons unrelated to their specifications, for example due to the owner's financial situation.

We have filtered our data through a number of operations. First, we exclude all fixtures outside the North Sea. This reduces the number of fixtures to 17 800. To complement our main sources of data, service speed and corresponding consumption is obtained from individual vessels' specification sheets. For vessels where values for speed or consumption are missing, we adopt the Fully Conditional Specifications (FCS) imputation methodology (Heitjan & Little, 1991; Schafer & Schenker, 2000; Liu et al, 2000). Thus, we impute missing values from a set of observed values, in our case size, engine power, speed, beam, draft, propulsion type and build year, to predict values that are closest to the real value. According to Allison (2009), this methodology ensures that imputed values are similar to real values. In line with Jia (2017), we assume that vessels of similar design and age tend to have similar fuel consumption.

Our dataset contains both term and spot fixtures. Previous literature has analyzed these contract types separately. As we want to identify vessel-specific determinants of total revenue, we do not make this separation. Thus, our analysis is not ideal for shipowners who primarily are interested in one of the two markets. However, we argue that our approach is more relevant, as most shipowners employ their vessels in both markets. 90 % of the vessels in our dataset have been employed on spot contracts, while 70 % have had term contracts. Moreover, previous literature has found only minor preference differences between the two contract types (Tvedte & Sterud, 2016; Dahle & Kvalsvik, 2016).

When calculating the revenue from each fixture, we use dayrates in GBP. For fixtures where dayrates are stated in other currencies, we use the average exchange rates for the contract period to calculate revenue in GBP for each period. These rates are multiplied with number of contract days a fixture has in each time period. Thus, we assume that payments are evenly distributed over the duration of the contract.

Furthermore, certain assumptions are made as to when vessels are part of the North Sea market throughout the period. First, if a vessel is delivered in the middle of a period, it is excluded until the beginning of the next period. Thus, we prevent underestimating the revenue of new vessels in their period of delivery. Second, vessels are removed from the dataset in periods where they have zero revenue under the assumption that they are not part of the North Sea market, unless they are in lay-up. It could be argued that some of these vessels are actually standby in the North Sea, and should therefore be included in the dataset with zero revenue. However, vessels also operate outside the North Sea, where low quality of data make it difficult to separate them from idle vessels. We therefore believe our method has fewer drawbacks than its alternatives.

4.4 Descriptive statistics

Tables 2, 3 and 4 summarize the descriptive statistics for the North Sea PSV and AHTS fleets, respectively. The number of vessels in the fleet has increased significantly from 2005 to 2016; from 64 to 283 PSVs, and from 39 to 162 AHTS vessels. As Figures 4 and 5 highlight, the average size and engine power of newbuilds has also increased consistently throughout our sample period. Thus, the fleet has grown larger in number, with the largest vessel segments accounting for most of the growth.

Since 2014 however, newbuilding activity has declined significantly. Consequently, the average age of the fleet has increased consistently during the past three years. The decline in newbuild deliveries during recent years is evident from Figures 4 and 5, showing delivery and average size for the vessels in our sample.

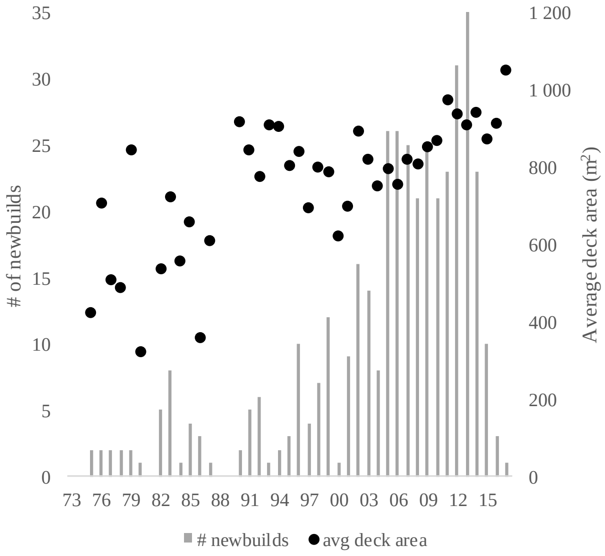


Figure 4 - *PSV deliveries in the North Sea*

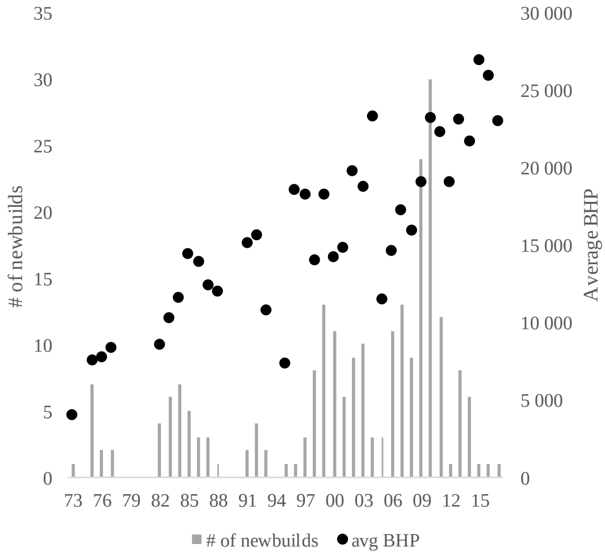


Figure 5 - *AHTS deliveries in the North Sea*

The figures above also highlight the clear trend towards larger vessels within both vessel classes. Average clear deck area for PSVs has increased by 7 %, from 802 m^2 to 859 m^2, since 2005. Similarly, average brake horsepower for AHTS vessels has increased by 21 % from 15 245 in 2005 to 18 433 in 2017. The largest vessel segments have the highest average revenue during all the years included in our sample. Thus, PSVs with more deck area and AHTS vessels with higher BHP seem to earn more than the smaller vessels.

PSVs had their highest average revenue in 2012, with average revenue of 826k GBP per quarter. AHTS revenue peaked in 2013 at an average revenue of 1 008k GBP per quarter. Following the oil price decline in 2014, revenue generated by the fleet has decreased significantly. 2016 was the worst year in terms of average revenue in our sample for both vessel classes with average quarterly revenue of 339k and 240k GBP in the PSV and AHTS segments respectively. The recent weak market is also reflected in the unprecedented number of vessels in lay-up during the last three years.

Throughout the period, the fleet has become more fuel-efficient. The average fuel-efficiency index has been reduced from 10,1 to 9,6 for PSVs, and from 5,5 to 3,5 for AHTS vessels. Although average consumption has increased for PSVs, their operational capabilities measured by size and speed have increased, improving the average fuel-efficiency index. Average consumption has decreased slightly for AHTS vessels, and in combination with increased average speed and power, the average fuel-efficiency index has improved.

A larger proportion of the fleet, 93 % for PSVs and 86 % for AHTS vessels, have dynamic positioning systems. The proportion of the fleet with a DP II system has increased by 29 and 23 percentage points for PSVs and AHTS vessels respectively. 92 % of the large PSVs currently have DP II, compared to just 71 % for smaller PSVs. An increasing share of PSVs has ice-class and fire-fighting capabilities, while the proportion of vessels with a moonpool and conventional propulsion has decreased. The percentage of the fleet with ROV-support capabilities has been consistently higher within the AHTS segment than for PSVs. For AHTS vessels, the proportion of vessels with ice-class has remained relatively stable, while helideck, moonpool, fire-fighting capabilities and conventional propulsion have decreased.

The proportion of the fleet built in Northwest Europe has also decreased. In 2005, 73 % of PSVs and 72 % of AHTS vessels in the North Sea were built at yards in Northwest Europe, while in 2017, the proportions have been reduced to 62 % and 58 %, respectively.

Table 2 *- North Sea PSV fleet*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017*
PSV - All													
No. of obs.	250	365	429	503	587	580	604	617	635	693	840	960	464
No. vessels	64	107	116	138	162	166	167	176	190	201	239	283	252
No. in lay-up	1	0	0	0	8	11	9	11	9	20	113	180	160
Avg revenue	344	582	715	731	791	630	742	826	778	808	592	339	210
Min. revenue	8	0	0	0	0	0	0	0	0	0	0	0	0
Max revenue	1 275	1 676	2 520	2 912	2 880	2 880	2 880	2 912	2 973	3 060	3 060	2 639	1 710
Avg age	6,3	7,4	7,7	7,0	7,2	7,8	8,7	7,7	7,4	7,4	7,8	9,0	9,8
Min. age	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,4
Max. age	28,5	29,5	30,5	31,5	32,5	33,5	34,5	35,5	35,5	34,5	35,5	39,8	40,5
Avg deck area	802	792	789	798	811	824	838	858	866	880	876	861	859
Min deck area	525	525	500	525	525	553	551	506	506	506	506	506	506
Max deck area	1 220	1 220	1 270	1 220	1 270	1 270	1 270	1 220	1 377	1 377	1 377	1 377	1 377
Avg.FEI	10,1	10	10,2	10,1	10,1	10	10	9,9	9,7	9,6	9,5	9,5	9,6
Min. FEI	4,2	4,2	4,2	4,2	4,2	4,2	4,2	4,2	4,2	4,2	4,2	4,2	4,2
Max. FEI	20,2	20,2	24,7	24,7	24,7	24,7	24,7	24,7	24,7	20,2	20,2	20,2	20,2
Avg bulkcap	1 780	1 721	1 823	1 916	2 002	2 042	2 087	2 274	2 244	2 265	2 209	2 111	2 124
Avg consumpt.	12,1	12,1	12,2	12,5	12,6	12,7	12,9	13,1	13,1	13	12,9	12,8	12,8
Avg speed	13,8	13,9	13,9	14,1	14,1	14,1	14,1	14,2	14,1	14,0	14,0	14,0	14,0
Proportion of fleet (%)													
DP	85,9	83,2	81,9	84,8	88,3	88,6	87,4	89,8	92,6	93,5	93,7	93,3	93,3
DP1	32,8	25,2	27,6	23,9	23,5	21,7	16,2	16,5	16,3	13,9	13,0	13,8	12,7
DP2	51,6	57,0	52,6	59,4	63,6	66,3	70,7	72,7	75,8	79,6	80,8	79,5	80,6
DP3	1,6	0,9	1,7	1,4	1,2	0,6	0,6	0,6	0,5	0,0	0,0	0,0	0,0
Iceclass	7,8	6,5	9,5	10,9	10,5	13,3	15,0	18,8	19,5	22,9	20,1	19,1	18,7
Helideck	0,0	0,9	1,7	0,7	1,2	1,2	1,2	0,0	0,0	0,5	0,8	0,7	0,4
Moonpool	10,9	8,4	5,2	3,6	4,3	4,8	4,2	1,7	2,6	1,5	2,5	1,8	2,4
Firefight	18,8	15,9	22,4	26,1	30,9	30,1	31,7	31,8	33,7	35,3	35,6	37,5	35,3
Conv. Prop	70,3	72,9	71,6	67,4	64,8	60,2	55,1	48,3	46,8	43,8	45,2	48,8	48,4
ROV	14,1	15,9	12,1	9,4	8,6	9,0	6,6	6,8	6,3	6,5	8,4	8,5	8,7
Oilspill rec.	23,4	20,6	23,3	22,5	24,1	25,9	28,7	27,8	30,5	29,4	28,0	24,7	23,4
NWE built	73,4	74,8	69,8	68,1	66,7	68,1	68,9	68,2	67,9	67,7	64,4	64,0	61,9
PSV Small - Clear deck area < $900m^2$													
No. of obs.	159	236	268	289	327	308	306	284	293	309	387	505	250
No. vessels	41	70	75	84	96	92	88	85	92	92	114	147	133
No. in lay-up	0	0	0	0	5	11	8	11	9	13	74	111	101
Avg revenue	315	542	645	649	656	462	482	583	640	573	379	207	109
Avg age	6,9	8,4	8,8	7,5	7,8	8,9	10,9	10,3	9,8	9,1	9,4	10	10,7
Avg deck area	717	704	690	690	697	699	705	715	722	733	731	730	730
Avg bulkcap	1 730	1 651	1 687	1 762	1 806	1 737	1 714	1 816	1 803	1 820	1 755	1 772	1 831
Avg FEI	10,9	10,8	11,1	11,2	11,2	11,4	11,4	11,4	11,2	10,9	10,8	10,7	10,7
DP (%)	78,0	74,3	72,0	75,0	80,2	79,3	76,1	78,8	84,8	85,9	86,8	87,8	88,0
DP1 (%)	43,9	32,9	34,7	29,8	29,2	27,2	20,5	22,4	22,8	22,8	19,3	19,0	17,3
DP2 (%)	31,7	40,0	36,0	44,0	50,0	51,1	54,5	55,3	60,9	63,0	67,5	68,7	70,7
DP3 (%)	2,4	1,4	1,3	1,2	1,0	1,1	1,1	1,2	1,1	0,0	0,0	0,0	0,0
Iceclass (%)	9,8	5,7	8,0	4,8	1,0	2,2	2,3	2,4	4,3	8,7	7,9	10,2	8,3
Helideck (%)	0,0	1,4	1,3	1,2	1,0	1,1	1,1	0,0	0,0	1,1	0,9	0,7	0,0
Moonpool (%)	14,6	11,4	5,3	4,8	5,2	7,6	6,8	3,5	5,4	2,2	3,5	2,0	3,0
Firefight (%)	24,4	20,0	29,3	33,3	38,5	38,0	40,9	41,2	43,5	45,7	44,7	47,6	48,9
ConvP. (%)	82,9	85,7	86,7	85,7	85,4	79,3	76,1	76,5	73,9	72,8	71,1	70,7	70,7
ROV (%)	19,5	17,1	13,3	11,9	9,4	10,9	6,8	7,1	7,6	6,5	7,9	8,8	9,8
Oil rec. (%)	17,1	18,6	20,0	17,9	18,8	20,7	25,0	23,5	27,2	22,8	17,5	16,3	15,8
NWE built (%)	63,4	68,6	62,7	63,1	63,5	65,2	68,2	62,4	63,0	62,0	59,6	58,5	56,4
PSV Large - Clear deck area > $900m^2$													
No. of obs.	91	129	161	214	260	272	298	333	342	384	453	455	214
No. vessels	23	37	41	54	66	74	79	91	98	109	125	136	119
No. in lay-up	1	0	0	0	3	0	1	0	0	7	39	69	59
Avg revenue	396	658	842	858	987	840	1 030	1 053	908	1 006	787	482	322
Avg age	5,3	5,7	5,7	6,1	6,3	6,4	6,2	5,2	5,1	5,9	6,4	8,0	8,8
Avg deck area	953	959	969	967	976	980	985	991	1 002	1 004	1 009	1 003	1 004
Avg bulkcap	1 870	1 852	2 073	2 157	2 288	2 420	2 503	2 701	2 658	2 642	2 624	2 477	2 452
Avg FEI	8,6	8,5	8,5	8,5	8,3	8,2	8,4	8,5	8,4	8,5	8,3	8,3	8,4
DP (%)	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	99,3	99,2
DP1 (%)	13,0	10,8	14,6	14,8	15,2	14,9	11,4	11,0	10,2	6,4	7,2	8,1	7,6
DP2 (%)	87,0	89,2	82,9	83,3	83,3	85,1	88,6	89,0	89,8	93,6	92,8	91,2	91,6
DP3 (%)	0,0	0,0	2,4	1,9	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ice-class (%)	4,3	8,1	12,2	20,4	24,2	27,0	29,1	34,1	33,7	34,9	31,2	28,7	30,3
Helideck (%)	0,0	0,0	2,4	0,0	1,5	1,4	1,3	0,0	0,0	0,0	0,8	0,7	0,8
Moonpool (%)	4,3	2,7	4,9	1,9	3,0	1,4	1,3	0,0	0,0	0,9	1,6	1,5	1,7
Firefight (%)	8,7	8,1	9,8	14,8	19,7	20,3	21,5	23,1	24,5	26,6	27,2	26,5	20,2
ConvP. (%)	47,8	48,6	43,9	38,9	34,8	36,5	31,6	22,0	21,4	19,3	21,6	25,0	23,5
ROV (%)	4,3	13,5	9,8	5,6	7,6	6,8	6,3	6,6	5,1	6,4	8,8	8,1	7,6
Oil rec. (%)	34,8	24,3	29,3	29,6	31,8	32,4	32,9	31,9	33,7	34,9	37,6	33,8	31,9
NWE built (%)	91,3	86,5	82,9	75,9	71,2	71,6	69,6	73,6	72,4	72,5	68,8	69,9	68,1

* Only includes 1st half of 2017

Table 3 - *North Sea AHTS fleet*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017*
AHTS - All													
No. of obs.	148	179	236	246	278	319	332	305	291	333	420	512	250
No. vessels	39	61	68	72	83	101	99	93	94	108	134	162	137
No. in lay-up	1	0	1	1	5	10	12	12	17	34	89	126	105
Avg revenue	318	497	577	864	634	510	877	847	1008	879	387	240	117
Min. revenue	0	6	8	0	0	0	0	0	0	0	0	0	0
Max revenue	674	1 435	4 190	2 340	4 126	2 700	3 568	3 608	3 568	3 568	3 568	3 608	1 112
Avg age	10,2	10,1	10,8	11,4	10,8	9,9	9,9	11,3	10,9	11,8	12,7	12,9	13,1
Min. age	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	1,5
Max. age	31,5	31,3	31,5	33,0	34,0	34,5	35,8	36,5	37,5	38,5	40,3	40,5	41,5
Avg. BHP	15 245	16 328	15 385	15 896	16 043	16 379	17 038	17 151	18 160	18 249	18 373	18 168	18 433
Min. BHP	4 000	6 120	6 000	6 000	6 000	6 000	6 000	6 000	6 000	5 150	5 150	5 150	6 000
Max. BHP	27 920	27 920	27 920	27 920	27 920	36 000	36 000	36 000	36 000	36 000	36 000	36 000	36 000
Avg.FEI	5,5	4,4	4,7	4,6	4,5	4,3	4,1	4,2	3,9	3,7	3,8	3,7	3,5
Min. FEI	1,4	1,5	1,5	1,5	1,5	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,3
Max. FEI	16,4	13,4	13,4	13,4	13,4	13,4	11,9	11,9	12,7	13,9	13,9	13,9	13,4
Avg Cons.	21,4	20,2	20,5	20	20,1	20,3	20,2	20,1	19,8	19,4	19,6	19,5	19,5
Avg Speed	14,7	15,1	15	15	15,2	15,5	15,6	15,7	15,6	15,6	15,6	15,6	15,6
Proportion of fleet (%)													
DP	74,4	77,0	75,0	73,6	77,1	78,2	80,8	79,6	83,0	83,3	82,8	84,0	86,1
DP1	23,1	14,8	19,1	16,7	13,3	11,9	14,1	12,9	9,6	14,8	10,4	10,5	11,7
DP2	51,3	62,3	55,9	56,9	63,9	66,3	66,7	66,7	73,4	68,5	72,4	73,5	74,5
DP3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Iceclass	48,7	47,5	41,2	44,4	43,4	41,6	43,4	45,2	51,1	50,9	50,7	44,4	44,5
Helideck	7,7	3,3	1,5	2,8	2,4	2,0	2,0	1,1	0,0	0,0	1,5	1,2	1,5
Moonpool	10,3	13,1	7,4	11,1	9,6	5,9	6,1	5,4	4,3	5,6	7,5	6,2	5,1
Firefight	59,0	42,6	51,5	41,7	45,8	49,5	47,5	41,9	40,4	46,3	47,8	48,8	48,2
Conv. Prop	94,9	96,7	94,1	93,1	90,4	84,2	81,8	79,6	76,6	79,6	81,3	82,7	83,9
ROV	12,8	11,5	7,4	11,1	9,6	8,9	11,1	9,7	9,6	10,2	9,7	8,0	8,8
Oilspill rec.	51,3	55,7	57,4	47,2	45,8	40,6	39,4	36,6	37,2	39,8	37,3	40,1	42,3
NWE built	71,8	73,8	76,5	72,2	71,1	67,3	59,6	62,4	61,7	60,2	60,4	59,9	58,4

* Only includes 1st half of 2017

Table 4 *- North Sea AHTS fleet, by size*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017*
AHTS Small - BHP < 16k													
No. of obs.	79	86	133	120	144	138	142	131	101	112	137	180	91
No. vessels	21	30	38	36	39	48	42	40	33	40	48	57	46
No. in lay-up	1	0	1	1	3	6	10	8	9	16	37	50	42
Avg revenue	158	295	503	604	430	345	371	461	428	350	198	87	72
Avg age	15,1	15,3	15	17	16,8	15,6	17,2	19,2	19,6	20,2	21,8	20,8	20,4
Avg BHP	10 641	11 970	11 803	11 266	11 270	11 287	10 919	10 795	11 014	11 459	11 165	11 864	12 235
Avg FEI	7,2	5,7	5,9	6,2	6,3	6,2	6,4	6,4	6,2	5,8	6,2	5,7	5,5
Proportion of fleet (%)													
DP	52,4	53,3	57,9	50	53,8	56,3	57,1	55	54,5	57,5	54,2	59,6	63
DP1	38,1	23,3	28,9	22,2	20,5	20,8	26,2	25	18,2	25	18,8	19,3	19,6
DP2	14,3	30	28,9	27,8	33,3	35,4	31	30	36,4	32,5	35,4	40,4	43,5
DP3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Iceclass	28,6	36,7	28,9	27,8	23,1	20,8	21,4	22,5	30,3	30	31,3	22,8	19,6
Helideck	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Moonpool	4,8	3,3	2,6	2,8	2,6	0,0	0,0	0,0	0,0	2,5	4,2	3,5	0,0
Firefight	81	53,3	57,9	44,4	51,3	60,4	61,9	55	54,5	52,5	62,5	57,9	60,9
Conv. Prop	95,2	93,3	94,7	94,4	92,3	93,8	92,9	97,5	97	95	97,9	96,5	95,7
ROV	0,0	3,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oilspill rec.	52,4	73,3	71,1	58,3	56,4	58,3	57,1	52,5	57,6	60	56,3	59,6	60,9
NWE built	66,7	76,7	71,1	69,4	66,7	70,8	66,7	72,5	69,7	65	66,7	64,9	60,9
AHTS Medium - 16k < BHP < 20k													
No. of obs.	31	49	63	67	69	74	76	84	90	104	118	147	75
No. vessels	8	15	19	19	23	26	27	26	30	33	35	50	43
No. in lay-up	0	0	0	0	2	4	2	4	6	11	26	38	31
Avg revenue	138	190	620	587	503	250	557	849	632	547	370	225	86
Avg age	6,1	6,5	5,8	6,4	6,3	6,2	6,2	7,4	9,1	9,3	9,3	10,4	10,6
Avg BHP	17 317	17 243	17 657	17 898	17 657	17 557	17 454	17 540	17 558	17 642	17 625	17 487	17 325
Avg FEI	3,8	3,5	3,3	3,2	3,1	3,2	3,2	3,1	3,0	2,8	3,0	3,0	2,9
Proportion of fleet (%)													
DP	100,0	100,0	94,7	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	98,0	100,0
DP1	0,0	13,3	10,5	21,1	13,0	7,7	11,1	7,7	10,0	15,2	11,4	10,0	14,0
DP2	100,0	86,7	84,2	78,9	87,0	92,3	88,9	92,3	90,0	84,8	88,6	88,0	86,0
DP3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Iceclass	62,5	53,3	47,4	47,4	52,2	50,0	59,3	61,5	63,3	63,6	57,1	48,0	53,5
Helideck	12,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Moonpool	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Firefight	37,5	46,7	57,9	57,9	65,2	65,4	63,0	53,8	60,0	69,7	77,1	70,0	69,8
Conv. Prop	100,0	100,0	94,7	94,7	95,7	92,3	96,3	96,2	93,3	97,0	100,0	98,0	100,0
ROV	25,0	6,7	5,3	5,3	4,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oilspill rec.	50,0	40,0	42,1	36,8	43,5	26,9	37,0	42,3	43,3	45,5	45,7	42,0	48,8
NWE built	75,0	66,7	84,2	78,9	82,6	61,5	51,9	53,8	53,3	45,5	42,9	42,0	44,2
AHTS Large - BHP > 20k													
No. of obs.	38	44	40	59	65	107	114	90	100	117	165	185	84
No. vessels	10	16	11	17	21	27	30	27	31	35	51	55	48
No. in lay-up	0	0	0	0	0	0	0	0	2	7	26	38	32
Avg revenue	206	214	646	669	1011	450	546	1305	1044	995	469	437	202
Avg age	3,2	3,9	5,1	5,1	4,4	3,2	2,9	3,3	3,3	4,7	6,5	7,0	8,3
Avg BHP	23 254	23 644	23 838	23 463	23 139	24 296	25 231	26 193	26 350	26 580	25 670	25 321	25 365
Avg FEI	3,2	2,7	2,8	2,7	2,6	1,9	1,9	1,8	2,2	2,1	2,1	2,1	2,2
Proportion of fleet (%)													
DP	100,0	100,0	100,0	94,1	95,2	96,3	96,7	96,3	96,8	97,1	98,0	96,4	95,8
DP1	10,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,9	2,0	1,8	2,1
DP2	90,0	100,0	100,0	94,1	95,2	96,3	96,7	96,3	96,8	94,3	96,1	94,5	93,8
DP3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Iceclass	80,0	62,5	72,7	76,5	71,4	70,4	60,0	63,0	61,3	62,9	64,7	63,6	60,4
Helideck	20,0	12,5	9,1	11,8	9,5	7,4	6,7	3,7	0,0	0,0	3,9	3,6	4,2
Moonpool	30,0	43,8	36,4	41,2	33,3	22,2	20,0	18,5	12,9	14,3	15,7	14,5	14,6
Firefight	30,0	18,8	18,2	17,6	14,3	14,8	13,3	11,1	6,5	17,1	13,7	20,0	16,7
Conv. Prop	90,0	100,0	90,9	88,2	81,0	59,3	53,3	37,0	38,7	45,7	52,9	54,5	58,3
ROV	30,0	31,3	36,4	41,2	33,3	33,3	36,7	33,3	29,0	31,4	25,5	23,6	25,0
Oilspill rec.	50,0	37,5	36,4	35,3	28,6	22,2	16,7	7,4	9,7	11,4	13,7	18,2	18,8
NWE built	80,0	75,0	81,8	70,6	66,7	66,7	56,7	55,6	61,3	68,6	66,7	70,9	68,8

* Only includes 1st half of 2017

5. Results and discussion

In this section, we will present and discuss the results from our regression models. The discussion is split into five sub-sections. First, we investigate the PSV market in the North Sea from 2005 until July 2017, both aggregated for all PSVs and in groups separated by size. We then proceed with an equivalent analysis of the AHTS segment, aggregated and split into three size segments by brake horsepower. Thereafter, we investigate how the importance of vessel specifications have changed after the oil price decline of 2014. Finally, we present our variance decomposition, quantifying how much of the variance in revenue is attributable to vessel specifications compared to our estimated market index proxy.

5.1 PSV regression results

The results from the PSV regression model are summarized in Table 5 below.

Table 5 *- PSV Regression model, by size*

	All PSV[4]	Clear deck area < 900m^2	Clear deck area > 900m^2
Age	15835,2**	10522,7	29119,8**
	(6626,0)	(8395,6)	(11566,2)
AgeSq	-821,0***	-490,9**	-2236,9***
	(222,8)	(229,5)	(503,8)
DeckArea	543,3***	23,16	542,8
	(196,8)	(310,3)	(526,5)
Bulkcap	45,30**	80,97***	17,11
	(21,22)	(30,07)	(29,22)
NWEbuilt	93084,5***	118332,1***	95282,7
	(36055,3)	(41112,2)	(68042,9)
FEI	10009,1	10264,1	-490,9
	(8588,1)	(8535,6)	(21776,6)
DP1	144462,8**	198736,6***	459446,0***
	(59681,6)	(63291,8)	(158294,7)
DP2	134697,3*	205255,9**	398710,3***
	(69475,0)	(81106,8)	(141157,5)
DP3	822386,2**	1342895,9***	809032,5***
	(342027,8)	(157098,9)	(220439,6)
ConvProp	-98822,1**	-48354,6	-86090,0
	(44285,2)	(49767,7)	(89947,0)
ROV	-16536,4	71028,9	-113108,3
	(77769,0)	(88979,0)	(137253,2)
Ice	51423,4	-27450,0	33639,0
	(48897,4)	(62033,4)	(65509,7)
Oilrec	9515,3	4938,5	-10116,5
	(39918,1)	(52318,4)	(61570,1)
Heli	-4690,0	52472,4	-27649,9
	(157312,2)	(112994,6)	(174197,4)
Moonp	-229348,3**	-229813,1**	-198956,9
	(92785,5)	(106212,4)	(145260,8)
Fifi	-139538,1***	-102986,0**	-161489,2**
	(37491,1)	(45793,7)	(73427,4)
No observ.	7527	3921	3606
R^2 within	0,21	0,22	0,24
R^2 between	0,38	0,42	0,26
R^2 overall	0,29	0,30	0,23

***, ** and * indicate significance at the 1%, 5% and 10% level, respectively
Robust standard errors in parenthesis

In accordance with our hypothesis, we find that vessel age, size and carrying capacity are significant determinants of PSV revenue, along with dynamic positioning systems and build

[4] A comparison of revenue sensitivity to the continuous variables in the model is available in appendix 1

region. Contrary to our expectations, we find no evidence to support that ROV-support and ice-classification affect revenue.

We find a non-linear relationship between vessel age and revenue for PSVs. The linear term positively affects vessel revenue, while the squared term is negative, indicating a turning point at which the effect of PSVs getting older turns from being positive to negative. This may be due to a perceived risk associated with contracting a vessel with no previous track record. Vessels might initially earn higher revenue as they age and gain operational experience, but the effect of aging will eventually turn negative as the vessel age gets high enough to adversely affect performance. Another possible explanation is that a vessel's delivery from yard is followed by a period without revenue as the vessel waits to commence its first contract. It is also possible that the large amount of vessels delivered just prior to the market for OSV deteriorated is contributing to the partially positive effect of aging.

The squared term indicates that the negative effect of aging increases exponentially after the turning point. This effect is therefore stronger for older vessels. As the squared term has higher significance for vessels above 900m^2, the effect seems to be stronger for the largest vessels.

Larger PSVs earn a revenue premium in the North Sea. Measured by clear deck area (m^2), the size of a vessel is positively related to revenue. Driven by an increase in size of offshore installations, demand has increased for PSVs with more clear deck area. The increasing proportion of PSV newbuild deliveries with clear deck above 900 m^2 reflects this development. In addition to servicing larger installations, large PSVs can carry more cargo per trip, thus economizing on scale and decreasing the unit transportation cost. Tasks carried out by larger vessels are also typically more complex in nature, and might help explain the observed revenue premium.

Closely related to deck area, PSV bulk capacity (m^3) is also subject to a revenue premium in the North Sea market. As for clear deck area, PSVs with higher bulk capacity can carry more cargo and benefit from economies of scale. The coefficients for clear deck area and bulk capacity are not significant for vessels above 900m^2. As the size variation within the 900+m^2 segment is smaller than in the below 900m^2 segment, we suggest this result is less robust, and that higher bulk capacity is a desirable feature also for the largest PSVs.

PSVs built at yards in Northwest Europe are also awarded a revenue premium in the North Sea freight market. OSVs are a technically complex shipbuilding segment that include a high degree of customization and cooperation with equipment manufacturers during the construction process. Premium PSVs of higher technical complexity have historically been built in Northwest Europe and North America (OECD, 2015). Larger PSVs tend to require yards with a higher level of technical capability, usually associated with yards in Northwest Europe, which are commonly perceived to deliver higher quality.

Contrary to our hypothesis, we find no significant revenue premium for Northwest Europe-built vessels in the above $900m^2$ segment, in which many vessels are recently delivered. Asian yards offering a lower cost package are increasing their market share in the PSV shipbuilding segment (OECD, 2015). This is in line with the decreasing proportion of Northwest Europe-built PSVs above $900m^2$ deck area trading in the North Sea market.

Having a dynamic positioning system is rewarded for PSVs. The effect is observable for all size segments. Dynamic positioning seems to be an important requirement for North Sea operations, and practically all active PSVs in the North Sea have a DP system. More advanced systems are preferred, with a significant premium awarded to the few PSVs with a more advanced DP class III system.

In line with our a priori expectations, conventional propulsion systems are associated with a revenue discount, suggesting a preference for more modern diesel electric or hybrid propulsion systems in the PSV segment.

5.2 AHTS regression results

The results from the AHTS regression model are summarized in Table 6 below.

Table 6 *- AHTS regression results, by size*

	All AHTS[5]	**BHP < 16k**	**16k < BHP < 20k**	**BHP > 20k**
Age	12041,8*	26104,2***	-3798,6	95711,7***
	(6402,6)	(8196,3)	(21910,4)	(31377,0)
AgeSq	-395,7**	-589,0***	-381,8	-5544,7***
	(165,2)	(186,8)	(858,9)	(1670,1)
BHP	33,22***	21,80	115,5**	25,59
	(7,500)	(20,41)	(56,33)	(19,48)
NWEbuilt	-32696,9	-31607,8	-37595,3	-11782,2
	(55762,7)	(74220,6)	(108791,4)	(116252,7)
FEI	47959,4***	48756,0***	154373,9**	3051,8
	(12928,6)	(15873,2)	(76636,1)	(15442,2)
ConvProp	-283733,1***	-98894,7	-351631,5	-352509,9**
	(105436,3)	(116390,4)	(247708,1)	(175785,3)
DP1	-37677,3	105067,0	-33880,1	-291311,8
	(87750,7)	(102882,7)	(141432,2)	(335017,4)
DP2	-23232,5	146524,8	-57386,7	-22785,0
	(88142,7)	(112991,3)	(110534,0)	(315117,9)
ROV	227725,6*	-397755,5***	-641940,7***	310305,0**
	(130769,0)	(97485,2)	(154852,6)	(138759,8)
Ice	118630,7**	18716,8	261901,1**	-14844,0
	(59638,5)	(78669,2)	(101851,8)	(134428,7)
Oilrec	160504,5***	140879,3**	335059,7***	50593,8
	(54400,3)	(63666,9)	(98554,7)	(126147,4)
Heli	-237704,9	0	-11199,9	10127,5
	(330164,7)	(,)	(174047,8)	(441405,1)
Moonp	87170,0	-353827,8***	0	68977,0
	(212090,5)	(104696,6)	(,)	(304953,2)
Fifi	-487,3	-31175,9	-16072,5	191064,5
	(61045,2)	(63858,1)	(114165,8)	(158160,5)
No observ.	3849	1594	1047	1208
R^2 within	0,19	0,20	0,22	0,33
R^2 between	0,39	0,31	0,44	0,44
R^2 overall	0,28	0,23	0,36	0,39

***, ** and * indicate significance at the 1%, 5% and 10% level, respectively
Robust standard errors in parenthesis

In line with our hypothesis, vessel age, engine power, fuel-efficiency, propulsion system and ROV-support are significant determinants of AHTS revenue. Contrary to our expectations, we find no evidence that being built in Northwest Europe or having dynamic positioning systems affect revenue.

[5] A comparison of revenue sensitivity to the continuous variables in the model is available in appendix 1

Equivalent to our findings for PSVs, we find a non-linear effect of age on vessel revenue for AHTS vessels. This effect is however absent for the medium sized AHTS vessels.

More powerful AHTS vessels earn a revenue premium in the North Sea. Measured by brake horsepower (BHP), the engine power of a vessel is positively related to vessel revenue. As the size of offshore installations has increased, so has the demand for AHTS vessels with higher BHP. Smaller vessels with lower BHP are often not powerful enough to support larger installations, and face increased competition from PSVs (Clarksons Platou Project Finance, 2016). In predominantly mid- and deepwater regions such as the North Sea, powerful AHTS vessels usually service conventionally moored floating offshore installations, such as semi-submersible drilling rigs. For prevalent tasks, such as rig moves, employing vessels with higher BHP can reduce the number of vessels needed to complete a given task, thus making powerful vessels more attractive to contractors.

Contrary to findings from the PSV segment, we find no evidence of a revenue premium for AHTS vessels built in Northwest Europe. This is the case for all three AHTS size segments. Thus, there is nothing to suggest that AHTS vessels built in Northwest Europe are perceived to be of higher quality. As in the PSV segment, AHTS shipbuilding has gradually shifted towards Asian yards in line with the observed decreasing proportion of Northwest Europe-built AHTS vessels in our sample. It would seem that Asian yards have successfully closed the gap between their European competitors, and that charterers are not willing to pay a premium for AHTS vessels built in Northwest Europe.

In accordance with Adland et al. (2017b), we find that fuel-efficiency is not rewarded, and in some cases penalized in the North Sea AHTS freight market. A somewhat unintuitive result as more fuel-efficient vessels could be expected to earn a premium as charterers carry the bunker costs and lower emissions is a positive side effect. However, the timeliness and security of OSV services is extremely important to charterers, and any delays could have severe financial consequences (Adland, 2017b). Fuel-efficient vessels may be unable to maintain high speeds during adverse weather conditions, and thus be more prone to delays compared to less efficient vessels.

Charterers of large AHTS vessels disfavor conventional propulsion systems, suggesting that alternatives such as more modern diesel electric or hybrid systems are preferred. This effect is observable for the largest vessel segment, where the adverse effect of fuel-efficiency is not significant. This makes sense, as modern propulsion systems are expected to be more fuel-efficient. The above 20k BHP vessel segment also has the lowest proportion of conventionally propelled vessels.

Our results suggest that having a DP system does not affect revenue for AHTS vessels in any of the size segments. Most likely, this outcome can be attributed to limited variation in our data, as the vast majority of AHTS have a DP class II system. There are no observations of AHTS vessels with a DP class III system.

Large AHTS vessels that have ROV-support capabilities earn a revenue premium, while this specification is associated with a discount for small and medium sized vessels. We suggest this is due to larger and more sophisticated vessels being better suited for complex subsea operations where ROV-support is needed. Similarly, having a moonpool is associated with a revenue discount for the smallest AHTS vessels. Larger, more complex vessels may be needed to make use of the opportunities afforded by a moonpool, such as deployment of subsea equipment, ROVs and divers. Small and medium sized AHTS vessels might be more suited for rescue and recovery work than the larger vessels, and are rewarded for oil-spill recovery capabilities.

5.3 PSV market condition comparison

The results from the PSV market condition comparison are summarized in Table 7 below.

Table 7 *– PSV regression results, by market condition*

	2005 – Q2 2017	2005 – Q3 2014	Q4 2014 – Q2 2017
Age	15835,2**	41512,8***	-8586,0
	(6626,0)	(7225,6)	(11761,8)
AgeSq	-821,0***	-1707,9***	-101,2
	(222,8)	(245,7)	(347,7)
DeckArea	543,3***	535,1**	370,7
	(196,8)	(213,0)	(255,8)
Bulkcap	45,30**	78,83***	50,10*
	(21,22)	(22,69)	(27,77)
NWEbuilt	93084,5***	82232,9**	146116,9***
	(36055,3)	(40202,3)	(56144,0)
FEI	10009,1	18801,1**	18174,4
	(8588,1)	(9586,8)	(14384,7)
DP1	144462,8**	158103,2**	110431,7
	(59681,6)	(71935,8)	(95762,7)
DP2	134697,3*	165044,7*	66674,5
	(69475,0)	(88033,2)	(72394,8)
DP3	822386,2**	797635,2**	0
	(342027,8)	(364744,3)	(,)
ConvProp	-98822,1**	-80606,9	-176791,4***
	(44285,2)	(50220,4)	(62311,1)
ROV	-16536,4	43461,4	-188762,9**
	(77769,0)	(85611,8)	(94043,4)
Ice	51423,4	129005,1**	-69945,8
	(48897,4)	(58737,4)	(62589,8)
Oilrec	9515,3	32254,5	-26490,5
	(39918,1)	(41174,7)	(63971,3)
Heli	-4690,0	386669,5***	-373774,3***
	(157312,2)	(85684,3)	(68103,0)
Moonp	-229348,3**	-299969,3***	-123235,6
	(92785,5)	(100103,4)	(87111,6)
Fifi	-139538,1***	-128605,6***	-172943,2***
	(37491,1)	(42919,0)	(56355,8)
No observ.	7527	5089	2438
R^2 within	0,21	0,07	0,19
R^2 between	0,38	0,28	0,29
R^2 overall	0,29	0,20	0,26

***, ** and * indicate significance at the 1%, 5% and 10% level, respectively
Robust standard errors in parenthesis

Contrary to our hypothesis, most variables do not increase in significance after the oil price decline. The expected effect is limited to build region and conventional propulsion along with fire-fighting capabilities. We argue that this result is largely attributable to limited variation, and fewer observations in the post 2014 subsample.

The preference for vessels built in Northwest Europe is significant at an even higher level after the crash. Although a lower proportion of the North Sea fleet is built in Northwest Europe during recent years, the perceived quality premium is of higher importance during the weak market condition. This is in line with our a priori expectations, and we suggest this is due to increased competition. Faced with greater choice, charterers emphasize vessel quality, and choose to employ vessels of perceived higher quality. We suggest that stronger competition may also explain the preference for diesel electric or hybrid propulsion systems being stronger after the oil price decline.

In the period preceding the oil price decline, ice-classification is rewarded in both the PSV and AHTS markets. After the oil price decline however, there is no longer a revenue premium for ice-classed vessels. Due to lower oil prices, activity in harsh environment arctic areas might not be economically feasible. Thus, the demand for ice-classed vessels, which may be heavier and have reduced carrying capacity due to their reinforced hulls, is reduced.

Our results further suggest that vessel age’s effect on vessel revenue is not statistically significant in the period following the oil price decline. We present two main reasons for this. First, fewer contracts have been awarded after the market downturn. Vessels fixed on contracts before the market softened may keep working at favorable terms, while recently delivered vessels are unable to win contracts. Moreover, new contract awards may be at significantly less favorable terms. Second, the many vessels delivered during the period leading up to the downturn, could be perceived as lacking necessary operational experience, and thus generate lower revenues.

The results also indicate that deck area no longer significantly affects revenue during the recent weak market. However, the PSV fleet has grown, and become more homogenously large over time, thus reducing the size variation for PSVs towards the end of our sample. Based on this reasoning, we argue that this result is less robust, and that the positive relation between size and revenue should still hold after Q3 2014. This is supported by the second variable for PSV carrying capacity, bulk capacity, remaining significant after the oil price decline.

DP I and DP II are no longer significant determinants of revenue in the recent weak market. Similar to the reasoning for clear deck area, we suggest this is due to less variation in the fleet, as a larger proportion of vessels has dynamic positioning systems after the market downturn. None of the PSVs active in the North Sea after Q3 2014 have DP III systems.

During the recent weak markets, we find that ROV-support functions negatively affect PSV revenue. This suggests that ROV-support is an unattractive feature for PSVs, although a slightly larger proportion of the PSV fleet has this specification in recent years.

5.4 AHTS market condition comparison

The results from the AHTS market condition comparison are summarized in Table 8 below.

Table 8 *- AHTS regression results, by market condition*

	2005 – Q2 2017	**2005 – Q3 2014**	**Q4 2014 – Q2 2017**
Age	12041,8*	29768,3***	-15723,4
	(6402,6)	(10302,7)	(10206,2)
AgeSq	-395,7**	-1023,1***	263,5
	(165,2)	(302,4)	(254,4)
BHP	33,22***	45,39***	9,869
	(7,500)	(10,52)	(7,076)
NWEbuilt	-32696,9	-19629,5	13133,2
	(55762,7)	(69379,6)	(52121,0)
FEI	47959,4***	60474,6***	25934,7**
	(12928,6)	(18444,6)	(12679,7)
ConvProp	-283733,1***	-344528,8***	-215779,8*
	(105436,3)	(115711,2)	(120616,1)
DPI	-37677,3	-143977,5	66911,6
	(87750,7)	(106931,9)	(101587,9)
DPII	-23232,5	-73539,6	1762,2
	(88142,7)	(113743,7)	(85901,6)
ROV	227725,6*	205074,0	238883,1*
	(130769,0)	(151115,4)	(127677,4)
Ice	118630,7**	146811,3**	95845,8
	(59638,5)	(72551,5)	(64129,1)
Oilrec	160504,5***	204310,1***	60997,7
	(54400,3)	(73599,1)	(49986,6)
Heli	-237704,9	-122809,2	-597078,2*
	(330164,7)	(397228,9)	(312597,4)
Moonp	87170,0	68465,5	200993,3
	(212090,5)	(236161,3)	(259377,7)
Fifi	-487,3	10524,5	-49560,8
	(61045,2)	(79189,4)	(61303,3)
No observ.	3849	2630	1219
R^2 within	0,19	0,12	0,15
R^2 between	0,39	0,35	0,31
R^2 overall	0,28	0,24	0,24

***, ** and * indicate significance at the 1%, 5% and 10% level, respectively
Robust standard errors in parenthesis

Somewhat surprisingly, ROV-support and helideck are the only variables that develop in line with our expectation and increase in significance after the oil price decline. Consistent with the results from the PSV segment, age is no longer significant in the recent weak market, and we argue that the same reasoning applies for AHTS vessels.

Furthermore, we find that BHP no longer significantly affects revenue in the recent weak market. As for clear deck area in the PSV segment, we suggest supply side development as a possible explanation. The AHTS fleet has grown more homogenously powerful over the course of our sample, thus reducing the variation in the subsample following the decline in oil prices. We therefore suggest that this result is less robust, and that BHP is still a significant determinant of revenue also in the soft market.

In contrast to the PSV market, vessels with ROV-support functions earn a revenue premium in the AHTS market after the oil price decline. As E&P companies have reduced their exploration budgets, focus on brown-field development and improved recovery from existing fields has increased. Maintenance of existing subsea infrastructure that requires ROV-support services may therefore have increased in demand. This result further suggests that AHTS vessels are better suited than PSVs to perform ROV-support functions.

In line with our findings from the PSV segment, the presence of a helideck negatively affects revenue, while ice-classification is no longer rewarded for AHTS vessels during the recent weak market.

5.5 Variance decomposition

A summary of the decomposed revenue variance is presented in Table 9 below.

Table 9 *– Total variance of revenue decomposed, from models with all periods and vessels included.*

	PSV model		**AHTS model**	
	Value	Proportion	Value	Proportion
Variance (vessel)	4,9E+10	12 %	6,7E+10	11 %
Variance (market)	9,2E+10	22 %	7,6E+10	13 %
Variance (residual)	2,7E+11	65 %	4,2E+11	72 %
Covariance	9,1E+08	0 %	2,1E+10	4 %
Total variance	**4,1E+11**	**100 %**	**5,8E+11**	**100 %**

We find that a larger proportion of the variance in revenue is attributable to the variance in our estimated market index proxy compared to vessel specifications. This is in accordance with our expectations and previous research, and the market condition seems to be of higher importance than vessel specifics in determining the revenue of individual vessels.

As shown in Table 9, 12 % and 11 % of the variance in revenue can be attributed to vessel-specifics, for PSVs and AHTS respectively. By comparison, the contribution of the general market condition is higher, particularly for PSVs, where 22 % of the variance can be attributed to the market index proxy. The proportion of variance attributable to the residual is expectedly large, given the explanatory power of our models.

6. Concluding remarks

This thesis attempts to explain how vessel specifications affect OSV revenue in the North Sea. While previous literature has focused either on utilization or freight rates, we argue that our findings are more valuable to shipowners, as vessel revenue is what matters for their bottom line.

In line with our expectations and previous research, we find that larger and more powerful OSVs have higher revenue. In general, younger vessels are preferred, although aging has a positive impact on revenue until a certain point, likely due to charterers' willingness to pay for operational experience. Dynamic positioning appears to be important for PSVs, while ROV-support, oil-recovery, ice-class, non-conventional propulsion and fuel inefficiency is valued for AHTS vessels. For PSVs we find that vessels built in Northwest Europe have significantly higher revenue, while no such preference is found in the AHTS segment. Through variance decomposition, we find that vessel specifications contribute 12 and 11 % of the total variance in revenue, for PSVs and AHTS vessels respectively.

Moreover, we find that preferences have changed after the drop in oil prices during the second half of 2014. Age is found to no longer have a significant effect on revenue. However, we suggest this is due to the large amount of vessels built during the years before the market downturn, and their difficulty in winning contracts at competitive terms compared to those awarded before the market softened. Ice-class capabilities have gone from being a valued specification to having no significant effect after Q3 2014. Less E&P activity in hard-to-reach areas is a possible explanation. The preference for diesel electric or hybrid propulsion is persistent for AHTS vessels, and also becomes significant for the PSV segment after the downturn. ROV-support has been rewarded for AHTS vessels, but penalized in the PSV segment during the recent weak market.

Our analysis is almost entirely based on data from a single source. We have therefore not been able to crosscheck fixture details and vessel specifications with other sources. Moreover, our regression models may suffer from an omitted variable bias. As Adland et al (2016) find, characteristics of owners, charterers and the combination of the two, have significant impact on bulk freight rates. This may also be the case for the North Sea OSV market. Important operational decisions, such as the lay-up decision, may be affected by characteristics like firms size and capital structure (Sværen, 2017). Aas et al (2009) find that loading and unloading capabilities are among the main features of a PSV. These capabilities are only partly controlled for in our regression models. Furthermore, we do not disentangle the effects of utilization and dayrates on revenue, which would have provided additional depth to our analysis. More observations following the oil price decline would also have been advantageous, increasing the robustness of our estimates during the recent weak market. Lastly, we acknowledge that only parts of the variance in revenue can be attributed to the variables included in our models.

We believe our thesis can serve as a basis for further research on OSV markets, with a more commercial perspective studying revenue instead of utilization or dayrates. A similar analysis can be done for other geographical areas, or other shipping markets where specifications are expected to affect vessel revenue. Our analysis can also be extended by investigating vessel-specific determinants of revenue while simulating future supply and demand. For further commercialization of similar analyses, one can take operational expenses into account, to study determinants of operational profit. Furthermore, investigating how time spent in lay-up might affect the commercial attractiveness of OSVs could be an interesting point of study.

7. References

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

Adland, R., Alger, H., Banyte, J., & Jia, H. (2017). Does fuel efficiency pay? Empirical evidence from the drybulk timecharter market revisited. *Transportation Research Part A: Policy and Practice, vol 95*, 1-12.

Adland, R., Cariou, P., & Wolff, F.-C. (2016). The influence of charterers and owners on bulk shipping freight rates. *Transportation Research Part E: Logistics and Transportation Review, vol 86*, 69-82.

Adland, R., Cariou, P., & Wolff, F.-C. (2017). Energy efficiency and freight rates: The case of Offshore Support Vessels. *Working paper (NHH - Norwegian School of Economics).*

Adland, R., Cariou, P., & Wolff, F.-C. (2017). What makes a freight market index? An empirical analysis of vessel fixtures in the offshore market. *Transportation Research Part E: Logistics and Transportation Review, vol 104*, 150-164.

Agnolucci, P., Smith, T., & Rehmatulla, N. (2014). Energy efficiency and time charter rates: Energy efficiency savings recovered by ship owners in the Panamax market. *Transportation Research Part A: Policy and Practice, vol 66*, 173-184.

Alizadeh, A., Strandenes, S., & Thanopoulou, H. (2016). Capacity retirement in the dry bulk market: A vessel based logit model. *Transportation Research Part E: Logistics and Transportation Review*.

Allison, P. (2009). Missing Data (Quantitative Applications in the Social Sciences). *SAGE Publications Inc.*

Clarkson World Fleet Register. (2017). Retrieved from Clarkson Research Services Ltd: https://www.clarksons.net/wfr2/

Clarksons Platou Project Finance. (2016, 12 31). Retrieved from Clarksons Platou: https://www.clarksons.com/media/1092044/CPPF%20Market%20Report%202016%20ny.pdf

Clarksons Research. (2015, 09 22). Retrieved from Clarksons Research: https://clarksonsresearch.wordpress.com/category/ahts/

Dahle, A., & Kvalsvik, D. (2016). Freight rate determinants in the offshore market : does energy efficiency pay? *Master thesis*.

Døsen, H., & Langeland, J. (2015). Offshore freight rate determinants - A study of PSV term charter freight rates from 2004-2015. *Master thesis*.

Grøvdal, L., & Tomren, M. (2016). The lay-up decision in practice : how offshore supply shipowners respond to lower demand. *Master thesis*.

Haiying, J. (2017). Do oil buyers make green transportation choices? *Working paper (NHH - Norwegian School of Economics).*

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

Heitjan, D., & Little, R. (1991). Multiple imputation for the fatal accident reporting system. *Journal of the Royal Statistical Society: Series C (Applied Statistics), vol 40*, 13-29.

Köhn, S., & Thanopoulou, H. (2011). A gam assessment of quality premia in the drybulk time-charter market. *Transportation Research Part E: Logistics and Transportation Review, vol 47*, 709-721.

Liu, M., Taylor, J., & Belin, T. (2000). Multiple Imputation and Posterior Simulation for Multivariate Missing Data in Longitudinal Studies. *Biometrics, vol 56*, 1157-1163.

Maisiuk, Y., & Gribkovskaia, I. (2014). Fleet Sizing for Offshore Supply Vessels with Stochastic Sailing and Service Times. *Procedia Computer Science, vol 31*, 939-948.

Marine Money Offshore. (2017). Retrieved 12 11, 2017, from Marine Money Group: https://www.marinemoneyoffshore.com/node/4011

OECD. (2015, 12 01). *OECD Coucil Working Group on Shipbuilding*. Retrieved from OECD Coucil Working Group on Shipbuilding: http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=c/wp6%282014%2913/final&doclanguage=en

Ringlund, G., Rosendahl, K., & Skerpen, T. (2008). Does oilrig activity react to oil price changes: An empirical investigation. *Energy Economics, vol 30*, 371-396.

Schafer, J., & Schenker, N. (2000). Inference with imputed conditional means. *Journal of the American Statistical Association, vol 95*, 144-154.

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

Sværen, O. (2017). Determinants in the Lay-Up Decision: An empirical study on offshore support vessels. *Master thesis*.

Tamvakis, M., & Thanopoulou, H. (2000). Does quality pay? The case of the dry bulk market. *Transportation Research Part E: Logistics and Transportation Review, vol 36*, 297-307.

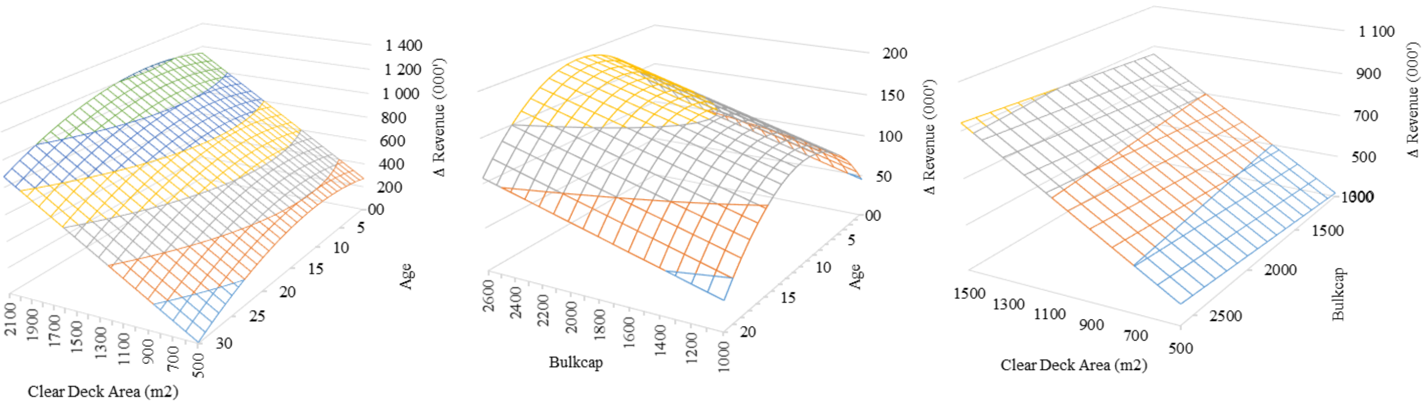
Tvedte, M., & Sterud, A. (2016). Obtaining contracts in the North Sea OSV market. *Master thesis*.

Verbeek, M. (2004). *A Guide to Modern Econometrics* (2nd ed.). John Wiley & Sons, Ltd.

Appendix

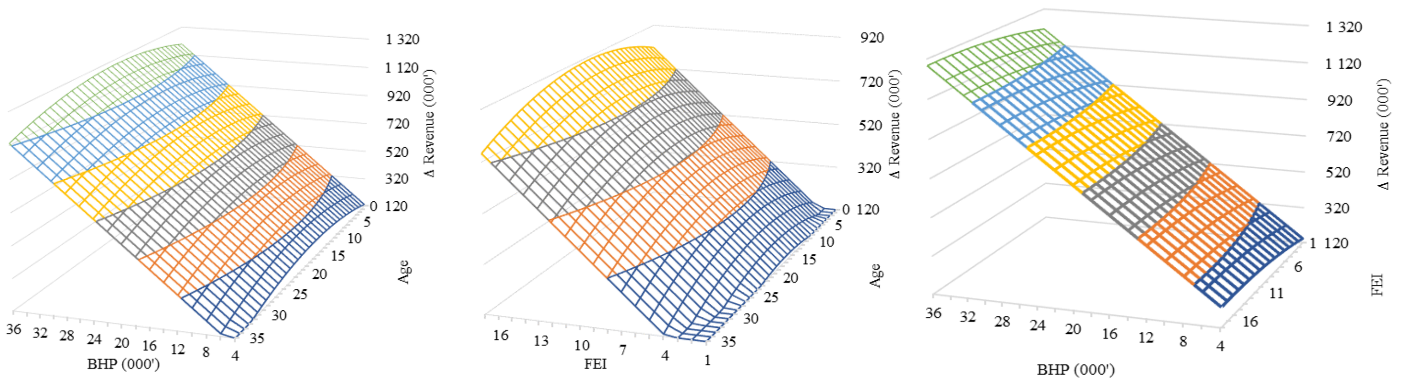
Appendix 1

Figure A1 *- PSV revenue sensitivity to Clear deck area, Bulk capacity and Age. Based on model including all PSVs*



Comment: The incremental revenue associated with larger deck area is higher than the effects from age and bulk capacity

Figure A2 *– AHTS revenue sensitivity to BHP, FEI and Age. Based on model including all AHTS vessels*



Comment: The incremental revenue associated with higher BHP is higher than the effects from fuel-efficiency and age

Appendix 2

Table A1 *– PSV correlation matrix*

PSV	Age	AgeSq	Deck Area	Bulk-cap	NWE built	FEI	DP1	DP2	DP3	Conv Prop	ROV	Oilrec	Ice	Heli	Moonp	Fifi
Age	1,00															
AgeSq	0,95	1,00														
DeckArea	-0,38	-0,37	1,00													
Bulkcap	-0,27	-0,29	0,37	1,00												
NWEbuilt	0,21	0,20	0,16	-0,06	1,00											
FEI	0,39	0,44	-0,63	-0,31	-0,09	1,00										
DP1	0,20	0,12	-0,21	-0,06	-0,06	-0,01	1,00									
DP2	-0,57	-0,54	0,46	0,23	0,00	-0,35	-0,71	1,00								
DP3	-0,02	-0,03	0,01	0,05	0,06	0,04	-0,03	-0,12	1,00							
ConvProp	0,35	0,30	-0,49	-0,25	-0,08	0,14	0,19	-0,28	-0,07	1,00						
ROV	-0,04	-0,07	0,00	0,01	-0,03	0,00	-0,12	0,12	0,20	-0,05	1,00					
Oilrec	-0,11	-0,10	0,15	0,18	-0,03	-0,06	-0,12	0,15	0,12	-0,12	-0,02	1,00				
Ice	-0,23	-0,18	0,32	0,16	0,13	-0,18	-0,08	0,15	-0,03	-0,21	-0,04	0,08	1,00			
Heli	0,06	0,07	0,03	-0,06	0,07	0,01	-0,04	-0,02	-0,01	-0,03	0,06	-0,05	0,03	1,00		
Moonp	0,00	-0,02	-0,08	0,00	0,01	0,07	-0,05	0,04	0,34	0,00	0,41	0,02	-0,07	0,13	1,00	
Fifi	-0,26	-0,20	-0,14	0,15	-0,26	0,05	-0,08	0,12	-0,05	-0,03	-0,10	0,21	0,07	0,05	-0,11	1,00

Table A2 *– AHTS correlation matrix*

AHTS	Age	AgeSq	BHP	NWE-built	FEI	Conv Prop	DP1	DP2	ROV	Oilrec	Ice	Heli	Moonp	Fifi
Age	1,00													
AgeSq	0,96	1,00												
BHP	-0,56	-0,54	1,00											
NWEbuilt	0,26	0,24	0,09	1,00										
FEI	0,52	0,55	-0,73	-0,04	1,00									
ConvProp	0,23	0,19	-0,46	-0,08	0,25	1,00								
DPI	0,13	0,09	-0,21	-0,04	0,15	0,01	1,00							
DPII	-0,60	-0,61	0,59	-0,05	-0,56	-0,13	-0,55	1,00						
ROV	-0,13	-0,13	0,40	0,12	-0,20	-0,14	-0,12	0,19	1,00					
Oilrec	0,23	0,17	-0,23	0,18	0,04	0,16	0,20	-0,16	-0,06	1,00				
Ice	-0,05	-0,07	0,17	0,13	-0,17	-0,13	-0,03	0,13	0,14	0,03	1,00			
Heli	-0,05	-0,04	0,18	0,04	-0,08	-0,04	-0,05	0,09	0,43	0,03	0,09	1,00		
Moonp	-0,06	-0,08	0,34	0,02	-0,17	0,00	-0,10	0,18	0,44	-0,10	-0,03	0,38	1,00	
Fifi	0,00	0,02	-0,29	0,03	0,14	0,16	0,19	-0,08	-0,22	0,27	-0,14	-0,07	-0,18	1,00

Appendix 3

Variance inflation factors (VIF)

Table A3 *– PSV VIF*

Variable	**VIF**	**1/VIF**
Age	2,40	0,42
Deckarea	3,10	0,32
Bulkcap	1,43	0,70
NWEbuilt	1,16	0,86
FEI	2,29	0,44
ConvProp	1,72	0,58
DP1	3,01	0,33
DP2	4,72	0,21
DP3	1,44	0,69
ROV	1,29	0,78
Oilrec	1,16	0,86
Ice	1,21	0,83
Heli	1,09	0,92
Moonp	1,54	0,65
Fifi	1,31	0,76
Mean VIF	**1,92**	

Table A4 *– AHTS VIF*

Variable	**VIF**	**1/VIF**
Age	2,93	0,34
BHP	4,56	0,22
NWEbuilt	1,33	0,75
FEI	2,74	0,36
ConvProp	1,57	0,64
DP1	1,93	0,52
DP2	4,06	0,25
ROV	1,56	0,64
Oilrec	1,47	0,68
Ice	1,21	0,83
Heli	1,30	0,77
Moonp	1,62	0,62
Fifi	1,49	0,67
Mean VIF	**2,14**	