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Energy efficiency and voyage rates

An assessment of a potetntial two-tier market. The case of the VLCC spot market

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Abstract

This thesis presents the first analysis of the two-tier market hypothesis, regarding realized operational efficiency in the VLCC spot freight rates. Investigating this hypothesis is an important objective, because the existence of an efficiency premium in the spot market will induce ship owners to invest in more environmentally friendly vessels.

We utilize a panel data set of 1,007 voyage rate fixtures between January 2013 and September 2016, on routes between the Persian Gulf and the Eastern part of Asia. We test for an energy efficiency premium by implementing two different multiple regression models, firstly by adopting the traditional approach using an "external" market index as the market proxy. Our results suggest that the market rate proxy for a standardised vessel is dominant in terms of explanatory power, and our findings show no evidence for an efficiency premium after controlling for macro-, contract- and ship-specific variables. Secondly, seeking to circumvent the problems, which the market rate proxy presents, we construct a new market indicator from microdata. We control for contract- and ship-specific variables, as well as time, charter and owner fixed effects, and we find weak evidence for a two-tier market where energy-efficient vessels attract a premium in the freight rates.

In a separate analysis, we examine whether fuel-inefficient vessels, which in theory should have a competitive disadvantage against more efficient ships, compensate by slowing down their speed. By estimating a multiple regression model with macro- and ship-specific variables, our findings suggest that energy-inefficient vessels tend to correspond to higher operational speed.

Preface

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

First and foremost we would like to thank our supervisor and interlocutor, Roar Os Adland, for great support and valuable insight into the shipping industry. Sound advice and constructive feedback have been essential for our progress. Furthermore, we would like to thank ORBCOMM and Clarkson Research for access to their comprehensive and detailed data sets. Finally, we would like to thank the Norwegian Shipowners' Association's Fund at NHH for their grants, hopefully our work will be of interest.

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1 Introduction

In late 2015, more than 190 countries adopted the first ever universal, legally binding global climate deal (Paris Agreement). The purpose of the deal is to keep the future rise in the global temperature well below 2 degrees Celsius (United Nations, 2015). International shipping currently contributes with 2,4% of the global greenhouse gas (GHG) emissions, and is estimated to reach about 18% by 2050 (UCL, 2016). Shipping falls outside of the Paris Agreement, but the debate regarding how the shipping industry should regulate their air pollution and greenhouse gas emissions has increased in the recent years. Hence, the industry relies on International Maritime Organization (IMO) and other regulatory bodies for policy changes, but progression is slow. As a result, understanding energy efficiency and how it may affect shipping freight rates would be of great interest to several stakeholders, such as ship owners and operators, charterers, shipbrokers, policy makers and, financiers.

Energy efficiency is defined as doing more useful work with the same amount of energy consumption (IMO, 2009). It applies to both the design and the operation of ships. As a function of the technological baseline and the operational management, energy efficiency can mainly be improved in two ways: Firstly, through technological specifications, such as Deadweight tonnage (DWT), engine power, design speed and hull designs, among others. Secondly, through operational efficiency, which refers to voyage optimization, and fleet and energy management. Efficiency has a significant impact on the operator's revenues and costs, as more efficient ships usually consume less fuel. As a result, energy efficiency is important, because being green seems to go hand in hand with profitability.

The purpose of this thesis is to investigate the two-tier market hypothesis on the basis of voyage charters. Specifically, we assess empirically whether more energy-efficient vessels attract a premium in the spot freight rates in the VLCC[1] market, for laden trips between the Persian Gulf (PG) and terminals in the Asian regions, between 2013 and mid 2016. We examine this hypothesis firstly by adopting the traditional approach using an "external"

[1] VLCC refers to vessels with a deadweight tonnage of 200,000+, which equals approximately 2,000,000 barrels of oil. The VLCC is mainly used for long haul operations, typically between the Persian Gulf and the Far East, Europe and North America.

market index as the market proxy. Secondly, we seek to circumvent the problems, which this approach presents, by constructing a new market indicator from microdata. Finally, we assess whether energy-inefficient vessels compensate by slowing down their speeds, known as slow-steaming.

Investigating this hypothesis is an important objective, because the existence of an efficiency premium in the spot market will induce ship owners to invest in more environmentally friendly vessels. Since owners can pocket any fuel savings, energy efficiency is, in theory, already rewarded. If energy efficiency leads to a premium in the freight rate on top of the fuel savings, ship owners are rewarded a bonus. This suggests that charterers care about being environmentally friendly. Furthermore, due to the increasing concern regarding environmental challenges, there is always a probability for policy changes to be made, e.g. introducing mandatory standards both for vessel characteristics and operational management. Hence, being precautionary, and having the ability to handle such potential changes may be an important step towards a sustainable competitiveness in the future.

The remainder of this thesis is structured as follows: Section 2 reviews relevant literature within the field of macro- and microeconomic determinants of the freight rate. In section 3 we present our methodological framework with choice of variables and the regression models. The data is presented and described in section 4. Section 5 contains results and discussion of our analyses. Finally, a conclusion with criticisms to our findings, and suggestions to further research, are presented in section 6.

2 Literature review

The formation of shipping freight rates has attracted a lot of attention in the early literature, where macroeconomic determinants, such as demand and supply, have been dominating (Tinbergen 1936; Koopmans 1939; Eriksen and Norman 1976). Demand for shipping services is a derived demand. For tanker services, the demand depends on factors such as international trade of oil and oil products, which in turn are linked to the world economic activity, consumption and imports of energy commodities, as well as seasonal and cyclical changes (Stopford, 2009). On the other hand, the supply mainly depends on the size of the tanker fleet, the tonnage available for trading, the rate which fleets are scrapped and built, productivity of the tanker fleet (e.g. speed optimization and time in port), and fuel prices.

However, the dynamics of freight rates also allows for pricing of heterogeneous micro factors, such as ship- and contract specific variables. These factors are represented through each individual fixture, and research within this field aims to investigate whether certain variables, e.g. quality or fuel efficiency, affects the freight rates. Micro determinants may influence the freight rates differently, depending on whether the fixture is within the time charter or the voyage charter market. In the time charter market, the contracts are fixed for a specified period of time, and the owner is being paid a freight rate on a dollar per day ($/day) or dollar per month basis. All of the voyage costs are borne by the charterer, such as fuel, canal and port charges, though the owner pays the operating expenes. In the voyage charter market, the owner is paid a predetermined voyage specific freight rate on a dollar per tonne ($/tonne) basis, which is normally quoted as Worldscale (WS)[2] points, or on a lump sum basis. All the voyage costs are borne by the owner (see *appendix B* for the cost allocation in shipping). Micro determinants have to some extent been examined in the early literature (see e.g. Bates 1969), however, it has received greater consideration the recent years. Providing the first empirical analysis of period time charter determinants, Köhn and Thanopoulou (2011) controls for contract-specific effects, such as place of de-

[2]The Worldscale index basically measures the breakeven rate of a standard tanker (Aframax) on a specific voyage under certain assumptions regarding the ship's specifications, fuel prices, port charges and other factors. See www.worldscale.co.uk for detailed definitions and explanations on how the Worldscale flat rate is calculated.

livery, duration of contract and number of days forward to delivery, as well ship-specific effects, through the boom period from 2003-2007. They find a pronounced two-tier market, suggesting a quality premium for younger vessels.

Kollamthodi et al. (2008), based on an interview with the Norwegian Shipowners' Association, claim that charterers are willing to pay higher rates for fuel-efficient ships, if this entails a reduction in their fuel costs. However, the literature survey and reports presented in Faber et al. (2011) conclude that charter rates do not reflect fuel efficiency, and that the owners who invest in fuel efficiency usually do not redeem their investments. Agnolucci et al. (2014) present the first analysis on how financial savings arising from energy efficiency are allocated between the owner and the charterer in the Panamax time charter market. They find their results to be significant, suggesting that only 40% of the financial savings are recouped by the owner. However, Adland et al. (2016) criticize their approach in accounting for the market conditions, as they ignore the changing relationship between the contract duration and the market rate. Adland et al. (2016) state that this relationship is nonlinear which needs to be accounted for. By accounting for this dynamic relationship, and by using a dataset stretching over a longer time-interval covering a full freight market cycle, they were able to control for both boom and bust periods. In their research they find that between 14% (Capesize) and 27% (Panamax) of the financial savings are reflected in the freight rates during normal market conditions, and that inefficient vessels attract a premium in boom periods. This suggests that charterers presumably are focusing on maximizing revenues by choosing vessels with high speed and engine power, over energy efficient vessels. This is as expected based on economic rationality, because any fuel savings become insignificant compared to the value of time during markets with high freight rates. On the other hand, the UCL report (2016) finds little to no evidence that preferences for more energy efficient ships are reflected in the tanker time charter rates.

Moving to studies concerning the determinants of spot rates, Tamvakis (1995) examine whether there exists a quality premium in the tanker freight rates, regarding age, hull construction and US operating region, but finds no strong evidence of a premium for better quality vessels. Furthermore, in a similar study, Tamvakis and Thanopoulou (2000) investigate a potential existence of a two-tier market in the dry bulk freight market with regards to age for medium and large bulk carriers. The majority of their findings show no statistically significant premiums for the younger fleet. Using non-linear equilibrium models, Strandenes (1999) finds through simulations that if a quality premium exists in the tanker market, such two-tier markets would not last for more than 3-5 years. This is interesting related to the present thesis. If the hypothesis of a two-tier market holds, suggesting that more efficient vessels attract a premium in the freight rates, it is likely that the potential premium will only be present for a limited period of time. With time, market participants will adopt each other's competitive advantages (efficient ships) and the potential two-tier market will most likely dissolve. Moreover, Alizadeh and Talley (2011a) investigate microeconomic determinants for spot rates in the tanker market by examining whether contract specific factors and laycan periods are of any importance. They find that double-hulled vessels trade at a premium related to single-hull vessels, and additionally, a relationship between the length of the laycan periods and the freight rates. Utilizing fixed effect models, Adland et al. (2016) examine the influence of fixed effects on spot freight rates in both VLCC and Capesize markets, related to charterers' and owners' fixed effects, as well as their matched fixed effects. Their results suggest that the contribution of the charterer fixed effects is large in the VLCC market, while the charterer and match effects are large contributors in the Capesize spot freight rate.

Voyage rates are freely negotiable, and the starting point for every voyage negotiation is the "last done", specifically, the last fixture known. In general, if the freight rates are not sufficiently high for the owner to be able to pay the variable costs, the vessels will not be chartered out. However, vessels that in nominal terms stand out as less energy-efficient and thus less cost effective, can still compete by slowing down the speed. Depending on the underlying market conditions, the extent to which the fuel savings of this operation is present, vary. Assman et al. (2015) investigates whether ships are slowing down when the freight rates are low, and fuel prices are high, hence, potential energy efficiency savings are significant. They find some support for this theory, but to a less extent than expected, and conclude that there is a potential for gains from more adoption of slow-steaming. This is in line with the findings in Maanum and Selnes (2015), which suggest that when in ballast, normal speed optimizing behaviour is more pronounced. Positioning data given by the global Automatic Identification System (AIS) gives us the availability to predict more accurate trade statistics for homogenous commodities. Kaluza et al. (2010) investigate the ship movements based on detailed departure and arrival information, derived by AIS data. They recognise that a few important ports and global routes handle a significant portion of the overall trade volumes, which indicate a fat-tailed distribution. More recent empirical studies on operational factors apply AIS data, such as vessel speed used by (Assman et al., 2015 and Maanum and Selnes, 2015) and observed capacity utilization (Adland and Jia, 2016).

To our knowledge, there has been no attempt in investigating whether there exists an energy efficiency premium in the tanker spot market, by including AIS data as a part of the analysis. Thus, the contribution of our thesis to the existing literature is twofold: Firstly, we conduct a more detailed research within the topic of energy efficiency in the VLCC market, by using revealed average speeds for each individual vessel provided by AIS data, as opposed to earlier studies which have used design speeds. We propose a model for freight rate formation in individual contracts that incorporates time, charterer and owner fixed effects. Secondly, we investigate whether energy-inefficient ships, which in theory should have a competitive disadvantage against more efficient ships, increase their competitiveness through slow-steaming.

3 Methodology

3.1 Assessing the two-tier market hypothesis

In this section we describe the methodological framework in our assessment of the two-tier market hypothesis. In the spot market it is difficult, *ex ante*, to say whether energy efficient vessels are rewarded or not due to the fact that the fuel costs are paid by the owner. We have examined this hypothesis firstly by adopting the traditional approach using an "external" market index as the market proxy. Secondly, we have tried to circumvent the problems, which this approach presents, by constructing a new market indicator from our microdata. The two models will be explained further in section 3.1.2 and 3.1.4, respectively.

3.1.1 A traditional approach using a market proxy

Our choice of variables is largely based on literature within the field, which we find appropriate for our analysis. The selected variables are the freight rate determinants that we *a priori* think will contribute with their significance and give us reliable results. All variables used are summarized in *table 1*, which also includes the variable's expected impact on the freight rate, the unit for measurement of each variable, and its interpretation. For comparison, the table also indicates whether the variables are presented in Köhn and Thanopoulou (2011) and Adland et al. (2016). We have included both micro and macro determinants of freight rates in our work, and due to structural reasons we have categorized them as macro-, contract- and ship-specific variables.

Macro-specific variables:
As mentioned in section 1, we will examine the crude oil transportation between the Persian Gulf and East Asia (e.g. China, Japan, Thailand and Singapore). To control for the underlying market, we have included a *market rate* proxy for each fixture. The chosen market rate proxy is the TD3 route, which is published daily on a Worldscale basis by the Baltic

Exchange[3], obtained from Clarkson Research. Thus, we are able to capture the effects of the sudden peaks and troughs in the volatile spot market. *A priori* we expect the market proxy to be highly correlated with the respective fixture rates, with a coefficient close to 1, and to be dominant in terms of explanatory power.

Table 1: List of variables: Two-tier market hypothesis

Variables	Exp. sign	Unit	Köhn	Adland	Explanation
Dependent variable:					
Contract rate		WS	x	x	Spot rate VLCC market
Macro-specific:					
Market proxy	+	WS	x	x	TD3 benchmark (PG-Japan), matched with each corresponding fixture
Contract-specific:					
Forward days	-	Days	x	x	Days from the fixture date until the first laycan date
TD2_D	?				Dummy variable for the South-eastern Asia
Ship-specific:					
DWT	-	Tonnes	x	x	Deadweight carrying capacity
Age	-	Years	x	x	Age of the ship at fixture date
Age^2	-			x	Squared age of ship to capture non-linear effects
Load Factor	-	%			Capacity used
Estimated consumption	-	tonnes/day	x*	x*	Estimated actual consumption, Fa=Fd*(Va/Vd)[b]
FEI Actual	-	g/tonnemile		x*	FEI=(Consumption/(DWT*Actual Speed*24))
Fueltonne	-	$/tonne			Fuel cost per tonne oil carried

Source: Authors' expectations and explanations

*Efficiency measures are included in Köhn and Thanopoulou and Adland et al. in nominal terms

However, the intention behind implementing the market proxy is not to obtain the explanatory power *per se*, but a failure in accounting for the underlying market, will bias the estimated coefficients.

Contract-specific variables:

Considering the contract-specific variables, we firstly account for the charterer's willingness to pay for instant access to a vessel, by including the lead time-variable (*Forward Days*). This refers to the number of days from the fixture date until the first day of the laycan period[4]. With a lower lead time, it is expected that charterers would have an increased

[3] The exchange quotes the Baltic Dirty Tanker Index (BDTI), which is based on the weighted average of ten different routes, whereas four of the routes are commonly operated by VLCCs:
TD1: 280 000mt, Ras Tanura (PG) to US gulf
TD2: 260 000mt, Ras Tanura (PG) to Singapore
TD3: 250 000mt, Ras Tanura (PG) to Japan
TD4: 260 000mt, Off Shore Bonny (WAF) to US gulf

[4] Laycan here refers to the time period between the "laycan from" date (the earliest day when the vessel should be at the port of loading) and the "laycan to" date (the latest day to reach the port of loading).

willingness to pay for the vessel, and *vice versa*. However, this relationship may be market dependent. Hence, we expect the lead time-variable to be negatively correlated to the spot rate when the future rates are expected to decrease. Conversely, when the future rates are expected to increase, the lead time-variable is expected to have a positive correlation with the spot rate. In order to capture some of the regional differences, we have created a dummy variable *TD2_D*. All of the fixtures included in our analysis are geographically divided based on the location of their respective discharge ports.[5]

<u>*Ship-specific variables:*</u>

To account for the differences within the VLCC fleet, we are taking some ship-specific variables into consideration. As the vessels are made for transporting large amounts of crude oil over long distances, the *DWT*[6] is an important property of the ship's carrying capacity. In accordance with the economies-of-scale, a smaller vessel is expected, *ceteris paribus*, to obtain higher rates per tonne freight in the spot market. This is in line with the findings reported by Tamvakis and Thanopoulou (2000).

Newer vessels are likely to be associated with a higher degree of safety (i.e. reduced chances of oil spill) and reliability. Thus, we expect the coefficient of age to be negative, as charterers may be willing to pay higher rates for newer vessels. It is not obvious that this relationship is linear, so we are also checking whether there exists a non-linear relationship by assessing the squared age (Age^2). We have also considered the vessel's *load factor*[7,8], to assess whether there exists a relationship between what size a charterer hires versus the size he actually needs, and the freight rate. We expect this variable to have a negative sign. The freight rate decreases when DWT increases, and in order to satisfy the owner enough as to accept the contract of a vessel with a given DWT, the smaller the size of the cargo, the higher should the freight rate be.

[5] Fixtures with discharge port south of Hong Kong are categorized as a TD2-route.

[6] We have divided this variable with 1000 to ease the presentation in section 5.

[7] The Load Factor is here defined as the ratio between the cargo and the vessel's carrying capacity (DWT).

[8] We have multiplied this variable with 100 to ease the presentation in section 5.

Continuing with our variables representing a vessel's energy efficiency, we define three different measures in order to check the robustness of any findings of a voyage rate premium. Empirical literature has so far relied on nominal data, such as nominal consumption and design speed. In what follows, we present energy efficiency measures exclusively based on the vessel's actual speed from AIS data. Our first energy efficiency variable is the estimated daily consumption at actual speed. Estimated daily consumption is calculated on the basis of the vessel's nominal consumption provided by Clarkson Research. By utilizing the commonly acknowledged equation for fuel consumption as a function of speed (Assmann et al. 2015), presented in equation (1), we are able to do an estimation of the individual ships' consumptions by using their actual speeds:

$$F_a = F_d \times \left(\frac{V_a}{V_d}\right)^{\beta} \tag{1}$$

where F_a is the estimated consumption, F_d is the vessel's nominal consumption, V_a and V_d are the actual and design speed respectively, and the β is a fuel consumption exponent which is, for VLCCs, typically between 2,6 and 3,0[9] (Assman et al 2015).

The frequently used "vessel's nominal consumption", may deviate a lot from real-life conditions, as these hypothetical design values are seldom achieved. We believe that our approximation is a more pragmatic approach to estimate a ship's daily consumption, and thereby be able to control for the real operation of vessels. However, by using this calculation for each individual vessel, we implicitly assume that each ship has the same "speed-consumption relationship," which is not likely to hold. An even more appropriate approach would be to use real fuel consumption data, but this is unfortunately not available for the fleet as a whole.

Secondly, we have calculated the *Fuel Efficiency Index* (FEI), an idea gathered from Adland et al. (2016):

[9]In our calculations, we have used an exponent of 2.738, gathered from lecture notes in ENE430-V16, Lecture 4, *"Freight Economics."*

$$FEI = \left(\frac{Consumption}{DWT \times Speed \times 24}\right) \times 10^6 \tag{2}$$

where $consumption$ is the estimated consumption from equation (1), DWT is the ship's deadweight capacity and $speed$ is the design speed for the given vessel. This is a measure of the consumption on a "grams per tonnemile" basis[10]. However, the equation does not account for all of the ship's technical specifications, and Adland et al. (2016) also only consider the nominal consumption and design speed. In contrast, we have used estimated consumption, which is calculated in (1) and actual speed (AIS data). Thirdly, we have estimated the fuel costs per tonne oil carried, for each individual fixture. Our approach is presented by the equations below. We start by calculating the amount of days each vessel spends while carrying oil:

$$Days\ laden = \frac{Distance\ laden}{Actual\ speed \times 24} \tag{3}$$

where the $distance$ used corresponds to the distance between the loading port and the discharge port (laden trip), and is quoted as nautical miles. The next step is to calculate the total fuel cost incurred by each vessel:

$$Total\ fuel\ costs = Days\ laden \times Estimated\ consumption \times Fuel\ price \tag{4}$$

where $days\ laden$ comes from equation (3), $estimated\ consumption$ from equation (1), and the $fuel\ price$ corresponds to the prevailing spot price at Fujairah[11], on the given loading date. By using equation (3) and (4), we are able to calculate the $fuel\ cost\ per\ tonne\ oil\ carried$ for each fixture:

$$Fuel\ cost\ per\ tonne\ oil\ carried = \frac{Total\ fuel\ costs}{Quantity\ carried} \tag{5}$$

[10]We have multiplied by 10^6, to convert from tonnes to grams for ease of presentation.
[11]Weekly fuel prices for Fujairah provided by Clarkson Research.

where $total\ fuel\ costs$ are given by equation (4). The $quantity\ carried$ is the number of metric tonnes of oil carried by each given vessel. It is worth mentioning that for all three energy efficiency variables, higher reading means lower energy efficiency. Hence, we expect negative coefficients with regards to the freight rate.

Finally, as mentioned above, we have dropped nominal efficiency measures, such as FEI, Nominal consumption and Existing Vessel Design Index (EVDI), as this part of the thesis is focusing on the realized operational efficiency. We also considered engine power and laycan days, but they were dropped, as they did not contribute with any significance across specifications.

3.1.2 Random effects model

To explain the determinants of the spot freight rates for fixture i at time t, we estimate various specifications of the following general model:

$$F_{i,t} = \beta_0 + \beta_1 I_t + \sum_j \theta_j R_{i,j} + \sum_j \omega_j S_{i,k} + \varepsilon_i \tag{6}$$

where F_i is the observed freight rate of the *i*th fixture signed at date t. β_0 represents the unobserved effect. The macro variable is represented by the implemented market proxy for a standardized vessel I_t at fixture date. $R_{i,j}$ is the set of j contract-specific variables, while $S_{i,k}$ is the set of k ship-specific variables. Lastly, ε_i is a random perturbation, known as the error term, such that $E(\varepsilon_i) = 0$ and $Var(\varepsilon_i) = \sigma^2$

For this analysis, we have used panel data techniques[12]. An alternative approach could have been to use pooled ordinary least squares estimation. However, this technique does not take into account the individual heterogeneity between the vessels over time, which in turn would lead to biased and inconsistent coefficients (Verbeek, 2012). Furthermore, we want to find out whether the Random Effects model is appropriate, and for that purpose

[12] We have used the statistical software package STATA for our panel data regressions

we conduct the Hausman test (Hausman, 1978). The null-hypothesis is that the individual unobserved effect is uncorrelated with the regressors that vary over time. If the p-value from the test is below 5%, we reject the null-hypothesis and implement the Fixed Effects model. We are not able to reject the null-hypothesis, suggesting that the Random Effects model is acceptable in all our specifications presented in section 5.2.

Heteroscedasticity does not bias our results, but it makes our coefficients less efficient as it affects the standard errors. We use the Breusch-Pagan test (Breusch and Pagan, 1979) to test for heteroscedasticity, and it shows that heteroscedasticity is present in all of our regressions. Serial correlation causes the standard errors of the coefficient to be smaller than they actually are, and also gives a higher R^2. However, due to the fairly short time horizon of our data set, it will not be exposed to serial correlation, as it is more pronounced when dealing with longer time horizons (Torres, 2007). To control for the present heteroscedasticity, we use the robust (Huber-White) standard errors. This option substitutes a robust variance matrix calculation for the conventional calculation, which makes our regression less unbiased and more consistent. Furthermore, even though it is not optimized for panel data, we have tested for multicollinearity by utilizing the Variance Inflation Factor (VIF) test. The variables are usually said to be prone to multicollinearity if the test statistic exceeds 10 (see *appendix D* for VIF-tests).

3.1.3 A new approach: Constructing a market indicator from microdata

Using microdata to explain the freight rates, recent literature has implemented a market index as a variable to account for the underlying market conditions. For instance, Alizadeh and Talley (2011a) includes the logarithm of the BDTI as a market indicator, to account for the existing market conditions. By construction, BDTI fails to capture the differences in vessel size and geographical regions, and by using it as a market proxy, it may bias the results. Agnolucci et al. (2014) introduces a Time Charter Benchmark Rate as their macroeconomic factor, when assessing the allocation of fuel savings in the Panamax market. Adland et al. (2016) calculated the average of TD1 and TD3 as their market proxy, when investigating charterer and owner fixed effects' and match effects' impact of the VLCC spot freight rates. However, as the dominant trade in their paper was from the

Persian Gulf to Asia, the constructed market proxy fails to properly reflect the real route composition.

We have adopted this traditional methodology mentioned above, in section 3.1.2. However, such an approach may result in some problems, as the market index should by construction be based on the fixtures observed in the market. This leads to a circularity problem where micro factors may be underestimated, as some of their influence should already be picked up by the market index. Characteristics describing market participants, as well as the fleet of the vessels, are changing over time. Such changes of unobserved heterogeneity are not being picked up by these market indices. Ideally one would like to open the ”black box” of the market index, and try to investigate what actually influences the average price. We are therefore in this section aiming to construct a time-series market indicator on the basis of our raw data, and thereby to a larger degree assess the importance of energy efficiency. This market indicator will be controlled for time fixed effects, charterer and owner fixed effects, as well as contract- and ship-specific variables, an idea gathered by Adland et al. (2016). We use the same contract- and ship-specific variables as presented in section 3.1.1.

3.1.4 Fixed effects model

For the presentation, let F_{covi} be the freight rate observed for a fixture F_i signed between charter c and owner o for a vessel v. To simplify the notation, we will use F_i across specifications. Each fixture i occurs at a given date t, following that notation i refers to $i(t)$. Our starting point of obtaining this time-series market indicator is to calculate the monthly average of our fixture freight rates. This makes us able to control for the time-fixed effects on a monthly basis. Without any constant, we estimate the following linear model:

$$F_i = \sum_{t=1}^{T} \delta_t I_t + \varepsilon_i \tag{7}$$

with I_t as a dummy variable such that $I_t = 1$ for time unit t and $I_t = 0$ otherwise, and ε_i is a random perturbation, known as the error term, such that $E(\varepsilon_i) = 0$ and $Var(\varepsilon_i) = \sigma^2$. In (7), the various coefficients δ_t (with $t = 1, ..., T$) correspond to the average freight rate for each time unit t.

The set of coefficients δ_t now provides us with a time-series market indicator, controlled for the time fixed effects. With this model as a baseline, we are able to control for the observed and unobserved heterogeneity by introducing ship and contract-specific variables, as well as charter and owner fixed effects. Firstly, we want to account for the contract and ship-specific characteristics.

$$F_i = \sum_{t=1}^{T} \delta_t I_t + \sum_j \theta_j R_{i,j} + \sum_j \omega_j S_{i,k} + \varepsilon_i \tag{8}$$

where $R_{i,j}$ is the set of j contract-specific variables, while $S_{i,k}$ is the set of k ship-specific variables. In equation (8), the set of coefficients δ_t now provides us with a time-series market indicator, controlled for the time fixed effects and ship and contract-specific variables.

Even though we have accounted for the influence given by some of the characteristics regarding the market indicator, the impact of market participants on the freight rate has yet to be assessed. Specifically, the role played by time-invariant unobserved heterogeneity of charterers and owners when a fixture is fixed, are likely to have an effect on the formation of the individual freight rate over time. The latter is confirmed by Adland et al. (2016). This leads us to our last specification, and we denote the two heterogeneity terms specific to the charterer c and owner o, by γ_c and ω_o respectively. When the number of owners and charterers is not too high, as in our dataset, we estimate the following two-way fixed effects regression, originally presented in Abowd et al. (1999):

$$F_i = \sum_{t=1}^{T} \delta_t I_t + \sum_j \theta_j R_{i,j} + \sum_j \omega_j S_{i,k} + \sum_c I_c \gamma_c + \sum_o I_o \gamma_o + \varepsilon_i \tag{9}$$

where I_c and I_o are dummy variables associated with the various charterers and owners, respectively. The set of coefficients δ_t obtained from equation (9) provides time averages of freight rates, net of the vessel's, charterer's and owner's observed and unobserved heterogeneity. Unlike our model presented in section 3.1.2, we are now dealing with fixed effects specifications, which means that we allow for some correlation between either the charterer or owner fixed effects, and the set of contract- and vessel characteristics. This may for instance relate to an oil major as a charterer who have preference for larger ships.

3.2 Assessing the determinants of observed speed

In order to investigate what influences the observed sailing speed for each vessel in our data set, we estimate a multiple regression model, which includes macro- and ship-specific variables. In this way, we are able to assess whether less energy efficient ships are slowing down their speed to compensate for lower technical specifications. *Table 2* presents the descriptive statistics, including the coefficients' expected sign, unit of measurement where applicable, and their respective interpretations.

Table 2: List of variables: Observed speed

Variables	Exp.sign	Unit	Explanation
Dependent variable:			
Observed speed		knots	Observed speed for each vessel
Macro-specific:			
Market proxy	+	WS	TD3 benchmark(PG-Japan), matched with each fixture
Fuel 380	-	$/tonne	Fuel price at Fujairah at loading date
Ship-specific:			
Cargo	-	tonnes	Tonnes of oil carried
Design speed	+	knots	Listed speed capacity
Nominal consumption	-	tonnes/day	Listed nominal consumption
FEI Nominal	-	g/tonnemile	FEI=(Cons./(DWT*Design Speed*24))

Source: Authors' expectations and explenations

Regarding macro factors, the actual speed for each vessel is likely to be influenced by the freight rates, and we have therefore implemented a market proxy. As freight rates increase, suggesting a stronger market, the vessels are expected to sail at a higher speed. These expectations are based on economic rationality, as the value of time exceeds fuel savings in times with high freight rates. Furthermore, we expect that an increase in the fuel price, all else equal, will reduce the actual sailing speed.

Moving to ship-specific variables, we expect a vessel with a larger cargo to be more fuel intensive due to its weight and draught condition. Therefore it is intuitive to think that vessels with larger cargoes compensate for higher fuel consumption, by slowing down their speed. The *design speed* refers to the speed of which the vessel is designed to sail at. It is expected that the real operating speed is positively related to the vessel's design speed. To measure a vessel's technical efficiency, we have relied on the *nominal consumption* and the vessel's fuel efficiency index, in nominal terms (*FEI Nominal*). We expect a negative relationship between energy efficiency measures and observed speed, as one would think that less energy-efficient vessels compensate for lower technical specifications by slowing down their speed. As mentioned, a higher reading of the energy efficiency variables, denote lower efficiency.

3.2.1 Regression model of observed speed

To explain the determinants of the observed speed for vessel i at time t, we estimate various specifications of the following general model:

$$V_{i,t} = \beta_0 + \beta_1 I_{j,t} + \sum_j \omega_j S_{i,k} + \varepsilon_i \tag{10}$$

where $V_{i,t}$ is the observed speed of the *i*th vessel at time t. β_0 represents the unobserved effect. $I_{j,t}$ is the set of j macro-specific variables, while $S_{i,k}$ is the set of k ship-specific variables. Lastly, ε_i is a random perturbation, known as the error term, such that $E(\varepsilon_i) = 0$ and $Var(\varepsilon_i) = \sigma^2$

Like in section 3.1.2, we are also here using panel data techniques, in order to account for the individual heterogeneity of ships, which is constant over time. Therefore, we are in this section, applying the same econometric tests, as well as controlling for heteroskedasticity.

4 Data

4.1 Data preparation

Our dataset, provided partly by Clarkson Research (2016), contains 6,474 fixtures before data cleansing. The sample covers VLCC fixture information between January 2013 and September 2016. After sorting for fixtures reported in Worldscale, the dataset was reduced to 3,633 observations. As mentioned in section 1, we have focused on routes between the Persian gulf and East Asia. These fixtures were combined with AIS data, kindly provided by ORBCOMM, ending up with a dataset of 1,007 observations between 3. January 2013 and 24. February 2016.

Clarkson (2016) provided the vessel specifications of 686 vessels in the VLCC fleet between 3. January 2013 and September 30. 2016. The chosen attributes for each vessel are listed below:

- Vessel name: (100%)
- Status (in service, storage, or laid up) (100%)
- Build year (100%)
- Deadweight (100%)
- Engine model (100%)
- Design speed (81.34%)
- Consumption (40,23%)

The data collected from Clarkson's was in some cases incomplete, mainly regarding the ship's nominal consumption, and in order to gain a sufficient sample size we had to make some assumptions. First, we identified the main engine used by the vessels with missing consumption data, and compared them with an identical, or nearly identical, engine which had the data provided. In order to get the most accurate results possible, we also took into account both the age and DWT of the ships. This process is likely to have introduced some measurement errors, but we believe the alternatives to have even greater shortcomings for our analysis. Still, we were in some cases unable to fill in the missing data, especially in cases dealing with rarely used engine models. Unfortunately, we had to exclude these fixtures in order for us to not compromise the results of our thesis. See *appendix A* for a more detailed data cleansing process.

4.2 Data description

Table 3 below summarizes the descriptive statistics for our variables, categorized by the dependent variable, macro variable, contract variables and ship specific variables. In addition, we have provided a correlation matrix between the variables, presented in *appendix B*.

Table 3: Descriptive statistics

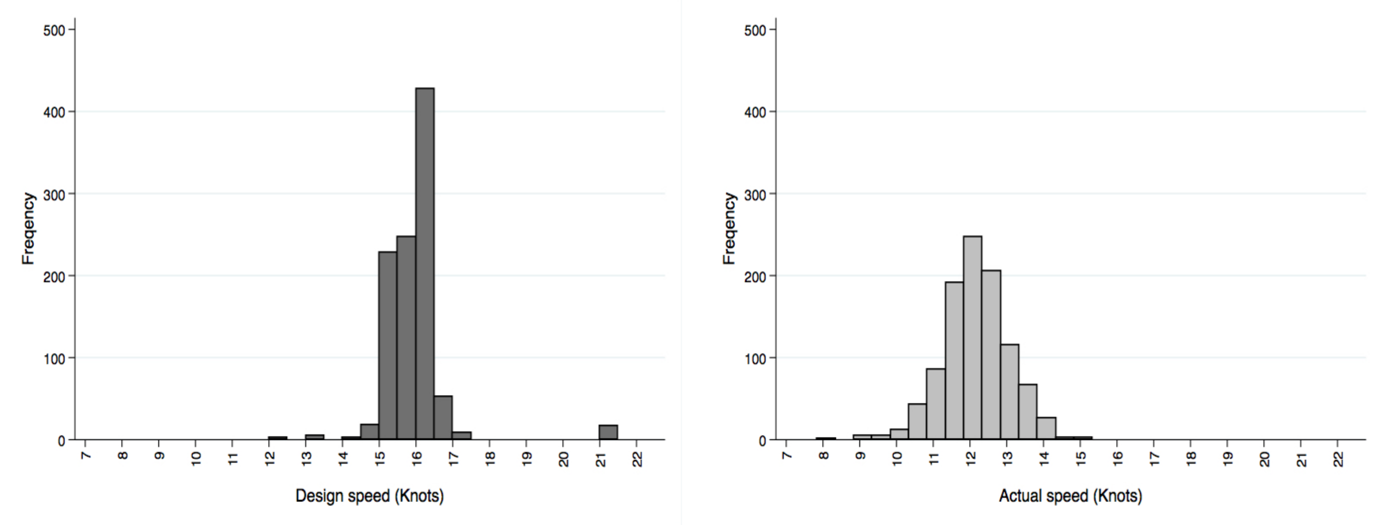
Variable	Obs.	Mean	Std.dev	Min	Max
Contract rate(WS)	1007	50.2	13.9	26.5	95
Market proxy (TD3)	1007	51.01	14.58	28.82	115.7
TD2_D	346				
Forward days	1007	15.7	3.79	0	34
DWT	1007	306,635	10,709	265,539	323,182
Age	1007	10.69	4.95	1	22
Age^2	1007	138.74	109.74	1	484
Load Factor	1007	88.07	3.24	81.28	101.68
Est. Cons.	1007	46.54	11.19	13.93	89.05
FEI Actual	1007	0.52	0.1	0.3	1.03
Fueltonne	1007	1.46	0.62	0.22	3.57
Slow-steaming statistics:					
Observed speed	1007	12.17	0.87	8.09	15.06
Design speed	1007	15.82	0.93	12.25	21.50
Nominal Cons.	1007	93.75	12.16	65.00	120.00
FEI Nominal	1007	0.81	0.10	0.53	1.05

Source: Authors' calculations, data from Clarkson Research and ORBCOMM

The monthly mean freight rate of the observed fixtures is WS50, with a minimum of WS26.5 and a maximum of WS95. This is very similar to our market proxy with a mean of WS51, and a minimum of WS28.82 and a maximum of WS115.7. We also note from the correlation matrix that the two are highly correlated (96%), which indicate that the micro determinants are not likely to add much of additional explanatory power. *Table 3* reports that 346 of 1007 fixtures had South East Asia as their place of delivery, which accounts for about 34% of all transactions. The rest had North East Asia as their place of delivery. Regarding the lead time for the transactions, the fixtures were on average fixed about 16 days prior to the first laycan day, varying from zero (0) days as the minimum, to 34 days for the longest lead times. The mean size of the VLCCs is a deadweight tonnage of about 306,000, and the average size of the cargo carried is 270,000, which contributes to an average vessel utilization ratio of about 88%. Average vessel age is 10 years, and a weak correlation with forward days, suggests that older vessels tend to have longer lead time than younger vessels. Moreover, age is highly negatively correlated with DWT, implying that newer vessels seem to have a larger transporting capacity than older vessels. The average fuel costs per tonne cargo carried is 1.46 $, with a minimum of 0.22 $/tonne and a maximum of 3.57 $/tonne. A highly negative correlation with the contract rate, suggests that lower fuel costs, i.e. higher fuel efficiency, attracts higher freight rates in the market.

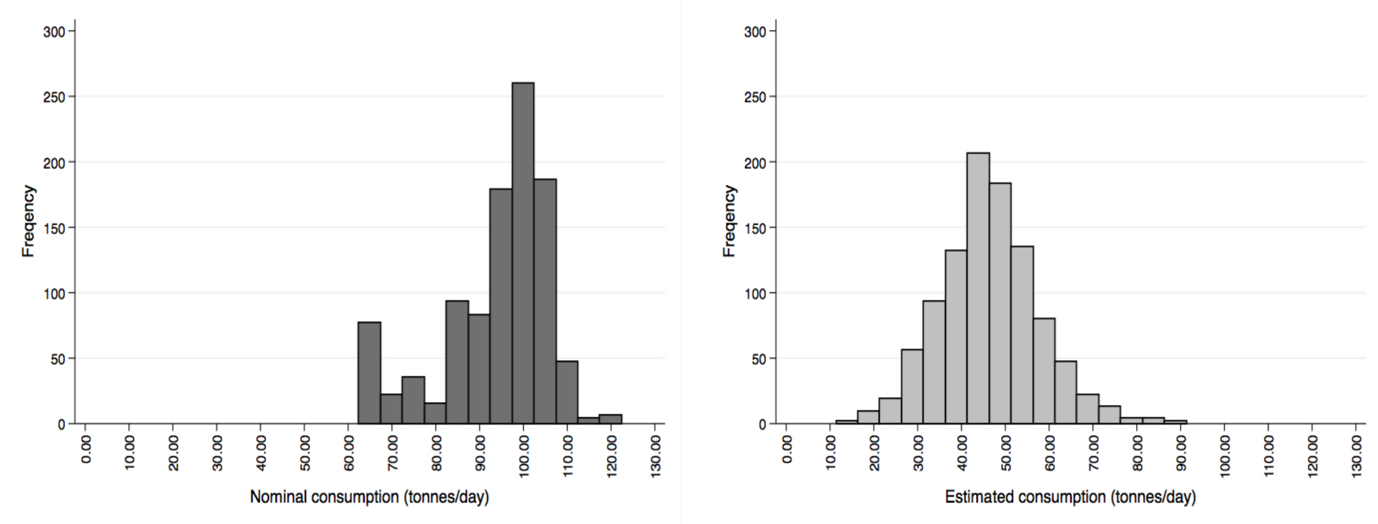
Figure 1 illustrates the distribution of the design speed compared to the actual observed speed, for the fleet in our dataset. We notice that the design speed of most ships falls between 15 and 17 knots. An interesting observation is that the observed actual speed for the fleet is noticeably lower, centered around 12 knots. Furthermore, *Figure 2*, illustrates how the speed affects consumption. Nominal consumption is based on the design speed, which results in a significantly higher consumption than when calculated using actual operational speeds. This shows that research based on nominal values may give unreliable results.

Figure 1: Design speed vs. Actual speed



Source: Authors' calculations, data from Clarkson Research and ORBCOMM

Figure 2: Nominal consumption vs. Estimated consumption



Source: Authors' calculations, data from Clarkson Research and ORBCOMM

Table 4 lists the top-10 owners and charterers for all of the VLCC fixtures. The top-10 charterers represent approximately 73% of all fixtures, while the top- 10 owners only account for 43% of the 1007 transactions. As discussed in section 3.1.4, the large shares captured by each of the 10 largest market participants, for both charterers and owners, may indicate that attributes such as bargaining power may have an impact on the freight rates.

Table 4: Top-10 charterers and owners

Charterer	Fixtures	Percentage	Cumul.	Owner	Fixtures	Percentage	Cumul.
Unipec	166	16.48	16.48	SK Shipping	79	7.85	7.85
PTT	100	9.93	26.42	Maran Tankers Mngt.	60	5.96	13.80
Chevtex	98	9.73	36.15	Altomare S.A.	49	4.87	18.67
S. Oil	91	9.04	45.18	Ocean Tankers	48	4.77	23.44
Shell	60	5.96	51.14	Ship Finance Inter.	43	4.27	27.71
Hyundai	54	5.36	56.50	Shpg Corp Of India	34	3.38	31.08
Day Harvest	52	5.16	61.67	Mitsui & Co. Ltd.	32	3.18	34.26
Glasford	45	4.47	66.14	Eastern Med. Mar.	31	3.08	37.34
Formosa	36	3.57	69.71	Aelos Management	29	2.88	40.22
CPC	33	3.28	72.99	Dynacom Tankers Mngt.	28	2.78	43.00
Other	272	27.01	100.00	Other	574	57.00	100.00
TOTAL	1007	100.00		TOTAL	1007	100.00	

Source: Authors' calculations, data from Clarkson Research

5 Empirical results

5.1 Estimation results using a market proxy

Table 5 presents the results of the voyage rate determinants, using equation (6).

Table 5: Random effects results

Variables	(1)	(2)	(3)	(4)
Market Proxy	0.9175***	0.9136***	0.9136***	0.9059***
	(0.000)	(0.000)	(0.000)	(0.000)
Forward Days		0.0478	0.0477	0.0548
		(0.156)	(0.157)	(0.113)
DWT/1000		-0.1217***	-0.1210***	-0.1267***
		(0.001)	(0.001)	(0.000)
Age		0.0605	0.0614	0.0616
		(0.639)	(0.631)	(0.626)
Age^2		-0.0071	-0.0071	-0.0074
		(0.189)	(0.183)	(0.155)
Load Factor*100		-0.3772***	-0.3779***	-0.3895***
		(0.001)	(0.001)	(0.001)
TD2_D		1.3619***	1.3634***	1.2077***
		(0.000)	(0.000)	(0.001)
Est. Cons.		0.0037		
		(0.754)		
FEI Actual			0.5000	
			(0.705)	
Fueltonne				-0.3470
				(0.278)
Constant	3.7710***	73.4216***	73.1695***	77.0952***
	(0.001)	(0.000)	(0.000)	(0.000)
R-squared within	0.9233	0.9254	0.9254	0.9255
R-squared between	0.9110	0.9173	0.9173	0.9173
R-squared overall	0.9185	0.9229	0.9229	0.9230
Hausman test (p-value)	0.5510	0.3258	0.3269	0.3528
Mean VIF	1.00	10.13	10.11	10.25
Observations	1,007	1,007	1,007	1,007

Source: Authors' calculations, data from Clarkson Research and ORBCOMM

Robust p-values in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Before adding any additional explanatory variables, the market proxy with a significance level of 99% explains 91.85% of the variation in the voyage rate. As expected *a priori*, the independent variables added to our regression only provide a marginal increase in the explanatory power, by approximately 0.45%.

Our estimate for the delivery lead time (Forward days), suggests that charterers are willing to pay a higher freight rate when the time between fixing the ship and delivery is increasing. However, our results prove no significance in any of our regressions. The South East Asia premium of about 1,3 WS points, is significant at a 99% level for all of our specifications. One might be tempted to assume that owners should prefer to charter out vessels in the South-eastern region of Asia, but our estimates may be biased due to measurement errors being picked up by not matching each port pair with its corresponding WS rate. Regarding the vessel size in terms of DWT, our result proves a discount in the freight rates for larger vessels with a significance level of 99% across all specifications. This as we expected, and in line with the results reported by Tamvakis and Thanopoulou (2000).

The load factor has a significant impact on the freight rate at a 99% level. The results indicate a negative relationship between the load factor and the spot rate. This is also in line with our expectations according to the theory of economies-of-scale, as the marginal cost of transporting an extra unit of oil, is expected to decrease. This theory holds, assuming that owners give some of the savings due to economies-of-scale to charterers, which apparently they do. Furthermore, our results show no evidence that a younger fleet attracts a premium in the spot freight rates.

Regarding energy efficiency, none of our measures proved to be significant, which implies that we are unable to confirm our two-tier market hypothesis caused by an efficiency premium.

5.2 Estimation results using time fixed effects

We have utilized three different specifications, as described in section 3.1.3: (1a and 1b) OLS using monthly time-dummies only – Equation (7); (2a-2c) adding contract- and vessel characteristics – Equation (8); and (3a-3c) adding a charterer fixed effect and an owner fixed effect - Equation (9). *Table 6* presents our estimates of the voyage rate determinants in the VLCC market using equation 7 (1a) and equation 8 (2a-2c).

Table 6: Fixed effects results

Variables	(1a)	(2a)	(2b)	(2c)
Forward Days		0.2222***	0.2227***	0.2241***
		(0.000)	(0.000)	(0.000)
DWT/1000		-0.2022***	-0.2037***	-0.2055***
		(0.002)	(0.002)	(0.001)
Age		0.0736	0.0778	0.0852
		(0.676)	(0.659)	(0.629)
Age^2		-0.0113	-0.0117	-0.0123
		(0.139)	(0.128)	(0.111)
Load Factor*100		-0.5952***	-0.5987***	-0.5992***
		(0.004)	(0.004)	(0.004)
TD2_D		2.0727***	2.0854***	1.9397***
		(0.000)	(0.000)	(0.000)
Est. Cons.		0.0072		
		(0.677)		
FEI Actual			0.1541	
			(0.938)	
Fueltonne				-0.3106
				(0.545)
Constant	39.6429***	150.7193***	151.7597***	153.1759***
	(0.000)	(0.000)	(0.000)	(0.000)
Monthly dummies	YES	YES	YES	YES
Charter fixed effects	NO	NO	NO	NO
Owner fixed effects	NO	NO	NO	NO
R-squared	0.8306	0.8419	0.8418	0.8419
Observations	1,007	1,007	1,007	1,007

Source: Authors' calculations, data from Clarkson Research and ORBCOMM

Robust p-values in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Our first specification in column 1a, shows, according to our expectations that our monthly time-dummies dominate in terms of explanatory power (R-squared). However, compared to the first specification in *table 5* where the market proxy explained 91,85% of the variation in the spot rate, the monthly time-dummies have a lower explanatory power of 83,06%. This implies that our new model does not let a "black box"third-party market index, which may include some of the heterogeneity effects that we want to find, influence the results. In other words, it allows us to shed light on what actually determines the freight rates in the VLCC market.

In column (2a-2c), we add the contract- and vessel specific determinants, which leads to an increase in R-squared by a little more than one percentage point (from 0,8306 to 0,8419) compared to the case where only time fixed effects are considered. Hence, R-squared increases more from column (1a) to (2a-2c) in this model, compared to the same exercise in *table 5*. All variables, which proved significant in section 5.1, are still significant, and their coefficients are bigger in absolute values across all specifications. In addition, our lead time-variable (Forward days) has become significant at a 99% level. By increasing the lead time with one day, the spot rate increases by 0,22 WS points. The sign of the coefficient contradicts what we expected as discussed in section (3.1.1). However, this may be explained by the underlying market conditions, where the charterer may gain by waiting an extra day, as the freight rates may be expected to increase. As expected, by introducing the time-dummy variables, each independent variable has been given higher influence regarding the freight rate.

As in section 5.1, none of our energy efficiency measures are proving any significance, so we are still not able to find any evidence of an efficiency premium in the VLCC spot market.

Finally, *table 7* presents the results after adding a charterer fixed effect and an owner fixed effect using equation 7 (1b) and equation 9 (3a-3c):

Table 7: Fixed effects results with charter and owner fixed effects

Variables	(1b)	(3a)	(3b)	(3c)
Forward Days		0.3049***	0.3061***	0.3106***
		(0.000)	(0.000)	(0.000)
DWT/1000		-0.0539	-0.0569	-0.0599
		(0.555)	(0.532)	(0.507)
Age		0.2804	0.2735	0.2774
		(0.299)	(0.312)	(0.299)
Age^2		-0.0148	-0.0148	-0.0152
		(0.196)	(0.197)	(0.180)
Load Factor*100		-0.1734	-0.1652	-0.1906
		(0.547)	(0.565)	(0.505)
TD2_D		0.9456	0.9428	0.2847
		(0.121)	(0.122)	(0.681)
Est. Cons.		-0.0258		
		(0.240)		
FEI Actual			-4.4559	
			(0.105)	
Fueltonne				-1.5073**
				(0.026)
Constant	35.7117***	65.2601	66.7176	70.9624
	(0.000)	(0.205)	(0.194)	(0.165)
Monthly dummies	YES	YES	YES	YES
Charter fixed effects	YES	YES	YES	YES
Owner fixed effects	YES	YES	YES	YES
R-squared	0.8654	0.8701	0.8703	0.8705
Observations	1,007	1,007	1,007	1,007

Source: Authors' calculations, data from Clarkson Research and ORBCOMM

Robust p-values in parentheses, *** p<0.01, ** p<0.05, * p<0.1

This leads to a further increase in the R-squared by 2,86% compared to the case where only time fixed effects and contract-and vessel characteristics are considered (from 0.8419 to 0.8705). This suggests that observed and unobserved characteristics of both charterers and owners play important roles in the determination of the freight rates. After adding charter and owner fixed effects, all of the independent variables that proved significant in *table 6*, have become insignificant. The only exception is Forward Days, which still is significant at the 99% level and has an even larger coefficient. The reason why some of our variables are losing their significance may be explained by charterers' and owners' preferences. For instance, charter A may have preferences for efficient ships, and charter B may deem other vessel specifications as more important, and thereby, indirectly have preferences for inefficient ships. Hence, the correlation between the charterers' unobserved heterogeneity and the vessels' characteristics, "steals" some of the other variables' significance, when controlling for charterer's and owner's fixed effects.

Figure 3: Monthly market indices of the VLCC spot freight rates

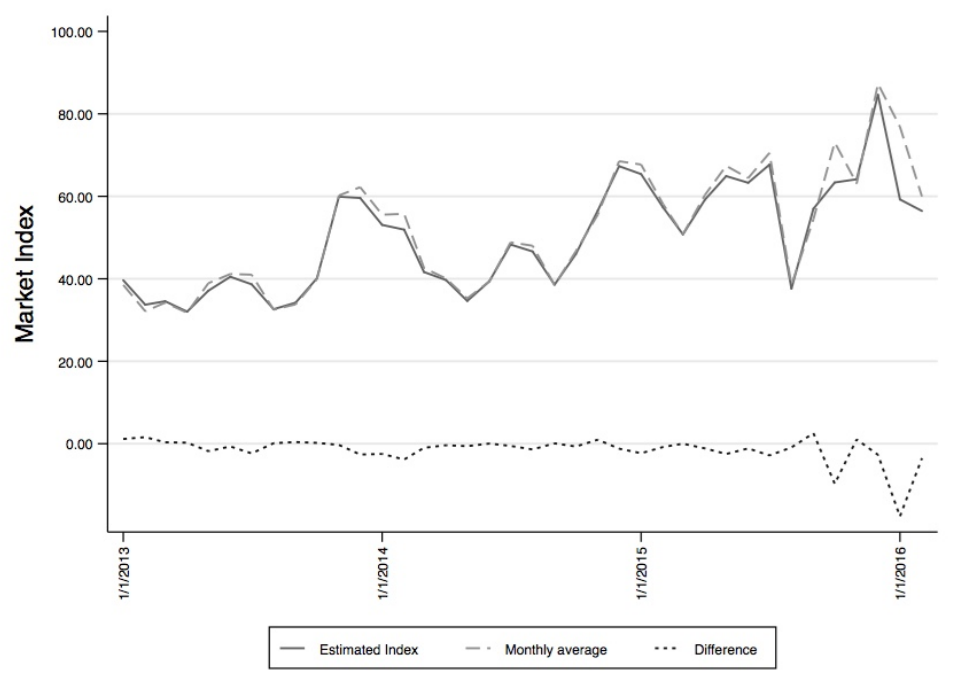


Figure 3 illustrates our constructed market indicator, net of the vessel's, and charterer's and owner's observed and unobserved heterogeneity.

Furthermore, by looking at our energy efficiency variables, some interesting inferences can be made. None of our energy efficiency variables have proved any significance yet, but after controlling for charterer and owner fixed effects, our efficiency variable (Fueltonne) becomes significant at the 95% level. Together with Estimated Consumption and FEI Actual, they are all having a negative coefficient, which implies a discount in the market for more inefficient ships. The fact that Fueltonne proves to be significant, suggests that there may exists an efficiency premium in the VLCC spot freight rates, when controlling for time fixed effects, contract- and ship specific characteristics, and charterer and owner fixed effects.

5.3 Estimation results of the observed speed

Table 8 presents the results of our estimations. For the sake of consistency throughout our thesis we are again starting by estimating a simple macroeconomic model, and then compare it with an extended model, which includes ship-specific variables.

Table 8: Estimation of the observed speed

Variables	(1)	(2)	(3)
Market Proxy	0.0046**	0.0048**	0.0048**
	(0.049)	(0.039)	(0.038)
Fuel380	-0.0009***	-0.0010***	-0.0010***
	(0.000)	(0.000)	(0.000)
Cargo		-0.0301***	-0.0302***
		(0.001)	(0.001)
Design speed		0.1305***	0.0933**
		(0.001)	(0.036)
FEI Nominal		0.7541**	
		(0.020)	
Nominal Conssumption			0.0056**
			(0.045)
Constant	12.3608***	17.8284***	18.5267***
	(0.000)	(0.000)	(0.000)
R-squared within	0.0543	0.0677	0.0682
R-squared between	0.0767	0.1130	0.1102
R-squared overall	0.0593	0.0839	0.0810
Hausman test(p-value)	0.3522	0.6349	0.5293
Mean VIF	1.87	1.36	1,41
Observations	1,007	1,007	1,007

Source: Authors' calculations, data from Clarkson Research and ORBCOMM

Robust p-values in parentheses, *** p<0.01, ** p<0.05, * p<0.1

We acknowledge that the macroeconomic model, included the market proxy and fuel price, has a very low explanatory power (R-squared of 4.03%), though they have their expected signs. We note that "R-squared within" is the variation in the observed speed for a specific ship across time, which is explained by the model, while "R-squared between" reflects the model's ability to explain the changes in speeds across vessels at each point in time.

Our results show progress when adding the ship-specific variables, all of which are statistically significant, however, the explanatory power is still modest. The cargo weight is negatively related to the vessel speed, which is in line with our expectations. The observed sailing speed is, as expected, positively correlated with the ship's design speed, across all specifications. Regarding energy efficiency, both our variables are significant at a 95% level, which suggests that energy-inefficient vessels tend to correspond to higher operational speed. This is surprising as it is intuitive to think that these vessels would slow down to be more competitive in the market. However, this is in line with the findings reported by Adland and Jia (2016), which show a positive relationship between energy inefficiency and observed speed, using EVDI as their nominal efficiency measure.

6 Concluding remarks

The objective of this thesis has been to investigate the two-tier market hypothesis on the basis of voyage charters. Specifically, we have assessed empirically whether more energy-efficient vessels attract a premium in the spot freight rates in the VLCC spot market, for specified routes between 2013 and mid 2016. In a separate analysis, we have examined whether fuel-inefficient vessels, which in theory should have a competitive disadvantage against more efficient ships, compensate by slowing down their speed.

There are some important takeaways from the methodology, and our empirical results. Firstly, we found that the market proxy has the greatest influence on the VLCC freight rates, and is dominating any contract- and ship specific determinants in terms of explanatory power. Some of the micro determinants proved to have a significant impact on the rates, however, none of the energy efficiency variables achieved the same level of significance. Based on these results, we find no evidence of a two tier market with respect to energy efficiency. Secondly, we substituted the market proxy by applying time, charterer and owner fixed effects, which made us able to construct a time-series market indicator net of the role played by observed and unobserved heterogeneity. We then managed to capture changes in the composition of the fleet and the agents over time. Specifically, this method allowed us to shed light on what actually determines the freight rates, by opening the ”black box” of the external freight rate market index. Still, our constructed market indicator is dominating in terms of explanatory power, and excluding efficiency variables, forward days is the only variable which remains significant. The reason why some of our variables are losing their significance, may be explained by charterers' and owners' preferences for different vessel characteristics. In regards to energy efficiency, our results show an evidence of an efficiency premium in the freight rates. Therefore, we find weak evidence for a two-tier market, where more energy-efficient vessels attract higher rates in the VLCC spot market. The emissions from the shipping sector has been increasing the last decades, and are likely to continue to do so. Combined with an evolving attention targeting issues related to global climate change, our findings are important to encourage uptake of more fuel efficient technologies among market participants.

The results from our final analysis show no evidence that inefficient vessels reduce their speed in order to compensate for lower specifications. Actually, our findings suggest that inefficient vessels tend to operate at a higher sailing speed than more efficient ships.

In tanker fixtures reports, it is very common with unreported rates, either through CNR (charterer not reported) or RNR (rate not reported). This has combined with filtering for omitted values related to ship specific characteristics, such as speed (AIS and design) and consumption, reduced our initial sample significantly. Another limitation to our work is that we are prone to failure in accounting for the geographical differences in our sample, because we have only included a single dummy variable representing the respective region for each fixture. The Worldscale of 30 for one route is not the same as Worldscale of 30 for another route, which is only the case for a standardized Aframax[13], and the ideal approach to account for these differences would have been to implement dummies related to each of the port pairs. Furthermore, we acknowledge a limitation within our fixed effects model. In this context, the model by construction assumes an existence of observed and unobserved characteristics which remains constant between owners and charterers over time. Intuitively, one would think that individual characteristics such as size, bargaining power and preferences, may change across time.

Further research within the field of energy efficiency in the tanker spot market is required. In order to establish support of our findings, we think it would be interesting to assess whether the two tier market hypothesis holds in other regions and for other tanker sizes (e.g. Suezmax and Aframax). It would then be natural to include a data set stretching over a longer time period to be able to examine how efficiency variables impacts the rates over a full freight cycle. However, we acknowledge that it is difficult to assess this issue as it is hard to obtain good satellite speed data prior to approximately 2012, though this is a very interesting avenue to be explored. Reduced consumption will benefit both shipowners and environmentalists. Hence, understanding what actually determines the real-life consumption is also an important subject for further investigation. Another potential area to future

[13] See www.worldscale.co.uk for detailed definitions and explanations

research within the field would be to investigate whether certain charterers tend to have repeated transactions with specific owners due to the level of energy efficiency of their fleet. In other words, do charterers care about being green?

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Appendices

Appendix A - Detailed data cleansing

Starting with 6,474 fixtures

- Removal of RNRs (Rate Not Reported) (-2,004 fixtures) and CNRs (Charerer Not Reported) (-184 fixtures)
- Removal of fixtures where rates were quoted in USD (-837 fixtures)
- Narrowing our geographical area of research (-1,704 fixtures)
- Ending up with 1,894 fixtures where only 834 fixtures included nominal consumption
- Filled in for missing consumption based on comparable specifications (+628 fixtures)
- Matched remaining fixtures with ORBCOMM's AIS data (-455 fixtures)
- Finally ending up with 1,007 fixtures

Appendix B - Cost allocation in shipping

Source: Rematullah et al. (2015)

Cost element	**Voyage charter** *$/tonne*	**Time charter** *$/day*
Cargo handling		
Voyage expenses		
Operating expenses		
Capital costs		

Charterer
Owner

Appendix C - Correlation matrices

Correlation matrix 1 : Assessing a two-tier market, variables

	WS	Market Proxy	Forward Days	DWT	Age	Age2	Load Factor	Est. Cons.	FEI Actual	Fueltonne
WS	1.000									
Market Proxy	0.960	1.000								
Forward Days	0.270	0.280	1.000							
DWT	0.038	0.020	0.013	1.000						
Age	-0.140	-0.110	0.053	-0.489	1.000					
Age2	-0.140	-0.110	0.056	-0.491	0.980	1.000				
Load Factor	-0.010	0.020	0.001	-0.958	0.460	0.453	1.000			
Est. Cons.	0.160	0.160	0.043	0.003	-0.184	-0.200	-0.011	1.000		
FEI Actual	0.120	0.120	0.031	-0.171	-0.103	-0.115	0.161	0.956	1.000	
Fueltonne	-0.520	-0.520	-0.028	-0.043	0.001	-0.007	0.017	0.231	0.281	1.000

Authors' calculations, data from Clarkson Research

Correlation matrix 2 : Slow-steaming variables

	Observed speed	Market Proxy	Fuel 380	Design speed	Cargo	FEI Nominal	Nom. Cons.
Observed speed	1.000						
Market Proxy	0.201	1.000					
Fuel 380	-0.238	-0.682	1.000				
Design speed	0.125	0.028	-0.021	1.000			
Cargo	0.054	0.122	0.127	0.003	1.000		
FEI Nominal	0.050	0.009	-0.012	-0.112	0.003	1.000	
Nom. Cons.	0.083	0.024	-0.024	0.359	0.014	0.844	1.000

Authors' calculations, data from Clarkson Research

Appendix D - VIF tests

VIF test random effects results (Est. Cons.)

Variable	VIF	1/VIF
Age2	26.01	0.03844675
Age	25.61	0.03904725
DWT	12.81	0.07806401
Load Factor	12.27	0.08149959
Market proxy	1.14	0.87719298
Forward Days	1.1	0.90909091
Estimated Consumption	1.09	0.91743119
TD2_D	1.02	0.98039216
Mean VIF	10.13	

VIF test random effects results (FEI Actual)

Variable	VIF	1/VIF
Age2	25.88	0.03863988
Age	25.54	0.03915427
DWT	12.9	0.07751938
Load Factor	12.24	0.08169935
Market proxy	1.13	0.88495575
FEI Actual	1.11	0.9009009
Forward days	1.1	0.90909091
TD2_D	1.02	0.98039216
Mean VIF	10.12	

VIF test random effects results (Fueltonne)

Variable	VIF	1/VIF
Age2	25.67	0.03895598
Age	25.49	0.03923107
DWT	12.76	0.07836991
Load Factor	12.25	0.08163265
Fueltonne	1.77	0.56497175
Market proxy	1.67	0.5988024
TD2_D	1.25	0.8
Forward days	1.13	0.88495575
Mean VIF	10.25	

VIF test observed speed results (Macro)

Variable	VIF	1/VIF
Market proxy	1.87	0.53475936
Fuel 380	1.87	0.53475936
Mean VIF	**1.87**	

VIF test observed speed results (FEI Nominal)

Variable	VIF	1/VIF
Fuel 380	1.88	0.53191489
Market proxy	1.87	0.53475936
Cargo	1.02	0.98039216
Design speed	1.02	0.98039216
FEINom	1.01	0.99009901
Mean VIF	**1.36**	

VIF test observed speed results (Nom. Cons.)

Variable	VIF	1/VIF
Fuel 380	1.88	0.53191489
Market proxy	1.87	0.53475936
Design speed	1.15	0.86956522
Nominal consumption	1.15	0.86956522
Cargo	1.02	0.98039216
Mean VIF	**1.41**	