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Determinants in the Lay-Up Decision

An empirical study on offshore support vessels

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Abstract

When a downturn hits the cyclical offshore service industry, shipowners attempt to improve their cash flow and the market balance by laying up vessels. The purpose of this master thesis is to evaluate how micro- and macro-level determinants affect the lay-up decision for platform supply vessels (PSV) and anchor handling tug supply vessels (AHTS) in the North Sea. This is done by investigating how vessel characteristics such as age, size, and technical specifications, along with market variables including the oil price, spot rates, and utilisation ratio, affect the probability of a vessel to be laid up and to stay in lay-up. For this analysis, panel logistic regressions and Cox proportional hazard models are specified.

The results indicate that the market condition is the most important determinant in the lay-up decision for both PSVs and AHTS vessels. The lay-up probability for a vessel increases when spot day rates, the oil price, and the share of vessels that is chartered (utilisation) are lowered. However, some vessel characteristics also have a significant effect, most evidently for PSVs.

In line with my expectations, older, smaller and less fuel efficient PSVs have a higher probability of being laid-up. For AHTSs, old vessels also seem to have a higher lay-up probability. Regarding size, the lay-up probability appears to be at the highest for vessels with around 20,000 brake horsepower, and then decrease for more powerful vessels. Other technical specifications, does not appear to substantially affect the lay-up decision on an aggregated level, for neither PSVs nor AHTSs.

This thesis contributes to the limited research on offshore support vessels (OSV) in general, and specifically the lay-up decision. Most of the previous OSV studies concern rate formation and vessel routing, while the lay-up decision mainly has been studied for shipping in general and ignoring vessel-specific factors. The research in this thesis can also be of interest to market participants, investors and analysts to predict which vessels are most likely to be laid up.

Preface

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

The shipping industry and its market dynamics is an interesting topic, and the recent downturn in the market for offshore support vessels provided an opportunity to study the lay-up decision in detail. Working with this thesis has been challenging, but rewarding. It has been exciting to explore the North Sea offshore industry in depth, and it will be interesting to see the development in the market the coming years.

I would like to thank my supervisor, Roar Os Ådland, for valuable discussions, guidelines and constructive feedback in the research process. Also, I would like to thank Ulstein International and Clarksons Platou Offshore Research for access to detailed datasets that have been the basis for the analyses conducted in this study.

I hope that this thesis will prove interesting for its readers, that my work is of relevance for market participants in the North Sea offshore industry and that it can be inspirational for further research on the offshore service industry and the lay-up decision.

Bergen, May 2016

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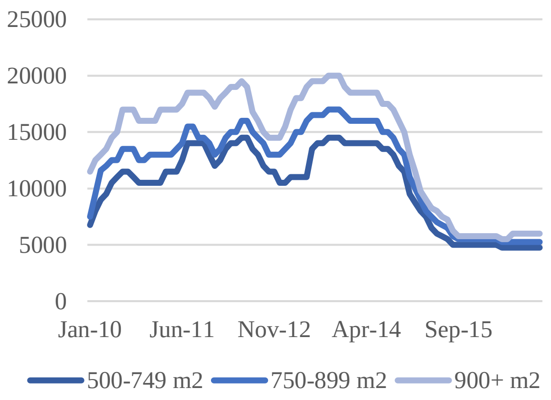
1. Introduction

Shipping markets are in their nature volatile and cyclical, and the offshore support vessel (OSV) industry in the North Sea has proved to be no exception. In times with low rates and utilisation, shipowners attempt to improve their cashflow and the market balance by reducing their capacity. The capacity reduction mainly takes three forms: 1) In the short term, a usual way is speed reductions, 2) in the medium-term, firms traditionally place vessels in lay-up and 3) in the long-term, firms resort to scrapping of vessels (Alizadeh, Strandenes, & Thanopoulou, 2016). Speed reduction is not relevant for OSVs as obligations to customers usually are time sensitive, and scrapping is often considered uneconomical due to the low steel value in OSVs. Consequently, the most used alternative in the North Sea is to lay up vessels, in other words, take vessels out of service and reduce their crew to a minimum. In a challenging market situation, when to lay up vessels and which vessels to choose are key decisions.

There is limited existing research on the lay-up decision in general, and specifically for OSVs. Most previous research on lay-up concerns other types of shipping and treats the vessels as homogeneous, only considering the market condition as a determinant. The lay-up decision may also be influenced by technical specifications and the state of the vessel in question, as shipowners most likely would prefer to keep vessels with potential to earn high day rates and cost-efficient vessels in the market. The challenging market situation (see Figure 1) arising from the drop in the oil price in 2014, the resulting reduced offshore activity, and oversupply in the OSV market allows for an empirical assessment of the lay-up decision, examining how different factors influence the decision.



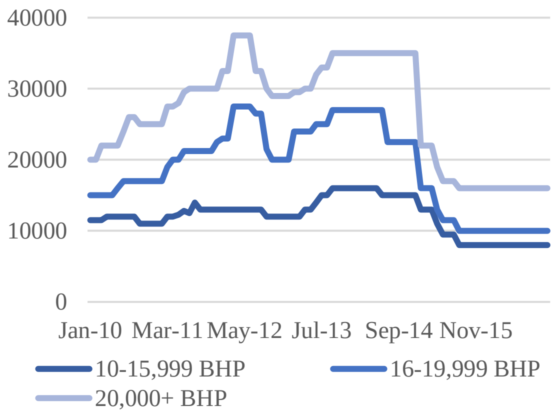


Figure 1 Monthly average of term day rates for different size segments for PSVs and AHTSs, GBP/day

Considering the above, this thesis will contribute to the limited research on this topic by evaluating which micro- and macro-level determinants that affect, and how they affect, the probability of lay-up for offshore support vessels. The aim is to increase the insight into how the lay-up decision is taken in this industry. Market participants, investors, and analysts may also use the findings from the research, to predict which vessels are most likely to be laid up. In a challenging and competitive environment, such as the North Sea OSV industry, knowledge about how market conditions affect shipowners, and the individual vessels are of vital importance.

The study will be limited to PSVs and AHTSs operating in The North Sea, and will only consider the decision to put vessel in “cold” lay-up. Vessels in cold lay-up are taken out of service, and are anchored with minimum crew and energy use, whereas vessels in “hot” lay-up can be reactivated at a short notice and a low cost. PSVs are designed to supply offshore installation with cargo such as drilling mud, fuel, and drinking water, whereas AHTS vessel’s primary tasks are to tow oil rigs to new locations and re-anchor them (Norwegian Shipowners' Association, 2014).

To achieve the objective of this study, I have addressed the research problem with a deductive and quantitative approach. Previous theoretical and empirical research on the lay-up decision and vessel characteristics is reviewed to evaluate how different vessel-specific and market factors may affect the lay-up decision. Then, data on the offshore fleet in the North Sea and market variables is analysed by combining survival analysis with logistic panel data regressions to empirically test the factors in question. The time scope will be limited to the current crisis (2014 -) in the offshore supply industry. As the data for this thesis was collected in January 2017, the empirical analysis will consider the development until end 2016.

The remainder of this thesis will be structured in 5 sections. After this introduction, literature regarding the lay-up decision and OSVs will be reviewed. Along with characteristics of the North Sea, the literature review will be utilised to form the basis for hypotheses on which micro- and macro level determinants that affect the lay-up decision, and how they affect the decision. The methodology of the thesis, the hypotheses for the included variables, and the obtained data will be described in section 3, and then the empirical results will be presented and discussed in section 4. Finally, I will present some concluding remarks and suggestions for further research in section 5.

2. Literature review

As mentioned, the literature on the offshore service industry is limited, but some studies examine the fleet composition and important specifications for offshore vessels. Also, literature on capacity reduction and the lay-up decision in shipping in general and for other industries will be reviewed as it provides useful insight. The first part of the literature review will focus on theoretical research and models for the lay-up decision, then empirical evidence on, and methodology used to evaluate preferred vessel specifications will be considered.

The lay-up decision in shipping was first examined by Mossin (1968) who studied the problem of deciding when a ship should be laid up and when it should go back into operation. He attempted to set a lower critical value of rates (*y*) as a limit for when a ship should be laid up and a critical value (*z*) as a threshold for when it should be put back into operation. According to Mossin (1968), these critical values (*y*, *z*) depend on the cost per day during operation, the cost per day during lay-up and the "in-and-out" cost, i.e. the sum cost of laying up and putting back a vessel into operation.

Mossin (1968) describes the lay-up decision as a real option, which has value due to the flexibility it gives the shipowner (Tvedt, 2000a). By putting a ship in lay-up, a shipowner loses the lay-up option, but at the same time gains the option to re-enter the market if the rates increase (Tvedt, 2000a). The value of these options increases as the volatility of the underlying price process, in this case, the day rates. Both Mossin (1968) and Tvedt (2000a) consider lay-up as a function of only freight rates and does not consider other factors or ship heterogeneity.

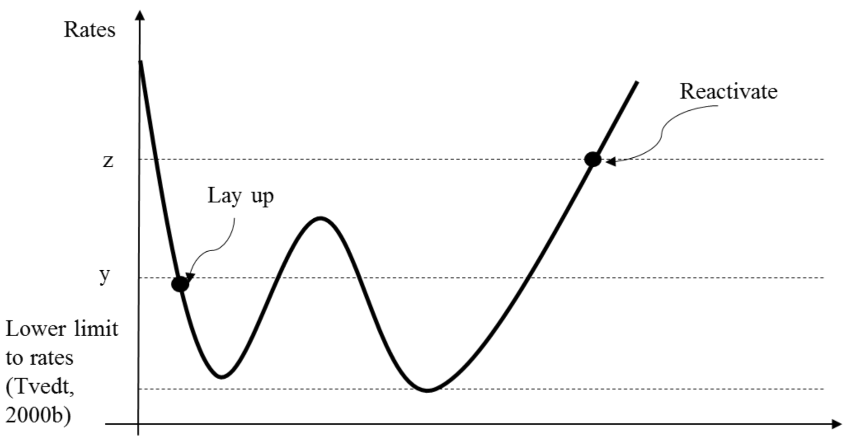


Figure 2 The lay-up decision as described by Mossin (1968), Tvedt (2000a) and Tvedt (2000b)

Dixit and Pindyck (1994) also examine a decision where a firm can suspend operation, and resume it later, if the profit flow turned positive, at a restarting cost, such as the lay-up decision. They develop decision rules with a similar real options approach as Mossin (1968) and Tvedt (2000a) but also include the investment and scrapping decision. In Dixit and Pindyck's model (1994) temporary suspension, or mothballing, requires a sunk cost E(M) and a continuous cost (M) to maintain the capital. Lay-up only makes sense if the maintenance cost (M) is less than the cost (C) of actual operation, and if the reactivation cost (R) is less than the cost of new investment (I) (Dixit & Pindyck, 1994).

Thus, the optimal strategy, illustrated in Figure 3, will take form of four threshold prices, P(H), P(M), P(R) and P(L). Starting from a state with no capital installed, the firm will invest if the price rises to a threshold P(H). The firm will mothball if the price falls to P(M), and reactivate the operation if the price rises to P(R). Since the cost of reactivation is less than that of investing from scratch P(R) will be below P(H). If the price falls further, the fourth threshold P(S) is where the mothballed project will be scrapped to save maintenance cost. Dixit and Pindyck (1994) assume that the rate evolves stochastically and a geometric Brownian motion price process, and does not consider firm or vessel heterogeneity.

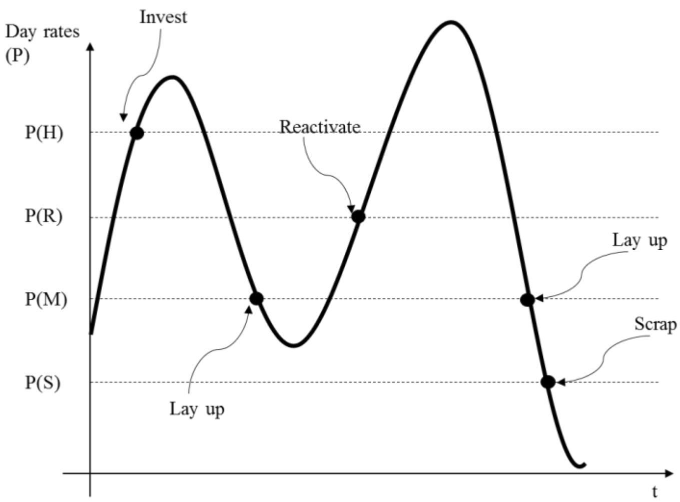


Figure 3 Illustration of the optimal strategy from Dixit and Pindyck (1994)

Tvedt (2000b) builds on Mossin's (1968) option approach but does to some extent consider the heterogeneity of vessels, by pointing out that vessels are not equally efficient. He also argues that the shipowners' flexibility to adjust capacity influences the equilibrium freight rate. According to Tvedt (2000b), assuming homogeneous vessels, it will be optimal for all shipowners to lay up their vessel(s) at *y* (From Mossin's model (1968)), and the rate will therefore never go below this common lay-up level. However, it is unrealistic to assume that all shipowners operate their vessels equally efficiently, due to aging ships, technological developments and changing requirements (Tvedt, 2000b). Tvedt (2000b) argues that the freight rate will never go below the level of exit of the most efficient vessel (as illustrated in Figure 2). However, Tvedt (2000b) does not consider that heterogeneous vessels may obtain different day rates and utilisation.

When a shipowner chooses to temporarily withdraw a ship from the market by laying it up, the aggregated supply falls accordingly, while re-entering will increase supply (Tvedt, 2000b). The changes in supply can clearly influence the day rates, as lower supply usually push prices upwards, and vice versa. This effect should be taken into consideration when evaluating the optimal lay-up policy in the first place (Tvedt, 2000b). Mossin's (1968) research suggests that there is a negative relationship between the day rate level and lay-up probability, but considering the effect described by Tvedt (2000b), the relationship may be ambiguous or non-linear.

Kovenock and Philips (1997) and Moel and Tufano (2002), both did empirical studies using logistic regressions on the closing of plants and mines, respectively, based on a real options model similar to Dixit and Pindyck's (1994). They use plant- and mine-specific, firm-specific and market variables to evaluate when the real option is exercised.

Corts (2008) also evaluates the lay-up (or cold stacking) decision as a real option, but with a slightly different approach, in his research on cold stacking and reactivation of offshore rigs. He argues that having an active rig provides a real option because it allows the firm to begin leasing the rig right away, without incurring reactivation costs. Therefore, it pays to stack a rig in period *t* if the current period profit ($\pi_{i,t}$) plus the option value ($\Phi_{i,t}$)[1] of an active rig is smaller than 0 if the rig is active ($S_{i,t-1} = 0$), and smaller than the reactivation costs ($R_{i,t}$) if it is already stacked ($S_{i,t-1} = 1$):

$$\pi_{i,t} + \Phi_{i,t} \leq S_{i,t-1} \cdot R_{i,t} \quad (1)$$

[1] Corts (2008) defines the option value as the discounted difference in expected profits in the next period conditional on the status of the rig: $\Phi_{i,t} = \delta\left(E\left[V_{i,t+1}|S_{i,t} = 0\right] - E\left[V_{i,t+1}|S_{i,t} = 1\right]\right)$

As the variables in the above inequality are largely unavailable, Corts (2008) utilised rig- and firm-specific variables ($x_{i,t}$) and market proxy variables ($z_{i,t}$) to determine when and how the lay-up decision is taken:

$$S_{i,t} = \begin{cases} 1 \; if \; \beta_i x_{i,t} + \gamma_i z_{i,t} - S_{i,t-1} \cdot R_{i,t} \leq 0 \\ 0 \; otherwise \end{cases} \tag{2}$$

Corts (2008) tested the model empirically with a panel logistic regression and a Cox proportional hazard model, which is a form of survival analysis.

In contrast to the temporary idling decision studied by Corts (2008), Alizadeh et al. (2016) evaluated the permanent scrapping decision, using a similar methodology. Alizadeh et al. (2016) utilised a panel logistic model to assess the probability of a dry-bulk ship being scrapped based on both vessel specific variables (size and age) and market variables (freight rates and volatility, bunker prices, interest rates and scrap steel prices). They found that age and size were significant determinants of the probability of a vessel being scrapped along with market forces such as the deviation of the freight rate from its long-run mean and bunker prices. Corts (2008) and Alizadeh et al. (2016) are the main inspirational sources for the empirical methodology used in this thesis.

A recent master thesis by Grøvdal & Tomren (2016) have through interviews with shipowners, linear regression and logit models examined the determinants affecting lay-up probability. To my knowledge, this is the only previous research on the specific topic: lay-up of OSVs. From their interviews with shipowners, they concluded that there are two main reasons to lay-up a vessel: 1) save operating costs and 2) reduce supply in order to increase day rates. The interviewees pointed out the age, effiency and capacity as important determinants for which vessels they preferred to keep in their fleet. In their quantitative models, they found that day rates are negatively correlated with lay-up levels and may have a lagged effect. By using logistic regression, the authors found that clear deck area for PSVs and bollard pull for AHTS, are negatively related to the probability for lay-up. Grøvdal & Tomren (2016) includes relatively few vessel specific variables, and does not pool the data over several time periods nor include market variables in the logistic model. This thesis attempts to further develop the understanding of determinants of lay-up probability by significantly expanding the quantitative models used in Grøvdal & Tomren (2016).

Aas et al. (2009) explored PSV's role in the oil industry supply chain on the Norwegian Continental Shelf and studied the main characteristics of a vessel through a logistic analysis. They argue that carrying capacity, sailing, loading and unloading capabilities are the main features of a PSV.

Carrying capacity can be divided into two main categories, deck capacity, which is given in square meters, and bulk capacity. Deck cargo is everything transported on the deck of the supply vessel, whereas bulk cargo, such as methanol, drill-fluids, and water, is transported in tanks below deck (Aas et al., 2009). In most cases, larger vessels give a lower transport unit cost due to economies of scale, given that a high capacity utilisation is obtainable (Aas et al., 2009). The preference for large vessels is supported by Halvorsen-Weare et al. (2012) who argues that deck capacity is the scarce capacity resource for PSVs, as well as by Maisiuk and Gribkovskaia (2014) who finds that the vessel's deck area is an important determinant of the day rate and utilisation obtained for the vessel.

Sailing capability refers to the ability of the vessel to sail under different conditions (Aas et al., 2009). Two main factors decide the loading/unloading capabilities of a PSV: the lifting capacity and the vessel's ability to keep its position (Aas et al., 2009). The latter suggests that having a dynamic positioning (DP) system is important. A DP system keeps the OSVs in the same position despite waves and currents when operating close to the installations, to reduce the risk of collisions and to simplify operations such as unloading PSVs.

Tvedte & Sterud (2016) used a vessel based logit model to analyse determinants for obtaining a contract for OSVs in the North Sea. For PSVs, charterers prefer young vessels with large deck area built in Northwest Europe for both spot and term contracts. The probability of obtaining contracts varies significantly with vessel specifications. Having ice class, fire-fighting capabilities and DP2 increase the likelihood of securing a spot contract. However, the ice class has no significant effect on term contracts, and fire-fighting capabilities reduce the term contract probability.

For AHTS vessels, young and powerful vessels built in Northwest Europe are preferred in the spot market, and vessel specifications such as DP2, ice classification, fire-fighting capabilities and ROV are rewarded (Tvedte & Sterud, 2016). In the term market, smaller and to some extent older AHTSs seem to be preferred, and having a DP2 system decreases the probability of obtaining a contract. Fire fighting capabilities are also rewarded in the term market.

Regarding moonpool and helideck, Tvedte and Sterud (2016) show that these are preferred features in the term market, but that they seem to be unattractive in the spot market.

Adland, Wolff, and Cariou (2017a) develop a market index for both PSV and AHTS rates based on hedonic price regression on a large set of heterogeneous transactions. They find that spot rates increase significantly with the size and power of the OSVs, and a non-linear effect of the age. Having ice class, a DP2 system and being built in the Northwest Europe yields a significant spot rate premium for both vessel types, whereas having a helideck causes a rate discount for AHTS vessels. In addition, Adland et al. (2017a) find a substantial seasonality where rates are higher during the summer season.

It is reasonable to think that many of the same determinants examined in Tvedte & Sterud (2016) and Adland et al. (2017a), also will be important determinants for the lay-up probability. Vessels with low probability to obtain a contract and high rates will most likely have a high probability to be laid up.

This thesis aims to contribute to the limited existing research on the OSV industry in general, and specifically the lay-up decision, by utilising methodology used in studies of scrapping and stacking decisions (Corts, 2008; Alizadeh et al., 2016). Specifically, the intended contribution to literature is threefold. Firstly, I show empirically how the market condition affects the lay-up probability, as shown theoretically by Mossin (1968), Dixit and Pindyck (1994) and Tvedt (2000b). Secondly, I investigate how vessel characteristics affect the lay-up decision for OSVs, with more detailed technical specifications than previously used, and in contrast to most literature treating the vessels as homogeneous. Finally, the research considers the timing of the lay-up decision by pooling the data over several years and using survival analysis.

3. Data and methodology

A twofold approach will be utilised to assess the micro- and macro-level determinants for the lay-up of OSVs. First, I will conduct survival analysis to evaluate how vessel characteristics such as age, size and technical specifications affect the probability of being laid-up. Then a panel logistic regression will be used to examine the lay-up probability based on vessel characteristics along with market variables. The inclusion of the chosen variables and the hypotheses regarding their expected sign largely follows previous research referred to in the literature review. This section will present the models; the variables included; hypotheses for the empirical results; and the data utilised in the models.

In both regression models, the data is pooled from June 2013 until December 2016, to include a period with high rates, oil prices, and utilisation before the market turned in 2014. This is done to properly see the effect of the market conditions on the lay-up probability.

3.1 Regression models

To analyse how vessel specifications affect the lay-up decision, considering the order the vessels were laid up, a type of survival analysis will be used inspired by the methodology employed in Corts' (2008) research on stacking of oil rigs. The model will follow each vessel from the start of the period until the month it is laid-up, and then the vessel is excluded from the sample. For the few vessels that shipowners have reactivated after being in lay-up, the vessel is removed from the sample after the first lay-up, as all of them are laid up again after a relatively short period (2-10 months). A Cox proportional hazard model will be utilised to examine how the vessel characteristics influence the probability to not "survive" in the market, i.e. be laid up.

The Cox proportional hazard model estimates the effect of the vessel's characteristics on the vessels survival function by estimating the hazard ratios for each variable describing the vessel. The hazard ratio represents the probability of an incident, in this case, lay-up, given that the incident has not yet occurred (Cleves, Gould, & Gutierrez, 2004). The Cox model is semi-parametric, as it does not require making any assumptions on the shape of the baseline hazard function ($h_0(t)$), but estimates the effect of the variables on the function, which is the main advantage of the model. According to Cleves et al. (2004), the Cox model is preferred to other non- or parametric models when the goal is to find the underlying effects of the variables.

The model is specified in accordance with econometric principles[2], and the hazard ratio of each vessel is estimated as a function[3] of vessel specifications as shown below:

$$h(t|x) = h_0(t) \cdot f(age_{i,t}, agesquared_{i,t}, size_i, bulkcap_i, FEI_i, dp2_i, oilrec_i, ice_i, fire_i, heli_i, moon_i, nwe_i) \quad (3)$$

The estimated coefficients from the model can be interpreted as follows: a coefficient over one means that the variable increases the probability of lay-up, while a coefficient below one signals the opposite. In the subsequent presentation of the variables, the expected effect on the lay-up probability will be indicated in parentheses. A negative sign corresponds to a Hazard ratio below one and a negative coefficient in the logistic models, and vice versa. The interpretation of the variables and their *a priori* expected effect are summarised for both vessel types in Table 1.

The age of the vessel is represented by $age_{i,t}$(+) as a discrete variable, and a variable with the squared age ($agesquared_{i,t}$(-)) is also included to check for non-linear relationships between age and the lay-up probability. To represent the $size_i$(-) of the vessel, clear deck area (m^2) is used for PSVs and brake horsepower for AHTSs[4]. A proxy ($bulkcap_i$(-)) for under deck bulk capacity[5] have been included for PSVs. In addition, dummy variables for being "large" based on the size segments used by brokers and analysts, over 900 m^2 for PSVs and 20,000 BHP for AHTSs, have been made, as being bigger than a given threshold may influence the lay-up probability.

There are clear indications in previous empirical research that young and large PSVs are preferred both in terms of higher utilisation and higher day rates. For AHTS vessels the empirical evidence on the age and size variables is less clear, for instance, Tvedte and Sterud (2016) show that young and large vessels are preferred in the spot market, but not in the term market. However, Grøvdal and Tomren (2016) found that shipowners consider young and

[2] The assumptions for the model are tested using a log-rank test, link-tests and a global test for proportional hazard ratios

[3] The function is specifically estimated like an exponential function of a vector x of variables: $h(t|x) = h_0(t)e^{\beta_i x_{i,t}}$

[4] The different size measures (length overall, deadweight tonnage, BHP, clear deck area and bollard pull (for AHTS)) for vessels are closely correlated, only one is therefore chosen for each vessel type to avoid multicollinearity. Clear deck area and BHP is the de-facto standard for classifying vessel size in the market for PSVs and AHTSs respectively.

[5] Bulkcap = Liquid mud capacity (m^3) + Drill water capacity (m^3) (Tvedte & Sterud, 2016).

powerful AHTSs more efficient. I, therefore, hypothesise that lay-up probability will increase with age and decrease with size also for both AHTSs and PSVs.

FEI_i(+) is a fuel efficiency index (FEI) measuring the fuel consumption adjusted for vessel speed and size, and is defined, inspired by Adland et al. (2017b), for PSVs and AHTS, respectively:

$$FEI_i^{PSV} = \frac{Consumption}{Dwt \cdot Speed \cdot 24} \cdot 10^6 \quad (4) \qquad FEI_i^{AHTS} = \frac{Consumption}{BHP \cdot Speed \cdot 24} \cdot 10^6 \quad (5)$$

As fuel expenditure typically is paid by the charterer (Stopford, 2009, p.182), and for PSVs fuel may be taken directly from the cargo bound for delivery, it is reasonable to think that high fuel efficiency (low FEI) reduces lay-up probability.

The variables $oilrec_i$(-), ice_i(-), $fire_i$(-),$dp2_i$(-) and nwe_i(-) are binary variables indicating whether each vessel has oil-spill recovery capabilities, ice classification, fire-fighting capabilities, a DP2 system or is built in Northwest Europe. For oil installations in the North Sea, there are strong requirements for emergency preparedness. In this regard, many OSVs have fire fighting and oil spill recovery capabilities, so that the vessels can be chartered for preparedness purposes in addition to their usual tasks. Ice classified vessels have a reinforced hull, and may operate in areas with ice cover or risk of ice, such as in the Barents Sea.

Previous empirical research indicates that having ice classification, DP2 system, fire-fighting capabilities and being built in the Northwest Europe will reduce the lay-up probability for both vessel types. The effect of oil-spill recovery capabilities is, to my knowledge, not studied in any previous research. However, as this feature adds to the variety of assignments a vessel can be chartered for, my hypothesis is that they reduce the lay-up probability.

Some OSVs are equipped with helidecks, i.e. landing plattforms for helicopters, and moonpool, a vertical well in the hull of the vessel providing access to calm sea to simplify some types of operations (Fredriksen, Kristiansen, & Faltinsen, 2014). As these features are most suitable for AHTS vessels due to their operational tasks (Tvedte & Sterud, 2016), the binary variables $heli_i$(-) and $moon_i$(-) are only included in the AHTS models. The effect of these factors in previous studies is unclear, but since the expand the range of possible assignments, I expect them to decrease the lay-up probability.

To complement the survival analysis, a panel logistic regression is conducted to evaluate the effect of vessel specifications further and include the effect of market variables that vary over time. In these models, whether a vessel *i* is laid up at time *t* is used as a dependent binary variable ($V_{i,t}$). Binary response models, specifically logistic regressions, are utilised to establish the probability of a vessel being laid up[6] as a function of its specifications, as well as market variables. A random effects (RE) panel regression is utilised, as the vessel specific variables (except age) are time-invariant. The econometric model is based on previous empirical studies such as Alizadeh et al. (2016) and Corts (2008) and in accordance with econometric principles.

As the dependent variable is a binary variable, regular linear regression (OLS) is not suitable, and a logistic regression model, hereafter logit model, is therefore used. A logit model has two primary advantages: it forces the fitted probabilities to be between 0 and 1 and allows the partial effect of any explanatory variable to be non-constant (Wooldrigde, 2013). The model is defined like this:

$$P\left(V_{i,t} = 1 | x_{i,t}, z_{i,t}\right) = \frac{1}{1 + e^{-\left(\beta_0 + \sum_i^n \beta_i x_{i,t} + \sum_j^m \gamma_j z_{j,t}\right)}} \tag{6}$$

Where $x_{i,t}$ are the vessels specific variables and $z_{i,t}$ are the market variables included in the model. The model utilises maximum likelihood estimation to estimate the "odds ratio" $\ln\left(\frac{p}{1-p}\right)$, which can be converted to the probability. The sign of the coefficients can be interpreted directly, i.e. a positive coefficient means that the variable gives a higher probability for lay-up and negative means a lower probability (Wooldrigde, 2013).

The probability of lay-up in the panel logit models, where both market variables and ship specifications are included, is specified like this:

$$V_{i,t} = f\begin{pmatrix} alreadylaidup_{i,t}, age_{i,t}, agesquared_{i,t} size_i, fexp_{i,t}, FEI_i, dp_i, oilrec_i, ice_i \\ , fire_i, heli_i, moon_i, nwe_i \; spotrate_{i,t}, oilprice_t, utilisation_{i,t}, month_t \end{pmatrix} \tag{7}$$

$V_{i,t}$ is equal to 1 if the vessel (*i*) is laid up at time *t*, and equal to 0 otherwise. Whether each vessel is laid up or not is specified for each month (*t*). The variable $alreadylaidup_{i,t}$(-) is a

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[6] More specific, the model estimates the probability for a vessel to be laid up and to stay in lay-up.

dummy variable for whether the vessels was in lay-up the previous month. If a vessel was in lay-up the previous month, this is expected to substantially increase the probability that it stays in lay-up due to the in-and-out costs (Mossin, 1968) and in line with the model in Corts (2008).

The panel data model includes market variables in addition to the vessel specifications explained earlier. The $spotrate_{i,t}$(-) represents the average spot dayrate in GBP for the vessel segment[7] at time t, and a squared version of this is tested ($spotrate_{i,t}^2$) to account for a potential non-linear relationship. Lower spot rates should lead to a higher lay-up probability for both vessel types, but as discussed earlier, there may be a non-linear or ambiguous relationship. The spot rate is used, and not term rates, because it is the spot market that often is the alternative for a non-contracted vessel not laid up.

Further, $oilprice_t$(-) is the Brent Crude Oil spot price (USD/barrel), which is assumed to reflect the market situation and sentiment as there is a positive relationship between the crude oil price and oilrig activity (Ringlund, Rosendahl, & Skjerpen, 2004), which again is heavily tied to the demand for OSVs. Consequently, a higher oil price should decrease the lay-up probability.

Finally, $utilisation_{i,t}$(-), represents the percentage of vessels in each segment available in the market that has been chartered the corresponding month (t). This variables reflects the market state, as a strong market typically will mean a high utilisation and vice versa. As it only includes vessels available on the market, it also adjusts for the effect of laid up vessels. It is likely that the higher the utilisation of vessels on the market, the lower is the probability for laying up a vessel.

A 1-month lag of the spotrate and utilisation is included in some models to test the hypothesis that the lay-up decision is affected by the market situation in the previous period. The three market condition variables are to some degree correlated, ranging from 0.33 to 0.75 in the correlation coefficient (see Appendix 2), but variance inflation factor tests (VIF) confirm that it is acceptable to use them in the same regression model. Monthly dummies are included to account for seasonal effects.

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[7] Day rates are received from Clarksons Platou. PSVs are divided in to segments based on deck area: 500-900m^2 and 900m^2+, while AHTSs are divided in three segments: under 16,000 BHP, 16,000-19,999 BHP and 20,000BHP+.

The last time-varying variable, $fexp_{i,t}(+)$, measures the deviation in the daily fuel expenditure of a vessel, compared to the average fuel expenditure in the fleet. Like for the fuel efficiency index (FEI), I expect that fuel efficient vessels are prefered. The variable is defined in line with Adland et al. (2017b):

$$fexp_{i,t} = (consumption_i - average\ fleet\ consumption) \cdot bunker\ price_t{}^{8} \tag{8}$$

Table 1 Summarised variable description

		PSV		AHTS		
Variable	**Unit**	**Included**	**Expected sign**	**Included**	**Expected sign**	**Interpretation**
age	Years	X	+	X	+	Age of vessel
agesquared	Years	X	-	X	-	Squared age of vessel
bhp	Horsepower			X	-	Brake horsepower of vessel
cleardeckarea	m^2	X	-			Outside clear deck area
DP2	Binary	X	-	X	-	Dummy for whether vessel has DP2
fifi	Binary	X	-	X	-	Dummy for whether vessel has firefighting capabilities
ice	Binary	X	-	X	-	Dummy for whether vessel has ice classification
oilrec	Binary	X	-	X	-	Dummy for whether vessel has oil spill recovery capabilities
nwe	Binary	X	-	X	-	Dummy for whether vessel is built in Northwest Europe
FEI	Index	X	+	X	+	Fuel efficiency index
fexp	USD/day	X	+	X	+	Deviation from average daily fuel consumption multiplied with bunker price
bulkcap	m^3	X	-			Proxy for under deck bulk capacity
Heli	Binary			X	-	Dummy for whether vessel has helideck
Moonpool	Binary			X	-	Dummy for whether vessel has moonpool
PSVlarge	Binary	X	-			Dummy for whether PSV has over 900 m^2 deck area
AHTSlarge	Binary			X	-	Dummy for whether AHTS has over 20,000 BHP
Oil price	USD/barrel	X	-	X	-	Monthly average Brent Crude Oil price
Spot rate	GBP/day	X	-	X	-	Monthly average day rate for vessel segment
Utilisation	%	X	-	X	-	Share of vessels chartered

Notes: Expected sign refers to the expected sign of the coefficient in the panel logit models. A positive expected sign corresponds to a hazard ratio over 1 in the Cox Proportional Hazard models, whereas a negative expected sign corresponds to an expected hazard ratio below 1.

[8] Historical bunker prices are daily 3.5%/380cst HFO Rotterdam (PEUR35RF Index) downloaded from the Bloomberg Terminal

3.2 Data and descriptive statistics

The data used in this study is sourced from ODS-Petrodata, Clarksons Platou Research Ltd. and Clarksons World Fleet Register (Clarkson Research Services Ltd, 2017). All three sources provide detailed specification data for OSVs in the North Sea, and a vessel specification register has been developed based on combining and cross-checking these sources. This overview contains age, size measurements and technical specifications used as variables in the proposed models. Missing fuel consumption in the dataset is handled by computing an implied consumption of tonnes/day in line with Dahle & Kvalsvik (2016), based on kW and motor specifications for each vessel[9]. Vessels that have been scrapped or converted to other purposes are removed from the dataset.

A register of vessels in lay-up including when each vessel was laid up, and taken out of lay-up, is sourced from ODS-Petrodata. Vessels are recorded as laid-up when they are in cold lay-up, also referred to as cold stacked. This register was cross-checked with open lay-up registers to ensure the validity of the data. Average monthly day spot rates were received from Clarksons Platou Research Ltd, while average monthly Brent Crude Oil prices were sourced from the U.S. Energy Information Administration (n.d.). The utilisation ratio is calculated based on a comprehensive dataset sourced from ODS-Petrodata containing both spot and term fixtures.

The vessel specification register, the lay-up register and the market variables were then combined to form the dataset used in both the survival analysis and the logistic regressions. The dataset is divided into the two vessel types PSV and AHTS, while the spot rates are segmented in classes based on deck area for PSVs and brake horsepower for AHTS.

The vessel specific variables are summarized in Table 2, with a simple t-test for whether there is a significant difference in the mean of the variable for vessels laid up versus vessels in service.

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[9] $Implied\ consumtion: kW \cdot {}^{g}/_{kW} \cdot {}^{24}/_{1''}$. Dahle and Kvalsvik (2016) used a fuel consumption on 170g/kWh for diesel-mechanical propulsion systems and 200 g/kWh for diesel-electric propulsion system based on discussions with the Ulstein Group

Table 2: Summary of vessel specifications for PSVs and AHTS vessels

	PSV				AHTS			
	All	**Laid-up**	**In Service.**	**T-test**	**All**	**Laid-up**	**In Service.**	**T-test**
Age	8.92	10.18	8.20	-2.07**	12.67	13.09	12.39	-0.39
Clear deck area	860.56	828.49	879.02	2.39**	-	-	-	-
BHP	-	-	-	-	16,937.70	17,996	16,240.32	-1.23
DP2	0.88	0.82	0.91	2.41**	0.67	0.76	0.61	-1.82*
DP1	0.07	0.11	0.045	-2.04**	0.10	0.06	0.13	1.47
fifi	0.43	0.48	0.39	-1.52	0.58	0.61	0.56	-0.58
ice	0.30	0.28	0.31	0.34	0.54	0.63	0.48	-1.63
oilrec	0.25	0.26	0.24	-0.41	0.35	0.39	0.33	-0.71
nwe	0.62	0.60	0.63	0.608	0.596	0.67	0.55	-1.37
bulkcap	2,551.96	2,310.70	2,717.30	3.06***	-	-	-	-
FEI	5.97	6.68	5.54	-3.57***	3.16	2.94	3.32	1.42
Bollardpull	-	-	-	-	192.19	199.46	187.40	-0.81
heli	-	-	-	-	0.007	0.018	0	-1.23
moonpool	-	-	-	-	0.04	0.07	0.02	-1.38
PSVLarge	0.52	0.39	0.59	3.55***	-	-	-	-
AHTSextlarge	-	-	-	-	0.05	0.00	0.09	2.23**
AHTSlarge	-	-	-	-	0.29	0.42	0.21	-2.79***
AHTSmed	-	-	-	-	0.23	0.24	0.22	-0.29

Notes: T-test checks whether the variable is significantly different between the laid-up and not laid-up vessels. * indicates significance at 10% level, ** at 5% and *** at 1%. The table is based on vessels in lay-up year end 2016.

PSVLarge: Dummy for PSV over 900m^2.
AHTSlarge: Dummy for AHTS between 20,000 and 30,000 BHP
AHTSextlarge: Dummy for AHTS over 30,000 BHP
AHTSmed: Dummy for AHTS between 16,000 and 20,000 BHP

For PSVs we see that vessels in lay-up are significantly smaller in terms of both deck area and bulk capacity, older and less fuel efficient, in-line with my expectations. In addition, the share of vessels with DP2 is significantly lower for laid-up ships. The other technical specifications do not have a significant difference in the mean between the two groups.

For AHTS vessels fewer variables have a significant difference between the two groups. Whether the vessel has DP2 is the only technical specification with significance, surprisingly, the laid-up vessels have a higher share with this system. The vessels kept in service are younger than those that are laid up, but the difference is not significant. Both measured in brake horsepower and bollard pull, the vessels in lay-up are large, but this is also insignificant. The significant difference for the dummy variables $AHTSextlarge_i$ and $AHTSlarge_i$, indicate that vessels over 20,000 BHP to a larger degree are laid up, but if they exceed 30,000 BHP they are historically not laid up.

The graphs below show the monthly average of the spot day rates for the two vessel types by the size segment used in the regressions. Although the rates are very volatile, they illustrate the worsened market situation for the shipowners in the OSV industry.

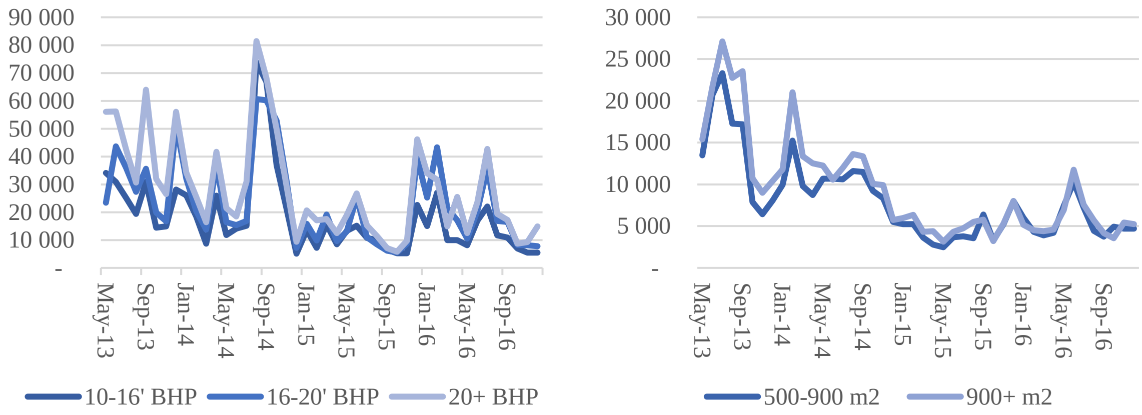

Figure 4 Monthly average of spot day rates for AHTSs and PSVs (GBP/day)

Figure 5 illustrates how the number of laid up vessels have increased significantly in the period studied. Clearly, the figure increases the most in the last months of the year, likely due to a higher activity level in the summer, in line with the findings of higher spot rates in the summer by Adland et al. (2017). According to Aas et al. (2009), the harsh weather conditions in the North Sea contributes to seasonal fluctuations.

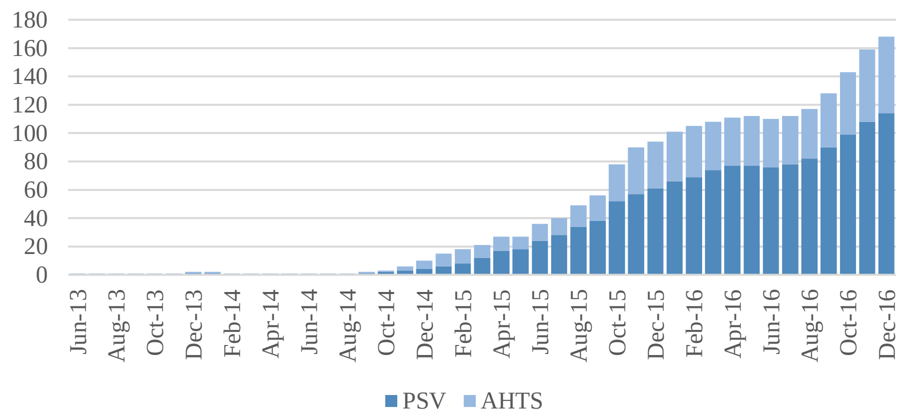

Figure 5 Number of vessels in lay-up in the North Sea

4. Results and discussion

4.1 Survival analysis

The results from the Cox proportional hazard models, where the effect of vessel characteristics on the "survival" of the vessels is estimated, for both PSVs and AHTSs are shown in the table below.

Table 3 Results from Cox proportional hazards regression for PSV and AHTS vessels

	PSV		AHTS
	(1)	(2)	(3)
Age	1.24***	1.18***	1.02
	(4.31)	(4.02)	(1.00)
Agesquared	0.99***	0.99***	-
	(-3.93)	(-3.71)	
Clear deck area/BHP	1.00	-	1.00
	(1.40)		(0.61)
PSVlarge	0.42**	0.61**	-
	(-2.21)	(-2.09)	
bulkcap	-	-	-
DP2	0.73	-	1.14
	(-0.97)		(0.78)
FEI	1.11**	1.09**	0.92
	(2.07)	(1.96)	(-0.62)
fifi	1.37	-	1.53
	(1.29)		(1.32)
ice	1.53	-	1.14
	(1.46)		(0.40)
nwe	0.82	-	-
	(-0.92)		
oilrec	1.33	-	1.24
	(1.19)		(0.63)
Subjects	259	259	121
Failures	96	96	54
Pseudo – R^2	0.043	0.034	0.025
P-value	0.000	0.001	0.865
Monthly dummies	N	Y	Y
Linktest	0.05*	0.53	0.34
Proportional H-test	0.003***	0.61	0.99

Notes: *Indicates significance at 10% level, ** at 5% and *** at 1%

For PSVs the most comprehensive model (1), including all the vessel specific variables, the global proportional hazard test and the link-test show that it violates the assumptions of the model. This was solved by developing a more limited model (2) by removing insignificant variables. The dummy variables for technical specifications in model (1) were all insignificant, but there are some indications that vessels with DP2 built in Northwest Europe are preferred, and that having ice classification, firefighting and oil recovery capabilities increase lay-up probability.

As expected, younger PSVs have a higher likelihood of "surviving" in the market, and the effect of the age is diminishing, which can be seen from the coefficient above 1 for $age_{i,t}$ and below 1 for $agesquared_{i,t}$. We also see that large PSVs (above 900m^2 clear deck area), have a hazard ratio far below 1, meaning that they survive longer in the market, and thus have a lower lay-up probability (Illustrated in Figure 6 below). Again, this is not surprising as large vessels have economics of scale and receive higher day rates in the market. Controlling for this threshold on 900m^2, which is commonly used by brokers, the variable $cleardeckarea_i$ has no significant effect. When removing the dummy variable $PSVlarge_i$, the hazard ratio for clear deck area is below 1.

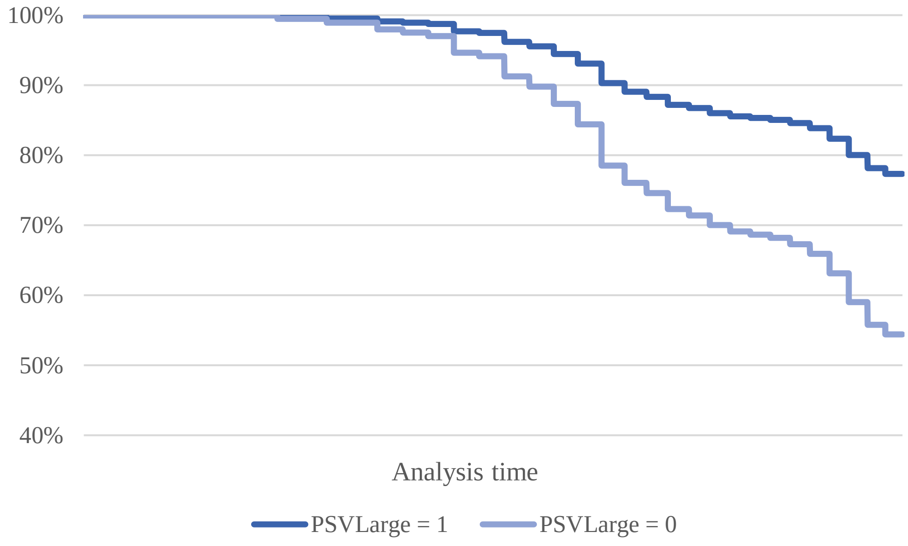

Figure 6 Survival rate for PSVs with over and below 900m^2 clear deck area

In addition, we also see that the hazard ratio is increasing with the fuel efficiency index (FEI_i), meaning that less fuel-efficient vessels have a higher lay-up probability. This is also in line with expectations, as the costs associated with being less fuel efficient should be unattractive for both shipowners and charterers.

The Pseudo R^2, measuring the improvement (ranging from 0 to 1) in log-likelihood from a model with no explanatory variables, for the model (2) is low, only 0.034, indicating that the vessel specific variables have limited influence on the survival of the vessels. However, Pseudo R^2 is often not reported in survival analysis, for instance not in Corts (2008), likely due to the difficulties in interpreting the measure and comparing it between different models (UCLA, 2011). The high proportion of censored data, i.e. vessels that are not laid up during the analysis time, probably contributes to the low value, a common problem with this measure in survival analysis (Schemper & Stare, 1996). One should therefore not put too much weight on the measure, although the low value indicates a weak effect of the technical factors.

For AHTSs, I do not find any significant results in the survival analysis. This may be due to the relatively low number of subjects and “failures”, which makes it hard to get significance. It may also indicate that vessel specific factors do not play a large part in the lay-up decision on an overall level. Then the lay-up decision will be taken based on market conditions, and a vessel which happens to be idle is laid up. Another explanation is that the decision is taken based on vessel characteristics, but that the desired features vary substantially, depending on the shipowner, available missions and other factors.

4.2 Panel logistic models

Monthly panel logistic models have been specified to evaluate how the vessel-specific variables along with the market variables affect the probability of lay-up. The results from the panel logistic models for PSVs are reported in Table 4 overleaf. Not surprisingly, vessels that were in lay-up the previous month has a substantially higher probability of being in lay-up. This is due to what was referred to as “in-and-out”-costs in Mossin (1968) and as reactivation costs in Corts (2008). When a vessel already has been laid up, it is likely to stay until the market improves substantially.

As in the survival analysis, we see that older and smaller vessels have a higher lay-up probability and that other technical specifications seem to have a limited effect. The effect of the age is non-linear and diminishing also in this model. When including the dummy for large PSVs, we see that these have a significantly lower lay-up probability than the vessels with under 900 m^2 clear deck area.

In some of the models, having firefighting capabilities, oil recovery capabilities and ice classification increase the lay-up probability of a PSV, whereas being built in Northwest Europe decrease it. However, as these effects are not consistent across the models when different variables are included, it is not possible to make a robust conclusion on the effect of these characteristics.

Table 4 Results from the panel logistic regressions for PSVs

	(1)	(2)	(3)	(4)	(5)	(6)
Already laid up	7.42***	7.38***	7.82***	7.97***	7.63***	-
	(15.18)	(15.20)	(13.40)	(14.04)	(13.24)	
Age	0.31***	0.36***	0.34***	0.34***	0.23**	1.92***
	(3.18)	(3.54)	(3.12)	(3.15)	(2.05)	(6.47)
Agesquared	-0.007***	-0.008***	-0.008***	-0.008***	-0.006*	-0.04***
	(-2.85)	(-3.07)	(-2.86)	(-2.93)	(-1.86)	(-5.85)
Clear deck area	-0.002	0.005**	0.004*	0.004*	0.004	0.019***
	(-1.37)	(2.15)	(1.70)	(1.73)	(1.35)	(3.48)
PSVlarge	-	-3.30***	-1.88**	-1.68**	-1.78*	-9.75***
		(-3.56)	(-3.52)	(-2.03)	(-1.92)	(-4.78)
bulkcap	-	-	-	-	-0.0004	0.0003
					(-1.04)	(0.59)
DP2	-0.59	-0.35	-0.81	-0.79	-0.58	-0.24
	(-0.81)	(-0.49)	(-1.22)	(-1.21)	(-0.86)	(-0.14)
FEI	-	-	0.25*	0.26**	0.22**	0.78**
			(1.77)	(2.44)	(1.96)	(2.09)
fexp	-	-	-0.00003	-	-	-
			(-0.07)			
fifi	0.91*	0.46	0.45	0.55	0.19	2.61**
	(1.85)	(0.93)	(0.97)	(1.21)	(0.38)	(2.02)
ice	0.75	1.06*	0.77	0.67	0.74	4.79***
	(1.33)	(1.81)	(1.39)	(1.23)	(1.24)	(2.93)
nwe	-0.35	-0.51	-0.59	-0.61	-0.47*	-2.79**
	(1.23)	(-1.15)	(-1.37)	(-1.44)	(1.69)	(-2.30)
oilrec	0.62	0.84*	0.83*	0.70	0.59	2.94**
	(1.31)	(1.72)	(1.74)	(1.50)	(1.22)	(2.02)
oil price	-0.07***	-0.07***	-0.07***	0.06***	-0.07***	-0.21***
	(-4.11)	(-4.15)	(-3.52)	(-3.18)	(-3.56)	(-9.58)
Spot rate	-0.0003***	-0.0003***	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(-4.12)	(-4.07)	(-3.29)	(-2.93)	(-2.89)	(-3.61)
Utilisation	-15.34***	-14.98***	-11.41***	-1.20	-12.62***	-60.78***
	(-3.90)	(-3.86)	(-2.58)	(-0.19)	(-2.70)	(-14.23)
Spotrate_1	-	-	-	-0.00003	-	-
				(-0.39)		
Utilisation_1	-	-	-	-10.81*	-	-
				(-1.84)		
Monthly dummies	Y	Y	Y	Y	Y	Y
Constant	12.80***	7.47*	3.70	4.48	6.55	21.73***
	(3.19)	(1.95)	(0.84)	(1.05)	(1.41)	(3.35)
Observations[10]	12,597	12,597	10,615	10,355	8,692	8,692
Pseudo – R^2	0.78	0.78	0.79	0.79	0.79	0.68
Lay-up correctly predicted	90%	89%	91%	91%	90%	15%
BIC	1,498.36	1,491.31	1,291.02	1,287.18	1,185.52	1,659.68
Log-likelihood	-631.17	-622.04	-515.73	-509.53	-465.78	-707.39
LR-test	4,391.10***	4,407.59***	3,840.61***	3,778.89***	3,485.69***	3,002.46***
P-value	0.000	0.000	0.000	0.000	0.000	0.000

Notes: *Indicates significance at 10% level, ** at 5% and *** at 1%. Z-values are in the parentheses.

[10] The number of observations vary due to missing observations when the variables fexp, FEI and bulkcap are included, and because the first month is removed when lagged values of rates/utilisation are included.

Like in the survival analysis, the fuel efficient PSVs have a lower lay-up probability in the panel logistic models. Hence, this seems to be a factor taken into consideration in the lay-up decision.

The market variables included, i.e. the oil price, day rates, utilisation and monthly dummies, seem to dominate in terms of explanatory power, as the Pseudo R^2 is significantly higher than for the Cox proportional hazard models, although not completely comparable as the models are different. The Pseudo R^2, measured as the improvement in log-likelihood compared with the benchmark model with no variables, is also high compared to similar studies such as Alizadeh et al. (2016).

As expected, a lower oil price increases the lay-up probability for PSVs, likely due to the oil price's connection to the activity in the North Sea (Ringlund et al., 2004). The spot rate also has a highly significant negative effect on the lay-up probability, as expected. When the spot rates decrease the probability to lay-up a vessel increases, this seems reasonable and is in line with the theoretical models (Mossin, 1968; Dixit & Pindyck, 1994) of the lay-up decision. As the variable $spotrate_{i,t}$ is segmented by the vessel size, and the large vessels get a higher day rate, the size effect is to some extent baked into this variable in addition to the pure size variables. It was also attempted to add a squared spot rate to check for non-linear effects, but this was not significant, and eliminated the significance of the spot rate due to multicollinearity.

As anticipated, the utilisation ratio also affects the lay-up probability. When fewer vessels are chartered, consequently more vessels are idle, and shipowners turn to lay-up to reduce operating costs and improve the market balance as described in Grøvdal and Tomren (2016).

In model (4), the one month lag of the spot rate and utilisation ratio were included, and we see that, now, the utilisation ratio seem to have a lagged effect on the lay-up probability. This indicates that PSV owners consider the utilisation of vessels the previous month in the lay-up decision. However, this result is not very strong with significance only at 10% level.

The seasonal effects are also significant, as illustrated in Figure 7, which shows the coefficients of the monthly dummies in model (2), the probability of lay-up is higher in the last months of the year. This is probably due to seasonal variations in the North Sea activity, as rough weather conditions in the autumn and winter make some operations more complex.

This is consistent with the results presented by Adland et al. (2017a) who found higher spot rates in the summer season.

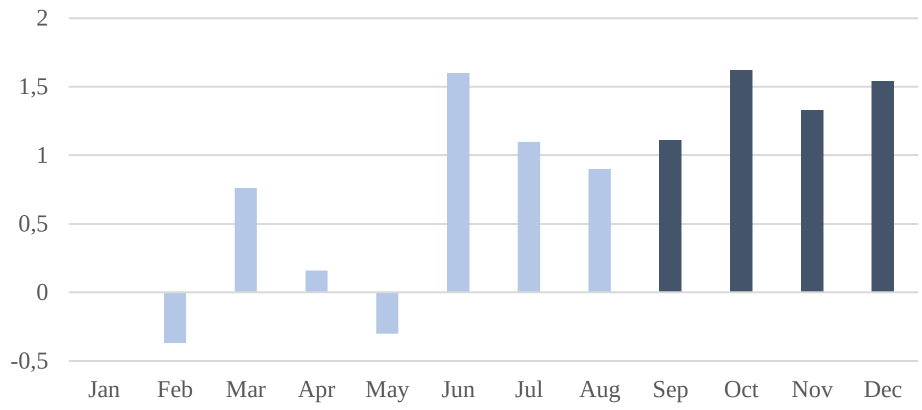

Figure 7 Seasonality in the lay-up of PSVs. The dark columns illustrate where the effect is statistically significant at a 5% level

The results from the panel logit regressions for the AHTS vessels are summarized in Table 5. As for PSVs, there is a strong positive relation between the lay-up probability and whether the vessel was laid up the previous month, in line with the *a priori* expectations. When including this variable, only the vessel age and the market variables, including oil price, spot rates, and seasonal effects have a consistently significant effect on the lay-up probability. Surprisingly, the age of the vessel seems to have only a weak effect. The squared age was removed from the models, as it was not significant, and ruined the linear relation due to the collinearity between age and squared age.

The empirical evidence on how size affects the attractivity of an AHTS vessel in previous studies is unclear, and this is the case also here. The brake horsepower of the vessels does not significantly affect the lay-up probability, but looking at model (2) vessels over 20,000 BHP have a higher lay-up probability than smaller vessels. However, further examination of the data showed that no AHTS vessels over 30,000 BHP have been laid up. This led to the hypothesis that there may be a non-linear relation between the size and lay-up probability, tested in model (3) - (6). In two of these models, the non-linear relation was weekly significant. The relation, illustrated in Figure 8, indicates that ceteris paribus the lay-up probability is highest for vessels around 20,000 BHP and then decreases for larger AHTS vessels. As this result lack consistency and is only weekly significant, we cannot make a robust conclusion about this relation, although it seems reasonable.

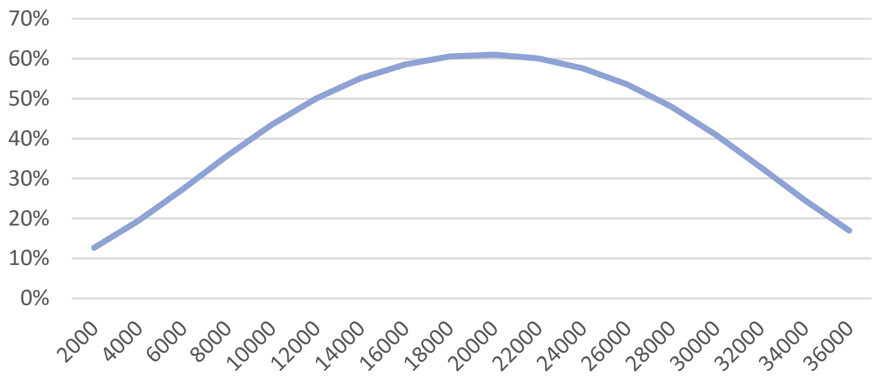

Figure 8 The estimated relationship between brake horsepower and lay-up probability for AHTS (Model (3))

Table 5 Result from the panel logistic regressions for AHTSs

	(1)	(2)	(3)	(4)	(5)	(6)
Already laid up	7.09*** (14.67)	7.17*** (14.23)	7.11*** (14.54)	7.09*** (14.45)	7.34*** (13.86)	-
Age	0.05* (1.70)	0.05** (1.83)	0.04 (1.44)	0.04 (1.35)	0.03 (1.28)	0.63*** (11.06)
BHP	0.00002 (0.52)	-0.00006 (-1.07)	0.0003* (1.82)	0.0001 (0.70)	0.0003* (1.88)	0.0002 (0.39)
BHPsquared	-	-	-7.81e-09* (-1.74)	-2.48e-09 (-0.49)	-7.30e-09* (-1.79)	2.08e-09 (0.18)
AHTSlarge	-	2.46** (2.56)	-	-	-	-
AHTSmed	-	0.99 (1.38)	-	-	-	-
DP2	0.53 (0.70)	0.36 (0.49)	-0.17 (-0.21)	-0.25 (-0.33)	-0.19 (-0.27)	3.28* (1.77)
FEI	-	-	-	0.05 (0.16)	-	0.19 (0.20)
fexp	-	-	-	-0.0001 (-0.76)	-	-
fifi	0.38 (0.76)	0.43 (0.93)	0.37 (0.75)	0.43 (0.90)	0.35 (0.80)	3.60*** (2.96)
ice	0.49 (0.98)	-0.01 (-0.02)	0.40 (0.18)	0.38 (0.79)	0.39 (0.85)	0.97 (0.81)
heli	0.47 (0.19)	-0.33 (-0.14)	0.43 (0.18)	-0.92 (-0.39)	0.37 (0.17)	-3.98 (-0.42)
moonpool	1.18 (1.00)	1.19 (1.01)	1.44 (1.19)	2.38* (1.87)	1.39 (1.27)	5.19 (1.09)
nwe	-0.06 (-0.12)	0.22 (0.45)	-0.02 (-0.03)	0.10 (0.21)	0.04 (0.09)	-1.74 (-1.13)
Oilrec	-0.12 (-0.24)	0.07 (0.15)	-0.38 (-0.73)	-0.11 (-0.22)	-0.33 (-0.71)	-1.00 (-0.79)
oil price	-0.06*** (-4.33	-0.06*** (-4.09)	-0.06*** (-4.28)	-0.06*** (-4.19)	-0.05*** (-3.68)	-0.15*** (-11.01)
Spot rate	-0.00004** (-2.48)	-0.00004*** (-2.68)	-0.00004** (-2.53)	-0.00004*** (-2.59)	-0.00004** (-2.37)	-0.00001 (-1.15)
Utilisation	-2.57 (-1.28)	-2.34 (1.16)	-2.57 (-1.27)	-2.48 (-1.23)	-0.05 (-0.02)	-9.62*** (-6.79)
Spotrate_1	-	-	-	-	-1.18e-06 (-0.08)	-
Utilisation_1	-	-	-	-	-3.04 (-1.13)	-
Monthly dummies	Y	Y	Y	Y	Y	Y
Constant	-1.30 (-0.73)	-0.83 (-0.46)	-2.99 (-1.49)	-2.18 (-0.62)	-2.55 (-1.31)	-10.06* (-2.38)
Observations[11]	5,718	5,718	5,718	5,120	5,582	5,120
Pseudo – R^2	0.74	0.74	0.74	0.74	0.74	0.53
BIC	950.19	958.69	955.44	947.08	962.94	1,502.10
Lay-up correctly predicted	87%	87%	87%	88%	88.0%	24%
Log-likelihood	-362.62	-358.23	-360.93	-350.08	-356.38	-635.75
LR-test	2,043.35***	2,052.16***	2,046.75***	1,990.40***	2,016.00***	1,419.08***
P-value	0.000	0.000	0.000	0.000	0.000	0.000

Notes: *Indicates significance at 10% level, ** at 5% and *** at 1%. Z-values are in the parentheses.

[11] The number of observations vary due to missing observations when the variables fexp and FEI are included, and because the first month is removed when lagged values of rates/utilisation are included.

For AHTSs, the market conditions seem to dominate the vessel specific factors, to a larger degree than for PSVs, although the difference may also be connected to the lower number of observations.

As expected, the oil price, utilisation ratio, although not significant, and the spot rate has a negative effect on the lay-up probability. When the market situation worsens, in terms of lower activity and income from rates, the lay-up option gets more attractive for shipowners to both reduce operating costs and to improve the market balance by reducing supply in the same way as for PSVs. As smaller AHTS vessels obtain a lower spot day rate, the effect of how much brake horsepower the vessel has, is to some extent incorporated in this variable. This suggests that smaller AHTSs may have a higher lay-up probability, despite the unclear effect of the BHP-variable. There is no evidence that there is a lagged effect of the spot rates and utilisation ratio.

If the variable representing whether the vessel already is laid up is excluded (model (6)), the model loses much of its explanatory and predictive power, but it increases the significance of the other variables. In this model, we see that age of the vessel substantially increases the lay-up probability as for PSVs.

Surprisingly, having a DP2 system increases the lay-up probability in this model. This indicates that DP2 systems are not an attractive feature for AHTS vessels in the North Sea, it may be thought of as unnecessary complicated or expensive. Note, however, that a large share of the AHTSs in the sample has DP2, which may disturb the result.

The seasonal variations are clear and similar to those for PSVs. The graph below illustrates the coefficients for the monthly dummies in model (1). Again, we see that the lay-up probability is largest in the last months of the year.

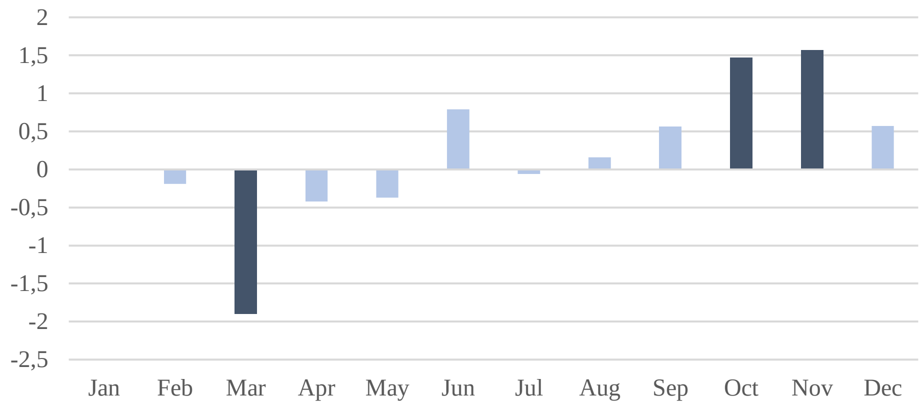

Figure 9 Seasonality in lay-up of AHTS. The dark columns show where the effect is statistically significant at a 5% level

Overleaf, the results from the panel logistic regressions for both PSVs and AHTS vessels are illustrated in three-dimensional graphs to visualise how the variables affect the lay-up probability together. One can see that the market variables seem to have the largest influence on the lay-up decision.

Both the survival analysis and the panel logistic regressions indicate that ship-specific factors, on an aggregated level, have a larger influence on the lay-up decision for PSVs. The significant vessel-specific variables are mainly related to vessel efficiency and capacity. A possible reason for this result is that PSV assignments are relatively homogeneous. The industry is therefore sometimes referred to as commoditised (Pedersen, 2015). Thus, economies of scale and cost efficiency may be more important in the PSV segment than in the AHTS segment where vessels more often are customized to individual contracts or clients.

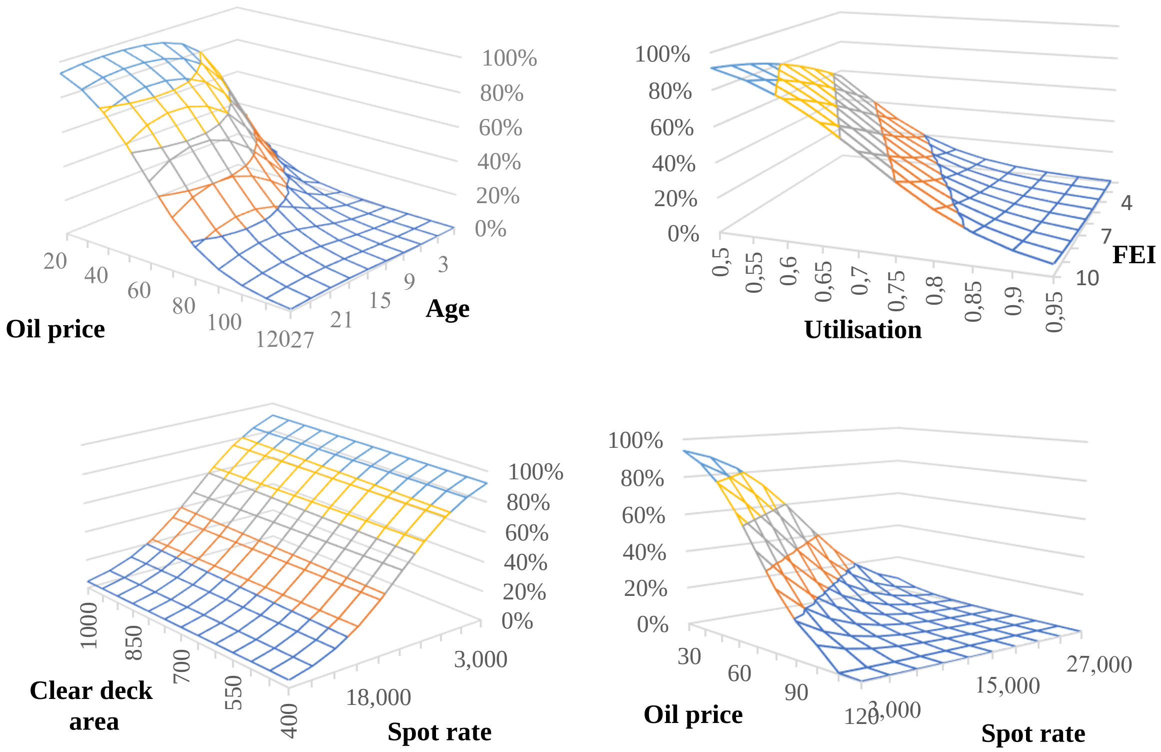

Figure 10 Estimated lay-up probability for PSVs, illustrations based on model (3)

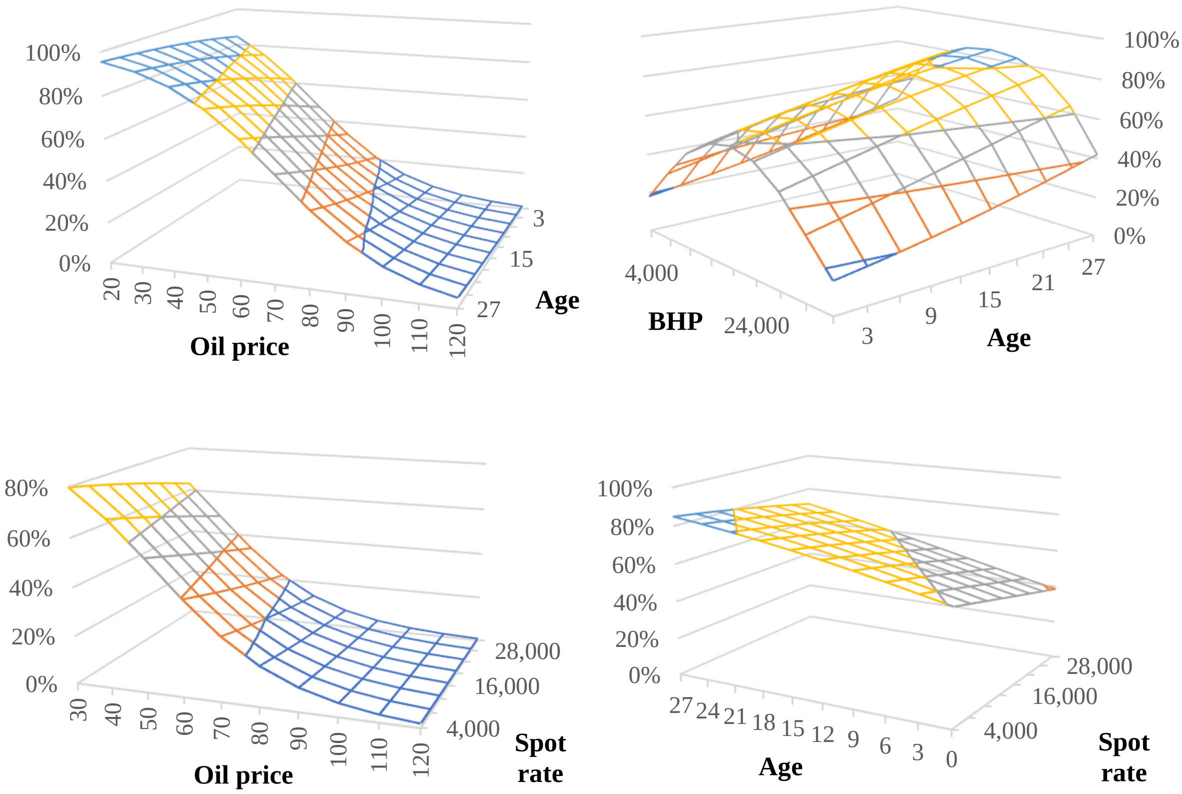

Figure 11 Estimated ay-up probability for AHTSs, illustrations based on model (2) and (3)

5. Conclusion

In this thesis, I have examined which and how vessel specific factors and market variables influence the lay-up decision, by empirically analysing how these factors affect the lay-up probability. The result shows that the market situation is the most important determinant, as the oil price, spot rates, utilisation and seasonal effects dominate in terms of explanatory power. As expected, lower oil price, spot day rates and utilisation rates (for PSVs) substantially increase the inclination to lay up OSVs. In addition, the lay-up probability is higher in the last half, and especially last quarter of the year, due to seasonal variations in the demand for vessels.

However, vessel characteristics and technical specifications also affect the probability of a ship to be laid up, most evidently for PSV vessels. In line with expectations, older, smaller and less fuel efficient PSVs have a higher lay-up probability. For AHTS vessels, the influence of vessel specifications is less evident. Shipowners seem to prefer keeping younger vessels in the market, and there are indications that there is a non-linear relation between the lay-up probability and the size of the vessels. The lay-up probability seems to be the highest for vessels around 20,000 BHP, and then decline for larger AHTS vessels. Other technical specifications do not have a consistently statistically significant effect, indicating that these do not substantially affect the lay-up decision, for neither PSVs nor AHTSs, on an aggregated level. However, this is not to say that they cannot play a part in individual lay-up decisions.

There are some limitations to this study that may be a threat to the reliability of the results. Firstly, the data material utilised is sourced from external sources. Thus I cannot completely guarantee the quality of the information although I have attempted to ensure the quality by cross-checking different sources. Second, I have not been able to obtain information about all technical specifications of interest, which may bias the result somewhat. Also, some of the variables have missing observations, and if the observations are not missing for random vessels in the sample, this can influence the estimations in the models. One could also argue that firm-specific factors such as firm size, market share and capital structure, can substantially affect the lay-up decision, and therefore should have been included in the models as Kovenock and Philips (1997) did in their study on plant closings.

Although this thesis has expanded the literature on the lay-up decisions for OSVs, there are several of potential areas for further research that will improve the understanding of this field. Possible opportunities are to expand this research to other geographic regions such as the Gulf of Mexico, or to include several vessel status options, such as production support, on spot market, scrapped, and converted, using a multinomial model, instead of a binary model with just cold stacked versus active vessels. Another option is to look at which vessels are likely to re-enter the market when (or if) the situation improves, as Corts (2008) do in his paper on cold stacking and reactivation of rigs. How much do the day rates and utilisation ratio need to increase before laid up vessels are reactivated? Does the reactivation follow a last-in-first-out (LIFO) principle? Finally, it would be interesting to look into whether shipowners manage to affect the day rates through lay-up.

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Appendices

Appendix 1: Correlation matrices

PSV	Already -laidup	Age	Age-squared	DP2	fifi	FEI	fexp	ice	nwe	oilrec	Clear deck area	Bulk-cap	Oil price	Spot rate
Already-laidup	1.000													
Age	0.138	1.000												
Age-squared	0.109	0.937	1.000											
DP2	-0.099	-0.488	-0.488	1.000										
fifi	0.015	-0.261	-0.166	-0.006	1.000									
FEI	0.163	0.465	0.467	-0.366	0.045	1.000								
fexp	0.046	0.165	0.120	-0.033	-0.110	0.616	1.000							
ice	-0.083	-0.249	-0.128	0.173	0.062	-0.276	-0.010	1.000						
nwe	-0.054	0.202	0.213	0.050	-0.254	0.034	0.111	0.154	1.000					
oilrec	0.032	-0.218	-0.168	0.204	0.069	-0.049	0.085	0.093	-0.076	1.000				
Clear deck area	-0.085	-0.364	-0.382	0.464	-0.269	-0.495	0.097	0.336	0.098	0.196	1.000			
bulkcap	-0.121	-0.335	-0.179	0.243	0.045	-0.391	-0.157	0.383	0.003	0.077	0.295	1.000		
Oil price	-0.307	-0.085	-0.049	-0.014	-0.023	0.012	0.009	-0.009	0.013	-0.005	-0.010	-0.011	1.000	
Spot rate	-0.197	-0.083	-0.058	0.036	-0.065	-0.048	0.022	0.035	0.031	0.018	0.095	0.035	0.729	1.000
Utilisation	-0.384	-0.086	-0.049	-0.012	-0.021	0.010	0.008	-0.008	0.011	-0.005	-0.007	-0.009	0.747	0.533

AHTS	Already laidup	Age	Age-squared	DP2	fifi	FEI	fexp	ice	nwe	oilrec	BHP	Bollard -pull	heli	Moon-pool	Oil price	Spot rate
Already laidup	1.000															
Age	0.125	1.000														
Age-squared	0.134	0.956	1.000													
DP2	-0.041	-0.476	-0.482	1.000												
fifi	0.006	-0.218	-0.170	0.041	1.000											
FEI	-0.023	0.090	0.107	-0.553	0.225	1.000										
fexp	-0.032	-0.330	-0.303	0.383	-0.040	0.019	1.000									
ice	0.025	-0.063	-0.111	0.278	-0.084	-0.262	0.205	1.000								
nwe	0.037	0.269	0.211	0.089	-0.108	-0.195	0.007	0.230	1.000							
oilrec	-0.002	0.226	0.161	-0.055	0.146	-0.068	-0.118	0.196	0.194	1.000						
BHP	0.003	-0.399	-0.381	0.668	-0.221	-0.678	0.570	0.322	0.177	-0.183	1.000					
Bollard-pull	-0.031	-0.395	-0.389	0.666	-0.193	-0.658	0.585	0.323	0.166	-0.180	0.976	1.000				
heli	0.058	0.045	0.009	0.059	0.080	-0.025	0.070	0.082	0.077	0.124	0.097	0.097	1.000			
Moon-pool	0.101	0.023	-0.027	0.120	-0.027	-0.043	0.154	-0.023	-0.033	-0.041	0.156	0.167	0.494	1.000		
Oil price	-0.310	-0.078	-0.046	-0.007	-0.016	0.003	0.018	0.005	0.008	-0.004	-0.003	0.000	0.002	0.003	1.000	
Spot rate	-0.132	-0.151	-0.131	0.154	-0.069	-0.148	0.166	0.104	0.025	-0.058	0.239	0.236	0.030	0.060	0.435	1.000
Utilisation	-0.266	-0.052	-0.031	-0.006	-0.011	0.003	0.011	0.003	0.005	-0.004	-0.003	-0.001	0.001	0.002	0.623	0.328

Appendix 2: Variance inflation tests

	PSV		AHTS	
Variable	**VIF**	**VIF excluding squared age**	**VIF**	**VIF excluding squared age**
Alreadylaidup	1.24	1.24	1.16	1.15
Age	14.74	1.93	16.62	2.02
Agesquared	13.73	-	14.14	-
DP2	1.56	1.55	2.44	2.43
Fifi	1.41	1.36	1.37	1.30
FEI	4.21	3.80	4.68	4.67
fexp	2.73	2.53	3.07	3.07
ice	1.45	1.34	1.28	1.26
nwe	1.19	1.18	1.36	1.33
Oilrec	1.12	1.10	1.40	1.38
Clear deck area	3.45	2.45	-	-
BHP	-	-	7.55	7.41
bulkcap	1.69	1.35	-	-
heli	-	-	1.41	1.41
moonpool	-	-	1.49	1.43
Oilprice	3.52	3.52	1.92	1.90
Spotrate	2.20	2.20	1.34	1.34
Utilisation	2.42	2.42	1.66	1.66
Mean VIF	3.71	2.00	3.93	2.25

Notes: The Variance Inflation Factor (VIF) is calculated using the Stata extension “*collin*".