MICROECONOMIC DETERMINANTS OF SECONDHAND VESSEL PRICES

By
Johannes Eckhoff & Kristoffer Dahl Sagmo
M.Sc. in Finance, Norwegian School of Economics,
Spring 2016

Supervisor
Prof Dr. Roar Os Adland

Submitted to the Department of Finance for the fulfilment of the Master
of Science in Economics and Business Administration at the Norwegian
School of Economics. Neither the institution nor examiners are responsible
- through the approval of this thesis - for the theories and methods used,
or results and conclusions drawn in this work.

"Like all good treasure hunters, shipping investors will be out there with their metal detectors in search of hidden treasure." – (Clarksons, 2011)

Abstract

This paper investigates the impact of microeconomic determinants on the second-hand vessel price, using data on actual concluded sales consisting of 2412 Handysize dry-bulk carrier and 398 VLCC tanker transactions. To determine the statistical significance of the microeconomic factors, we analyse observed transactions through the application of a parametric approach, utilizing multiple regression models. We confirm the previous findings in the literature, where market conditions and age largely explain the development in price. In addition, we find evidence that microeconomic factors, namely size, speed, number of holds, horsepower, builder country and fuel efficiency for Handysizes, as well as size and builder country for VLCCs, are significant and add explanatory power to our model. When we assess the interaction between the state of the market and microeconomic factors, we further find that for Handysizes, market players seek certain vessel attributes depending on the state of the market. Additionally, we perform a series of cross validation analyses to examine the predictive accuracy of our model when introduced to new, unseen data. Lastly, we test whether adding microeconomic variables increase the predictive power of our model. We find evidence that our Handysize model, incorporating heterogeneity in vessel characteristics, consistently estimate more accurate results than the benchmark, which tracks the standard vessel price. For VLCCs, the model displays ambiguous results regarding its ability to predict more accurate results than the benchmark.

Contents

Tables

Figures

1 Introduction

The maritime shipping industry is the single most important mean of international transportation. Vessels transport more than 90% of the world's goods, an operation made possible by a commercial shipping fleet of more than 90 000 ships (Clarksons, 2016). Stopford (2009) divides the industry into four markets: 1) the construction of new-builds, 2) the freight market, 3) the market for scrapping of vessels and 4) the sale and purchase of second-hand vessels, also called the S&P-market.

The S&P-market is an auxiliary market in the sense that transactions do not to affect the total fleet size and its dead weight capacity (Strandenes, 2002). The S&P-market allows for easy entry and exit for investors, and as such, simplifies restructurings of fleets and allocations of vessels between ship-owners. Moreover, trade globalization with expanding distances and increasing cargo volumes necessitate a considerable fleet with standardised cargo-handling equipment, which has opened for a high number of buyers and sellers. Because of the cyclical nature of the industry, market players perform asset-plays in order to exploit fluctuations in vessel prices, further boosting transaction volumes.

Due to its close integration with the freight market, the S&P-market is perceived as a competitive market. In the freight market, thousands of vessels deployed by a vast number of operators compete for the same freight contracts with brokers as intermediaries, contributing to a transparent market with well-informed participants (Strandenes, 1998). In disregard to the capital-intensive nature of the business, financing for vessels have remained widely available, further increasing the competitiveness in the market. Wiljnolst & Wegeland (2009) presents two main sources to comparative advantage in the shipping industry, namely economics of scale at firm level and service differentiation. Because of the homogeneous nature and well-functioning, liquid markets, the dry-bulk and crude oil freight markets possess none of these potential comparative advantages, making them ideal targets for empirical analysis of transaction data.

In competitive businesses, superior operating performance and informational advantages are key to succeed. Thus, correct valuation of vessels is crucial to control capital costs and stay competitive relative to peers. The bulk-carrying vessels are perceived as homogenous vessels; however, if one compares vessel characteristics, apparent homogenous vessels display heterogeneity. In fact, vessel specific factors that intuitively should affect the operational performance, and hence, also affect the price achieved in the second-hand market, differ. The interesting question is whether these vessel characteristics affect prices, and to what degree.

The emergence of online ship databases like the ones of Lloyds and Clarkson's have made empirical information on transactions and ship specifications readily available for research. Consequently, a new line of research has emerged, analysing actual concluded sales data from the S&P market to make inferences about price. By computing a comprehensible quantitative model, which in addition to macroeconomic factors, account for microeconomic factors, one could mitigate gaps in information, experience and negotiation skills. Furthermore, standardized valuation methods would result in a more efficient and transparent marketplace for second-hand vessels.

The goal of this paper is twofold. Firstly, we seek to make a realistic model to investigate the empirical influence of microeconomic factors on second-hand vessel prices. In addition, we examine how market players' emphasis on factors change given the state of the market (e.g. boom, trough). We base the model on reported transactions for individually sold second-hand Handysize dry-bulk carriers (Handysize) and very large crude carriers (VLCC). Secondly, we investigate whether our model, incorporating non-standard vessel characteristics, is able to predict more accurate second-hand prices than a model exclusively including the market rate index.

The remainder of this paper is structured as follows. Section 2 includes an exploration of the literature on second-hand ship valuation. In section 3, relevant vessel price determinants are discussed, before a description of the dataset and the discussion of the applied methodology follows in section 4 and 5. Section 6 comprises of the empirical results and a discussion upon the uncertainties concerning the model. Finally, section 7 presents the conclusion and suggestions for further research.

2 Literature review

The literature written on second-hand ship valuation is mainly twofold. One stream of research is devoted to testing the efficient market hypothesis (EMH) in the context of ship valuation, whereas the other seeks to find vessel price through structural models. The latter is split in time-series models and models focusing on raw sales data. In light of our research approach, particularly three questions need to be answered going through the literature. Specifically, (1) whether the market is inefficient, (2) which price determinants are examined in previous research and (3) what modelling techniques are used. The first question is relevant as we do not want our assumptions and variables to contradict a potential efficient market, whereas the second and third has relevance for our choice of model and price determinants.

2.1 Efficient Market Hypothesis

Hale and Vanags (1992) were the first ones to test for market efficiency in the second-hand market. They studied the second-hand prices of three different dry-bulk ship-classes and checked for co-integration. They found it for two of the three ship-classes, suggesting an inefficient market. Glen (1997) revisits Hale and Vanags' research using Johansen's maximum likelihood approach, at the time a new technique to test for co-integration. In his analysis, he expands Hale and Vanags' dataset and includes the tanker market to see if he can discover similar results. Glen finds evidence of co-integration for both dry-bulk and tankers; however, Glen argues that the question whether the second-hand market is efficient, remains unresolved. The co-integration might just as well be a result of a random external stochastic force, rather than actual co-integration of prices.

Kavussanos and Alizadeh (2002) attempt to prove the presence of excess return in the market, which would suggest inefficiency. As proposed by Campbell and Shiller (1988), they use four methods of Vector Autoregressive models and reject the EMH in all but a couple of cases at the five percent confidence interval. Adland and Koekebakker (2004) follow up on this idea by using trading rules to test for excess return. They discover that "trading rules are generally not capable of producing excess wealth above a buy-and-hold benchmark when accounting for transaction costs and the potential price-slippage in an illiquid market"; thus, their paper cannot reject the

EMH. Sødal et al. (2009) also pursue excess return, and applies a theoretical real options model to compare investments in dry-bulk and tankers. They seek to find market inefficiency through excess profits by following particular market switching strategies. Their strategy involved selling dry-bulk vessels and investing in tankers. Apart from one single observation, they found the market to be more or less efficient.

Pruyn et al. (2011) summarizes all extant research performed on second hand ships in the last 20 years. They claim that on the back of varying results, the question of whether EMH holds is still inconclusive. Their main argument being that broker bias makes it more likely that extant literature on efficiency has tested broker's expectations rather than actual market behaviour, due to a lack of underlying data points.

2.2   Econometric Models

The second stream of literature is twofold, with focus on identifying determinants that impacts price and sensible modelling techniques for them.

Charemza and Gronicki (1981) introduce equations arguing that freight and activity rates determine ship prices. Strandenes (1984, 1986) propose similar results stating that vessel prices are a function of expected long- and short-term profits adjusted for depreciation. Both depending on the spot freight rates in the long- and short-term, respectively. Beenstock (1985) also pursue potential interdependency between the freight market and the ship markets. However, in order to do so, he proposes an econometric model. Beenstock and Vergottis (1989a, 1989b, 1992) applies the econometric model to the dry bulk market and the world tanker market. They find that "inter alia, freight rates, lay-up, new and second-hand prices and the size of the fleet are jointly and dynamically determined". Subordinately they find that their tanker market model complements their dry-bulk model and that they are interdependent markets. The main reasons being that (1) combined carriers, which can carry both dry cargo and oil, can switch between tanker and dry cargo markets, and (2) shipyards can choose whether to produce dry bulk vessels or tankers.

Tsolakis et al. (2003) presents an econometric approach to second-hand price modelling. They provide a theoretical error correlation model with a structure based on cyclical businesses, a known feature in shipping economics. They find that both in the short- and long run, newbuilding and timecharter rates have the greatest effect on ship prices.

Adland & Koekebakker (2007) steps away from time-series analysis, side-stepping the problem of broker bias and measurement error. By using cross-sectional sales data directly, they analyse vessel prices through a multivariate non-parametric model. Based on data of Handysize dry-bulk carriers from 1993-2003 they find that vessel price is a function of Deadweight tonnage (DWT), age and the state of the freight market. Part of their conclusion states that by utilizing a non-parametric model, they limit themselves to the use of a three-factor model, which does not fully explain vessel prices. Adland & Koehn (2008) therefore extends Adland and Koekebakker's work by applying a multivariate semi-parametric approach allowing them to include more variables and assume less, possibly revealing more. They use a generalized additive model, and find that the second-hand price determinants for chemical tankers include ship size, age, market conditions, cargo diversity and IMO grade amongst others.

Following the literature, the natural way to bring the research forward is extend the research on second-hand transactions, including new variables to different segments and study their explanatory power on prices. In addition, we seek to maximise the explanatory power and prediction accuracy through the introduction of a market rate index for second-hand vessels. From extant literature, we gather that by applying non-parametric models, not enough variables can be included. On the other hand, by applying semi-parametric models, one assumes less at the cost of requiring a large dataset to be able to infer reliable results. We intend to utilize a parametric approach as we generally expect linear relations to determine the second-hand price, and the potential error that arises from the assumption is small enough to justify the approach. In addition, the approach allows us to infer more about second-hand Handysize and VLCC prices in limited datasets.

Table 2.1 Overview of the extant literature

Year	Author(s)	Testing for	Model	Market	Results/Determinants
Efficient Market Hypothesis					
1992	Hale and Vanags	Co-integration	Granger Causality	Dry bulk:30k,70k,120k DWT	EMH inconclusive
1997	Glen	Co-integration	Johansson's Maximus Likeliness	Dry bulk: 30k, 70k, 120k DWT Tankers: 32k,80k,250k DWT	Co-integration present, however EMH inconclusive
2002	Kavussanos and Alizadeh	Excess profits	Vector Autoregressive Models	Handysize, Panamax, Capesize	EMH inconclusive
2004	Adland and Koekebakker	Excess profits	Trading rules	VLCC, Aframax, Capesize, Panamax	EMH holds in Tanker, fails in Bulk
2009	Sødal et al	Excess profits	Theoretical real options model	Bulk/Tankers: 150k DWT	EMH fails only between 2000-2003
Econometric Models					
1981	Charemza and Gronicki	Interdependency	disequilibrium model	Bulk and tankers	Freight rates and activity rates determines ship prices
1984	Strandenes	Price determinants	OLS	Bulk: Panamax tankers: Medium, large	Spot freight rates
1985	Beenstock	Interdependency			
1989a	Beenstock and Vergottis	Interdependency	3SLS, OLS	Dry bulk	freight market and vessel market jointly determined
1989b	Beenstock and Vergottis	Interdependency	3SLS, OLS	Tankers	Dry bulk and tankers interdependent
2003	Tsolakis et al	Price determinants	Error correlation model	Bulk: Handysize, Panamax, Capesize Tankers: Handysize, Aframax, Panamax, Suezmax, VLCC	NB- and timecharter rates
2007	Adland and Koekebakker	Price determinants	Multivariate non-parametric model	Dry bulk	DWT, Age, Freight market
2008	Adland and Koehn	Price determinants	Semi-parametric generalized additive model (GAM)	Chemical Tankers	DWT, Age, Freight market, IMO grade, Cargo diversity

3 Price Determinants

In this section, we present a broad range of factors that should affect the valuation of second-hand Handysizes and VLCCs. Our choice of microeconomic variables follows the literature on structural models using raw sales data for second-hand valuation of vessels. For completeness, we introduce some additional variables based on economic theory, intuition and our maritime knowledge. Table 3.1 summarizes all variables in our multiple regression models, arranged in macroeconomic, microeconomic and interaction variables. Furthermore, we display the expected sign of the coefficient, the interpretation of the respective variables and whether the variables were included in the previous research of Adland and Koekebakker (2007) and Adland and Kohn (2008).

Table 3.1 Microeconomic price determinants

Determinants	Adland and Koekebakker	Adland and Koehn	Chosen variables	Exp. sign	Interpretation
Macroeconomic variables					
Market rate index	-	-	x	Pos	Age adj. Market rate for the standard vessel
Term structure	-	-	x	-	3year TC - 1year/6month TC
Newbuilding price	-	x	-	-	The contract price of a new ship
Earnings	x	x	-	-	Market rate for standarized vessel
Microeconomic variables					
Age	x	x	-	-	The vessel age
DWT	x	x	x	Pos	Deadweight carrying capacity of ship
Speed	-	x	x	Pos	Vessel design speed
Horsepowers	-	x	x	Pos	Number of horse powers
Fuel consumption	-	-	x	Neg	Fuel consumption at design speed
FEP	-	-	x	Neg	(FC/DWT - average(FC/DWT))*bunker
FEI	-	-	x	Neg	Consumption/(speed*DWT)
Country of build.D	-	x	x	Pos	Dummy for China, S. Korea and "Other"
Engine Manufacturer.D	-	-	x	Neg	Dummy for engine manu. other than B&W
Fuel type.D	-	-	x	-	Dummy for fuel types other than HFO
Handysize specific					
No. Holds	-	x	x	-	Number of holds
Grain capacity	-	-	-	-	Grain carrying capacity
Stowage utilization	-	-	-	Pos	Grain capacity/DWT
VLCC specific					
No. Pumps	-	-	x	Pos	Total number of pumps
PumpCap	-	x	x	Pos	Total pump capacity
Hulld_D	-	x	x	Pos	Dummy for double hull
Barrels	-	-	-	Pos	No. barrels capacity
Interactions					
Boom/Trough_Dwt	-	-	x	Pos	Interaction Boom/trough years w/DWT
Boom/Trough_Speed	-	-	x	Pos	Interaction Boom/trough years w/speed
Boom/Trough_Energy-eff	-	-	x	Pos	Interaction Boom/trough yrs w/energy-efficiency

3.1 Macroeconomic variables

The natural starting point is to include macroeconomic factors, as these should account for most of the explanatory power on the second-hand price. In order to investigate the effects of non-standard vessel characteristics, we include a market rate index representing the standard vessel adjusted for age. The reasoning behind the inclusion of the index follows Alizadeh and Talley (2011), whose idea, transferred to our analysis, suggests that the effects of non-standard vessel characteristics on the second-hand price is defined as the deviation from the observed price and the index.

Figure 3.1 Monthly market rate for a 5-year-old Handysize and VLCC
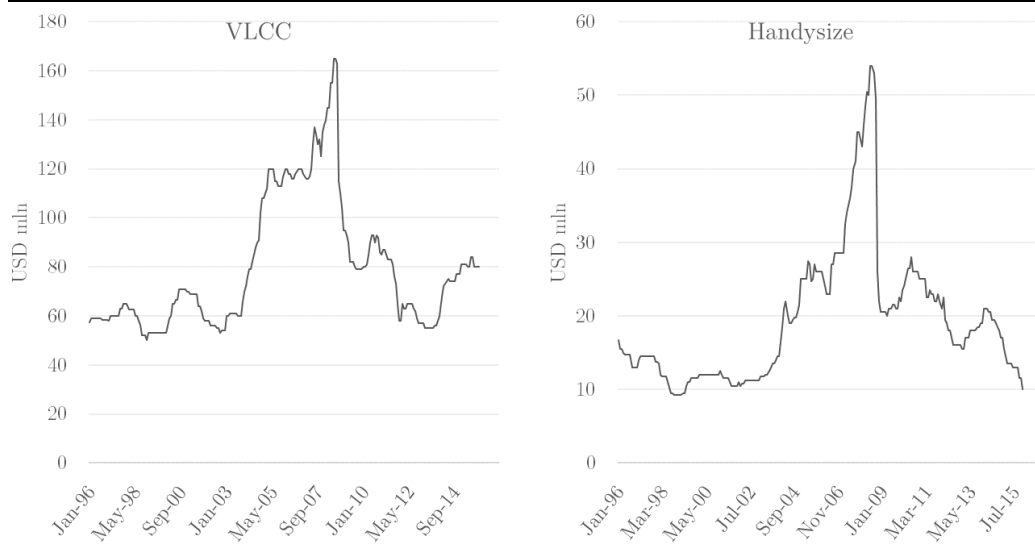
As discussed in Pruyn et al. (2011), former research on second-hand ship valuation have employed monthly estimates on vessel prices from either Clarkson's or Lloyd's Shipping Economist as the market rate for the second-hand price. In accordance with previous research, we define the vessel specific market rate index as the interpolated and extrapolated monthly time-series from Clarkson's on resale, 5-year, 10-year, 15-year, 20-year and scrap prices for a standardised vessel. The rationale is to compute a monthly depreciation curve for each individual vessel, and match the ship with the curve based on the vessel age. The process is conducted in two steps; first, we match the sale date with the second-hand values at the sale-date provided by Clarkson's, and second, adjust for the age of the vessel. The age-adjustment is conducted through interpolation and extrapolation from age zero to scrap age, where scrap age is fluctuating based on the state of the

13

market. We argue that the derived market rate index both reflects the movement of the second-hand prices in respect to macroeconomic factors, and the age-adjusted standardised microeconomic characteristics of a vessel. One benefit with the market rate index is that the piecewise linearity incorporates some of the expected non-linear decrease in vessel operational performance with age. Additionally, we include a proxy for the term structure of the freight market, where its relevance depends on the market efficiency. The 3-year TC-contract should equal the mean of the present value of all daily forward freight rates up to 3 years. However, should the market be inefficient, the question whether the steepness of the term structure affect price arises. We expect the effect to be both statistically and economically insignificant, as the market rate index should incorporate the full term structure. The term structure proxies are calculated based on available time-series on freight rates matching the time-span of the sample and the respective ship-class.

$$Handy\ term\ structure\ proxy = 3y\ TC\ rate - 6m\ TC\ rate \qquad (3.1)$$
$$VLCC\ term\ structure\ proxy = 3y\ TC\ rate - 1y\ TC\ rate \qquad (3.2)$$

3.2 Microeconomic variables

The size of the vessel is important, as more freight capacity should translate into higher timecharter-equivalent spot earnings. We discard the highly correlated grain capacity and barrels for the benefit of the dead weight tonnage (DWT), as it is the standard measure of size in the industry. Please refer to table A.1 and A.2 in the appendix for correlation matrices.

From a ship-owners perspective, quality do matter as it affects operating expenses and the uptime for the vessel in operations. It is a general understanding in the market that ships built in certain countries generally improve or decrease the quality of the vessel. As such, we include dummy variables for perceived quality differences between Chinese, Japanese and South Korean built vessels. We opt for the Japanese built vessels as our benchmark as Japan is the main builder for both ship-classes. Chinese vessels are expected to trade at a discount. Lastly, we believe that results regarding South Korean built vessel could be inconclusive, as the reputation of the Korean shipyards relative to Japanese might have changed over the last 20 years.

We also investigate whether differences in engine manufacturer has an impact on price due to perceived quality differences and/or spare parts availability by inclusion of dummy variables for engine manufacturers. Speed, translating into the design speed on the laden leg, is expected to have a positive effect on the second-hand price. Higher speeds lead to increased ton-miles, boosting earnings in good freight markets. Additionally, more horsepower enhances the vessels ability to keep optimal operating speeds in harsh weather, from which a positive effect is expected on price. Fuel type is included as a dummy variable in order to investigate whether the non-standard and more expensive Intermediate fuel oil (IFO) and Marine diesel oil (MDO) have an effect on the second-hand price.

In later years, owners have put increased emphasis on the fuel efficiency of vessels due to relatively high bunker costs. Hence, we formulate three proxies to check the effect of fuel efficiency on observed prices. Firstly, we include fuel consumption, defined as tons consumed per day at design speed. Secondly, the simplified fuel efficiency index (FEI) effectively measuring fuel consumption on a "grams per ton-mile" basis, as presented by Adland et al (2015).

$$FEI = \frac{Consumption}{DWT*Speed*24} * 10^6 \qquad (3.3)$$

Thirdly, we utilize the fuel efficiency proxy (FEP), defined as the difference between a vessel's fuel expenditure and the sample's average fuel expenditure per DWT:

$$FEP = \left(\frac{Fuel\ consumption_i}{DWT_i} - \frac{\overline{Fuel\ consumtion}}{\overline{DWT}} \right) * Bunker\ cost \qquad (3.4)$$

FEP is normalised for DWT as we observe heterogeneity in vessel size for both ship-classes. Furthermore, we assume that bunker prices follows a random walk process where market players assume that the bunker spot price remain the same ad infinitum (Geman, 2007). All proxies for energy-efficiency are expected to have negative coefficients as high positive readings translate into fuel inefficiency.

Some variables are class-specific for Handysize and VLCCs. The hull type is especially important for tankers due to the possibility of oil-leakage. Hence, international regulations have put restrictions on the use of single-hull tank-

ers from the years after 2010 (IMO, 2016). The current fleet consists exclusively of double hull tankers, however, in the past decades single-hull tankers constituted a considerable part of the fleet. Thus, hull type is added as a dummy variable to our model in the phase-out period, defined as the years 2000-2010 when we expect single hull tankers to trade at an increasing discount to double hull tankers. From 2011, we argue that a double hull tanker fully represents the standardised tanker. In addition, the variables number of pumps and pump capacity should affect port time for tankers, resulting in a potential premium for vessels with many or high-powered pumps.

In our analysis of Handysizes, we include a measure for stowage utilization and number of holds as variables. The stowage utilization describes the vessels ability to maximise the volume of grain transported.

$$Stowage\ utilization = \frac{Grain\ capacity}{DWT} \tag{3.5}$$

The proxy indicates whether the vessel is optimized for DWT or volume in terms of transport. However, one should interpret the variable with caution as variation in vessel design affects the relevance of the variable. Handysizes carry numerous commodities with different stowage attributes, and ships with tailored designs towards volume transport of forest products might yield a poor volume for transport of grain. We expect that vessels with a low reading or "poor cubic" might provide a discount. Moreover, Handysizes trade on regional routes to carry small bulk cargoes, often in parcel size where individual cargo holds carries different commodities. The impact of number of holds is tricky to predict, as it is a trade-off between economics of scale and diversification. Ideally, vessels should have an optimal number of holds, which both allows for some degree of diversification and economics of scale.

Lastly, the well-known cyclicality of the shipping industry implies that cost saving and income enhancing ship attributes should be in demand. Moreover, certain attributes will be especially attractive in troughs and peaks. Potential premiums or discounts depends on the interaction between vessel's specifications and the state of the market at the sale date. We include interaction dummies measuring the effect between the booming markets of the years 2003-2008 for Handysize and 2003-2008 and 2015-2016 for VLCCs together with DWT, speed and fuel efficiency. Size and speed should

be profit enhancing in boom markets with corresponding premiums in price. In addition, we include interaction dummies measuring the effect between the trough markets of the years 1998-1999, 2012 and 2015-2016 for Handysize and 1998-1999 and 2011-2012 for VLCCs, together with DWT, speed and fuel efficiency. The interaction dummies are included for one variable at a time due to the highly correlated nature of the dummies. We expect that the interaction effect on energy efficiency should produce a negative coefficient as owners pursue cost savings in depressing markets. Trough and boom years are determined by observing the time-series on second-hand prices and time-charter earnings.

4 Second-hand transactions data on tankers

The initial datasets obtained from Clarkson Research Ltd. (2016) comprise information of 2930 Handysize and 494 VLCC second-hand transactions over the period January 1, 1996 to March 31, 2016. Both contain information on the contractual specifications and vessel characteristics such as sale date, achieved price, size in dwt, builder country, speed, fuel consumption, horsepower, fuel type, engine manufacturer, in addition to number of pumps, pump capacity, barrels and hull type for VLCC and number of holds, grain capacity, cranes and hatches for Handysize vessels. Moreover, data on year and month of build, enables us to calculate vessel age. After filtering transactions of Handysizes for block sales, untrustworthy foreign currency sales and omitted values for Price, Age, DWT, Speed, number of holds, fuel consumption and fuel type - a total number of 2412 observations remain. Due to the limited number of transactions of VLCC's, we only eliminate transactions that are subject to block sales, vessels outside the class range of approx. 180,000-320,000 DWT and where price, DWT and age are omitted, leading to a total remaining number of 398 transactions. The vessels outside the size-class are omitted as they do not share important characteristics such as trading routes and available ports with the standard VLCC. In particular, we discard the few transactions of Ultra Large Crude Carriers (ULCC) and smaller tankers, which can sail through the Suez-canal.

In addition, Clarkson Research Ltd. (2016) provided weekly prices for Rotterdam 380Cst HFO, and the respective historical time-series on monthly second-hand prices, scrap age by year, monthly scrap prices, and monthly time-charter freight rates for 6-month, 1-year and 3-year for Handysizes and VLCCs. For Handysizes, we opt for the approximately 30k DWT second-hand price time-series as both the mean and median of our sample is close to 28k DWT. Furthermore, we utilize time-series on both second-hand prices of single - and double hull vessels for VLCCs. Please refer to Table A.3 in the appendix for a breakdown of the obtained macroeconomic data.

Table 4.1 Summary of microeconomic descriptive statistics

	Handysize dry-bulk carriers						VLCC tankers					
	No.	Mean	Median	Min	Max	SD	No.	Mean	Median	Min	Max	SD
Market rate index	2412	8.46	6.00	0.60	53.90	7.53	398	49.04	39.00	4.35	185.00	32.86
Term structure	2412	-2.00	-0.10	-22.00	4.00	4.17	398	-3.44	-2.00	-30.00	9.00	7.83
Age	2412	18.17	19.14	0.00	40.73	7.50	398	11.60	12.47	0.00	29.19	7.31
DWT	2412	28120	27887	10095	42208	6585	398	285755	296360	213855	323100	23091
Speed	2412	13.94	14.00	9.30	17.70	0.97	398	15.16	15.15	12.00	21.50	1.03
Horsepower	2412	9080	8740	3300	18700	2070	386	32881	34650	12000	45207	5966
Fuel consumption	2412	25.52	24.00	9.80	58.00	7.08	270	91.99	84.50	51.80	186.00	31.59
FEP	2412	0.00	-0.01	-0.26	0.43	0.07	270	0.00	-0.01	-0.06	0.12	0.02
FEI	2412	2.80	2.60	1.41	8.76	0.78	270	0.89	0.80	0.53	2.23	0.31
No. Holds	2412	4.84	5.00	2.00	10.00	0.81	---	---	---	---	---	---
Grain Capacity	2412	35840	36176	10336	79967	8310	---	---	---	---	---	---
cubic utilization	2412	1.27	1.28	0.00	2.06	0.10	---	---	---	---	---	---
No. Pumps	---	---	---	---	---	---	252	3.46	3.00	3.00	12.00	1.16
Pump Cap.	---	---	---	---	---	---	244	15652	15000	2700	33000	3319
Barrels	---	---	---	---	---	---	300	1990179	2042000	0	3508871	303309
Country of build												
Japan	73%						47%					
S. Korea	4%						38%					
China	6%						8%					
Other	17%						7%					
Engine Manufacturer												
Mitsubishi	24%						9%					
Sulzer	30%						23%					
Man B&W	41%						54%					
Other	4%						14%					
Fuel type												
IFO/MDO	14%						11%					
HFO	86%						89%					
Hull type												
Double hull	---						58%					
Other	---						42%					

Note: Original VLCC dataset is supplemented for missing data through Tradewinds articles and Aukevisser.nl

5 Methodology

As discussed in section 3, there are a broad range of microeconomic variables that should affect the price of a second-hand Handysize and VLCC. This section presents and evaluates the methodologies employed to test the stated microeconomic determinants. We conduct our analysis in two steps. Firstly, we describe the econometric framework for our multiple regression models. Secondly, we present the out-of-sample cross validation conducted in order measure the accuracy of our models' predictive power.

5.1 Cross-sectional analysis

We rely on multiple regression analysis to examine which variables that determine the second-hand price, and to what extent. The model contains numerous relations that we expect to be linear in parameters, advocating the parametric approach. For instance, DWT and the profit potential should display a linear relationship, and brokers tend to assume a linear depreciation down to scrap value. We argue that even in the case of non-linearity, it is a good-enough approximation and that the consequential error is small enough to justify the approach. Furthermore, the parametric model provides coefficients that are easy to interpret and could reveal more about microeconomic determinants in limited datasets at the expense of assumed normality of the residuals, homogeneity of variances and independence of data.

Our datasets are exposed to a time-series dimension, with presence of repeated sales, effectively pointing towards panel data analysis. The distribution of the observations is highly unbalanced through time; however, as there exists a natural order between the observations, the same notions established in the context of time-series applies to our dataset as well. In general, we would therefore want to investigate fixed- (FE) or random effects (RE) models, as unobserved and/or omitted individual fixed effects might affect regressors through the error term, and leave coefficients biased and inconsistent. On the other side, our dataset also possesses elements that argues against the use of panel data methods. Firstly, roughly 40% of Handysizes and 60% of VLCCs are not subject to repeated sales, limiting the potential benefits from utilizing panel data methods. Secondly, the vessel characteristics (e.g. Dwt, Speed, engine, builder country) are almost exclusively time-

invariant, and the FE-model would effectively omit all these essential variables, rendering our model incomplete. Thirdly, we argue that in terms of recurring sales, the market conditions surrounding each sale has likely changed to such a degree that every observation might be perceived as independent from each other. We also find it unlikely that there are prevailing endogenous effects for individual vessels in our model, and we opt for the purely cross-sectional ordinary least squares (OLS) method.

The Gauss-Markov theorem states that OLS is the best linear unbiased estimator (BLUE) if the error terms are expected to be zero, uncorrelated and have equal variances (Wooldridge, 2009). There could be potential weaknesses in our dataset that might violate the key assumptions of parametric models and the Gauss-Markov theorem, resulting in biases and inconsistencies. In order to ensure the robustness of our model of choice, we perform the following diagnostics tests.

First, we want to determine whether the residual errors are normally distributed, and in line with the assumptions of the parametric model with the Shapiro-Wilk test (1965). Calculations of significance tests for the coefficients are based on the assumption of normally distributed residuals, and if the assumption is violated, the significance tests are invalid. One important aspect of vessel valuation is the use of comparable sales by shipbrokers, from which concerns regarding potential serial correlation in second-hand prices appear. We apply the Breuch-Godrey test (1981) to check whether serial correlation is present in our data. Furthermore, issues regarding multicollinearity might arise in the case of correlation between independent variables such as speed and horsepower. Constant relationships between regressors, effectively multicollinearity, could cause biased coefficients as they measure the same. Hence, we inspect the correlation matrices prior to choosing the specifications for our model, along with the variance inflation factors (VIF) in order to ensure that the issue of multicollinearity do not exceed the threshold recommended by Woolridge (2009). Additionally, we test for heteroscedasticity with the Breuch-Pagan test (1979). Heteroscedasticity refers to a situation where the variance of a variable is non-constant over time. In the case of serial correlation between transactions, a period with a high number of concluded sales should lead to a reduced variance in price for the period. The OLS estimator would in the case of heteroscedasticity still be

unbiased; however, the estimated standards errors would be inconsistent. Lastly, we expect outliers in our dataset as we are unable to filter for transactions which are subject to special contractual terms and/or fire-sales. In order to reduce the impact of these observations, we winsorize price relative to the market rate index under the 1st and above the 99th percentile.

Our data stretches over at least one cycle in both the tanker and the dry-bulk freight market. Given the cyclicality of the business, the model should be applicable in both market troughs and peaks. In the state of a market trough, we expect that a convex function for the second-hand price, while in a boom, a concave function would be a better fit. The depreciation of a vessel is expected to fluctuate in accordance with the state of the cyclical freight market, and on average, we expect the level-level model to be an overall better fit.

5.2   Cross validation

The R squared is one of the standard measures of model fit in regression models. The ratio measures the explained variance over the total variance, where a higher ratio translates into better explanatory power. Each time an additional relevant variable is included in a model, an incremental quantity of the dependent variable's variance is explained, and the model's R squared increases. Therefore, complex multiple regression models risk fitting too many patterns, ultimately becoming overfitted. Overfitted models will provide high values of R squared, and be good at explaining that particular dataset, but they will be inaccurate in out-of-sample circumstances, as in the case of predicting new, unseen data.

Cross validation is a method of assessing the accuracy and validity of a statistical model through estimations of the out-of-sample error rate. We apply the one-step-ahead expanding cross validation method to quantify whether our predictions are generalizable, which means that the model is good at predicting unseen data. Our hedonic pricing model should, by default only include historical information regarding the price determinants influence on price. The one-step-ahead method fits our dataset well, as it account for the natural order through time. The procedure with a 50/50 split between training-set and test-set consists of the following steps:

1) The dataset is split in a training-set $(T = N/2)$ and a test-set $(N-T)$, where N is the total number of observations.

2) The observations $1, 2, \ldots, T + i - 1$ are used to estimate the forecasting model.

3) The price of observation $T + i$ is predicted based on the model and repeated for $i = 1, 2, \ldots, N - T$

Please refer to Appendix B for a full break-down of the R code.

We evaluate our model's predictive power in two ways. Firstly, we calculate the residuals by subtracting the predicted prices from the observed prices and graphically analyse how the residual errors change over time. Secondly, we compute the root mean standard error (RMSE), discussed in Chai & Draxler (2014), for both the Handysize and VLCC models and models including the market rate index as an independent variable exclusively (market rate model). Hence, through a comparison of RMSE, we observe whether adding microeconomic variables increase the predictive accuracy of our model.

6 Results

Separate OLS estimates for Handysizes and VLCCs are presented in table 6.1 and 6.2. The tables display our regression models, included variables with their respective t-values and coefficients, the number of observations and adjusted R squared. In terms of diagnostics and robustness tests, the VIF tests find no evidence of serious multicollinearity in our model specifications. In addition, the Shapiro-Wilk test for normality, Breuch-pagan test for heteroscedasticity and Breuch-Godfrey test for serial correlation find that our residuals are normally distributed and non-spherical in all scenarios. To obtain robust standard errors the Newey-West (1978) procedure is applied for all our specifications. Please refer to appendix A.4 and A.5 for test-results on our specific model (8) and (11) specifications.

We apply the General-to-Specific methodology as proposed by Hendry (2000) as our chosen framework. The procedure starts with a general model with a broad range of variables that is subject to a sequential reduction, where likely irrelevant variables are omitted based on the statistical significance of the estimated coefficients. The goal is to minimize informational loss relative to the general model.

6.1 Handysize results

For the most part, our expectations about the variables' influence on the Handysize second-hand price is confirmed by our results. In the following, the results are presented with a focus towards our specific and final model (8). Encouragingly, our market rate index is highly correlated and significant, with a coefficient of 0.863 and significance at the 99.9% level. In other words, the model suggests that a USD 1 mln increase in the market rate index will result in an increase of USD 863k in price. We also find evidence that the term structure has a price-effect, where a USD 1k increase in the term structure translates into a USD 93k discount.

Continuing with the microeconomic determinants, a 1k DWT increase in size increases the second-hand price by USD 151k. Speed also show a significant impact on price with a premium of USD 157k for a 1 knot increase in speed. Surprisingly, the number of holds turns out to be statistically significant at the 95% level and provides a premium of USD 239k for an increase

by one hold. One explanation for the observed premium is the added cargo stowage flexibility from increasing the number of holds. The perceived premiums and discounts for builder country are also present in the data, from which vessels built in China and other countries trade at a discount of USD 2.01 mln and USD 1.06 mln, respectively, compared to South Korean and Japanese built vessels. We argue that, conversely to our expectations, South Korean and Japanese built vessels are of equal quality for the sample. In model specifications (1) through (3), no evidence is found for neither a significant statistical nor economical difference between Japanese and South Korean built vessel. In addition, when we group the two as the benchmark builder from specification (4), the results of the other builder countries remain the same.

Out of our three initial proxies for energy efficiency, both fuel consumption and FEP display significance and a premium for fuel efficient vessels. We opt for the FEP as our chosen variable as it provides the highest adjusted R squared. Another benefit of the FEP compared to fuel consumption is that we sidestep the alarmingly high correlation between horsepower and fuel consumption. The remaining variables, including horsepower, measure of the stowage utilization, non-standard fuel type, engine manufacturer and FEI are all statistically insignificant, and hence, discarded in the sequential steps leading to the specific model (8).

The model specifications (9) through (11) confirm our anticipations that the profit enhancing attributes DWT and speed are more attractive in boom markets with statistically significant premiums of USD 32k for an increase of 1k in DWT and USD 30k for a 1 knot increase in speed. Moreover, we observe that there are discounts for both DWT and speed in trough markets, which coincide with our view that cost-saving attributes are attractive in market troughs. In addition, specification (11) shows, conversely to our expectation, that energy-efficient vessels trades at a discount in trough markets. Furthermore, the results states that there are significant premiums for energy efficient vessels in booming years, which is also in contradiction with our initial expectations. Two main reasons for the discrepancy between our à priori belief and observed results comes to mind. Both the boom in freight rates and commodity prices materialised at the same time in the years of 2003-2008, which might have spurred interest for fuel-efficient vessels due to

high bunker cost. Secondly, the discount in trough markets could be explained by asset players' pursuit for older, and ultimately less fuel-efficient tonnage, which has a greater upside potential due to the perceived convex function of second-hand prices in trough markets.

Table 6.1 Regression results for Handysize models 1 to 11

Model	Coef (1)	t-value (1)	Coef (2)	t-value (2)	Coef (3)	t-value (3)	Coef (4)	t-value (4)	Coef (5)	t-value (5)	Coef (6)	t-value (6)	Coef (7)	t-value (7)	Coef (8)	t-value (8)	Coef (9)	t-value (9)	Coef (10)	t-value (10)	Coef (11)	t-value (11)
Market Rate Index	0.855 ***	39.900	0.858 ***	40.070	0.853 ***	38.833	0.853 ***	38.201	0.853 ***	38.814	0.854 ***	38.388	0.859 ***	41.678	0.863 ***	41.350	0.865 ***	41.071	0.863 ***	41.512	0.857 ***	40.421
Term Structure	-0.090 **	-2.651	-0.088 **	-2.637	-0.100 **	-2.701	-0.100 **	-2.688	-0.100 **	-2.832	-0.100 **	-2.809	-0.096 **	-2.814	-0.093 **	-2.735	-0.008	-0.175	-0.052	-1.206	-0.105 **	-2.971
Size (DTW)	0.188 ***	11.663	0.185 ***	10.439	0.157 ***	10.294	0.157 ***	10.325	0.156 ***	11.274	0.155 ***	11.558	0.151 ***	11.854	0.151 ***	11.822	0.138 ***	10.641	0.150 ***	11.879	0.149 ***	12.103
Speed (Knots)	0.174 **	2.651	0.095 .	1.889	0.166 *	2.489	0.166 *	2.492	0.164 *	2.430	0.168 *	2.544	0.168 *	2.547	0.157 *	2.445	0.176 *	2.796	0.155 *	2.459	0.197 *	3.176
No. Holds	0.282 **	2.742	0.267 **	2.683	0.252 *	2.521	0.252 *	2.515	0.249 *	2.479	0.251 *	2.530	0.234 *	2.460	0.239 *	2.483	0.257 **	2.658	0.249 **	2.582	0.236 *	2.420
HP	0.000	0.177	0.000 .	-1.704	0.000	-0.247	0.000	-0.212	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cubic Utilization	0.484	0.659	0.505	0.670	0.446	0.608	0.451	0.607	0.454	0.622	---	---	---	---	---	---	---	---	---	---	---	---
Country of build other than Japan																						
S. Korea	0.061	0.149	0.093	0.232	0.072	0.179	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
China	-1.967 ***	-5.290	-1.966 ***	-5.262	-1.939 ***	-5.333	-1.948 ***	-5.194	-1.950 ***	-5.157	-1.952 ***	-5.154	-2.030 ***	-5.301	-2.014 ***	-5.289	-1.952 ***	-5.180	-1.983 ***	-5.227	-1.943 ***	-5.290
Other	-1.037 ***	-6.536	-1.040 ***	-6.573	-0.988 ***	-6.316	-0.994 ***	-6.280	-0.999 ***	-6.319	-1.011 ***	-6.407	-1.046 ***	-6.620	-1.057 ***	-6.570	-1.074 ***	-6.667	-1.063 ***	-6.548	-1.111 ***	-6.962
Engine Man. other than B&W																						
Sulzer	-0.200	-1.458	-0.221	-1.588	-0.185	-1.383	-0.189	-1.370	-0.189	-1.358	-0.194	-1.394	---	---	---	---	---	---	---	---	---	---
Mitsubishi	0.194	1.467	0.210	1.601	0.169	1.293	0.161	1.175	0.176	1.183		1.324	---	---	---	---	---	---	---	---	---	---
Other	-0.554	-1.073	-0.544	-1.088	-0.544	-1.052	-0.545	-1.063	-0.554	-1.041		-1.065	---	---	---	---	---	---	---	---	---	---
Fuel Type other than HFO																						
IFO/MDO	0.303	1.497	0.332	1.634	0.303	1.507	0.304	1.498	0.304	1.470	0.304	1.466	0.294	1.440	---	---	---	---	---	---	---	---
Energy Efficiency																						
Fuel Consumption	-0.036 *	-2.193	-0.034	-0.254	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
FEI	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
FEP	---	---	---	---	-3.993 *	-1.924	-3.999 *	-1.925	-4.088 *	-2.336	-4.134 *	-2.380	-4.592 **	-2.658	-4.680 **	-2.715	-5.098 **	-3.017	-4.936 **	-2.994	-1.080	-1.127
Interactions																						
Boom x Dwt	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.032 ***	4.074	---	---	---	---
Trough x Dwt	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-0.009	-1.798	---	---	---	---
Boom x Speed	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.030 *	1.968	---	---
Trough x Speed	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-0.013	-1.340	---	---
Boom x FEP	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-12.543 ***	-4.927
Trough x FEP	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	5.591 ***	4.365
Intercept	-8.306 ***	-6.547	-7.307 ***	-5.751	-7.929 ***	-6.329	-7.934 ***	-6.262	-7.933 ***	-6.448	-7.307 ***	-7.365	-7.262 ***	-7.270	-7.126 ***	-7.341	-7.257 ***	-7.601	-7.160 ***	-7.600	-7.530 ***	-7.671
N	2412		2412		2412		2412		2412		2412		2412		2412		2412		2412		2412	
Adj. R squared	0.9166		0.9164		0.917		0.9171		0.9171		0.9171		0.9167		0.9166		0.9184		0.9169		0.9211	

Note: Significance levels are respectively 0.1% (***), 1% (**), 5% (*) and 10% (.). Standard errors are Newey-West heteroskedasticity and serialcorrelation consistent.

6.2 VLCC results

As a general note, the dataset on VLCC transactions is unbalanced, effectively leading to a differing sample for the different model specifications. Thus, the deviating results might be a consequence of the changing sample rather than the different model specifications. The issue is observable in model specifications (7) and (11), where the samples increase from 176 to 262 and 280 to 398 transactions, respectively. Especially, we observe that country of build nearly loses all statistical significance from model specification (6) to (7). However, the other variables seem to be more or less unaffected by the varying sample, which suggest that the issue beyond the effect on builder country is limited in our data.

We can once again conclude that the market rate index dominates in terms of significance. Our specific model (11) show that a USD 1 mln increase in the market rate index increases the second-hand price by USD 902k. Furthermore, larger VLCCs command a premium in the market in the order of USD 101k for a 1k increase in DWT. We also find evidence that South Korean built vessels command a premium of USD 3.844 mln compared to the Japanese built reference ship. In addition, we observe that Chinese built vessels trades at a discount of USD 7.455 mln. In order to increase and improve our sample and the robustness of our findings for the more specific model specifications, we discard number of pumps and pump capacity in specification (7). However, before discarding the variables, we find slight evidence for a discount with increasing number of pumps. The counter-intuitive result could be explained by a non-linear relationship with the price. More pumps could be beneficial up to a point, before increasing number of pumps becomes a disadvantage due to the poor fit with standardised port infrastructure.

Energy efficiency results are converse compared to Handysizes, with insignificance in the specific model specification (11). The remaining variables, including the term structure, speed, engine manufacturer, pump capacity, fuel consumption, FEP, FEI and single hull are all statistically insignificant, and hence, discarded in the sequential steps leading to the specific model (11). The insignificance of hull type is likely due to a methodological problem between the market rate index and single hull dummy variable in our regression. The market rate index is derived through time-series that represent

both single hull and double hull tankers depending on the sale date. As such, one could argue that the effect of the single hull variable is partly explained by the index. Lastly, both dummy interactions between DWT and boom and trough markets are insignificant, which is contrary to our results for Handysize. We argue that the heterogeneity in regards to size is more evident for Handysizes, which could explain the greater significance.

**Table 6.2 Regression results for VLCC's models 1 to 12**

Model	1 Coef	1 t-value	2 Coef	2 t-value	3 Coef	3 t-value	4 Coef	4 t-value	5 Coef	5 t-value	6 Coef	6 t-value	7 Coef	7 t-value	8 Coef	8 t-value	9 Coef	9 t-value	10 Coef	10 t-value	11 Coef	11 t-value	12 Coef	12 t-value
Market Rate Index	0.889***	21.659	0.867***	22.213	0.889***	21.755	0.889***	21.506	0.892***	21.403	0.904***	23.804	0.901***	27.122	0.908***	28.114	0.910***	30.467	0.905***	32.599	0.902***	39.935	0.808***	36.210
Term structure	-0.080	-0.385	-0.080	-0.581	-0.080	-0.386	-0.079	-0.388	-0.068	-0.335	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Size (Dwt)	0.153**	3.228	0.170**	3.315	0.183***	3.361	0.183***	3.504	0.186***	3.567	0.188**	3.279	0.179***	3.402	0.200***	3.999	0.175***	3.539	0.124***	3.424	0.101**	3.122	0.100**	2.939
Speed (Knots)	-0.365	-0.542	-0.313	-0.468	0.062	0.085	0.085	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
HP	0.000.	-1.728	0.000	-1.366	0.000.	-1.762	0.000*	-2.097	0.000*	-2.214	0.000*	-2.079	0.000*	-1.983	0.000.	-1.834	0.000	-1.328	—	—	—	—	—	—
Total number of pumps	-1.302.	-1.831	-1.247.	-1.761	-1.290.	-1.802	-1.305.	-1.938	-1.345*	-2.145	-1.329*	-2.064	—	—	—	—	—	—	—	—	—	—	—	—
Pump capacity (tpd)	0.000	1.246	0.000	1.423	0.000	1.205	0.000	1.384	0.000	1.403	0.000	1.312	—	—	—	—	—	—	—	—	—	—	—	—
Country of build other than Japan																								
S. Korea	3.526.	1.851	3.650.	1.921	3.456.	1.806	3.452.	1.794	3.210.	1.712	3.080	1.528	3.170.	1.892	3.241.	1.804	3.659.	1.950	3.619.	1.776	3.844*	2.290	3.918*	2.208
China	-9.676***	-3.421	-8.526***	-3.316	-9.799***	-3.447	-9.897***	-3.699	-10.243***	-4.125	-11.059***	-3.916	-7.282.	-1.838	-7.201.	-1.907	-7.728*	-2.290	-7.327*	-2.211	-7.455**	-2.884	-6.622*	-2.346
Other	6.697***	3.547	6.411***	3.496	6.457**	3.336	6.427**	3.148	6.554**	3.117	6.640***	3.359	4.020	1.558	3.703	1.415	4.023	1.584	2.722	1.125	3.748.	1.792	3.681.	1.742
Engine Manufacturer other than M. B&W																								
Sulzer	3.257	1.471	3.208	1.478	3.312	1.493	3.320	1.497	3.344	1.554	3.317	1.572	3.033.	1.773	3.230.	1.831	—	—	—	—	—	—	—	—
Mitsubishi	-3.399	-1.124	-2.877	-1.032	-3.231	-1.103	-3.228	-1.083	-3.532	-1.200	-3.744	-1.368	-3.290	-1.335	-2.537	-0.999	—	—	—	—	—	—	—	—
Other	-3.984	-1.126	-1.282	-0.522	-3.957	-1.163	-3.928	-1.159	-4.751	-1.491	-5.088.	-1.705	-1.817	-0.613	-2.225	-0.782	—	—	—	—	—	—	—	—
Fuel type other than HFO																								
IFO	-0.642	-0.315	-0.632	-0.310	-0.572	-0.280	-0.569	-0.281	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hull type other than Double hull in 2000-2016																								
Single Skin	-3.004	-1.408	-3.430	-1.635	-2.708	-1.248	-2.707	-1.250	-2.906	-1.372	-2.507	-1.265	-2.676	-1.524	—	—	—	—	—	—	—	—	—	—
Fuel efficiency																								
Fuel consumption	0.076*	2.120	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fuel Efficiency Proxy (FEP)	—	—	70.085	1.892	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fuel Efficiency Index (FEI)	—	—	—	—	7.623*	2.242	7.590*	2.319	8.247**	2.727	8.820**	2.749	6.853*	2.232	8.046**	2.656	4.829*	2.033	2.388	1.510	—	—	—	—
Interactions																								
Boom x Dwt	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.004	0.875
Trough x Dwt	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.009	1.118
Intercept	-28.356.	-1.775	-29.443.	-1.890	-43.191*	-2.197	-42.373***	-3.421	-43.011***	-3.550	-43.863**	-3.184	-42.728**	-3.063	-52.741***	-4.375	-45.172***	-3.987	-35.519***	-3.660	-27.327**	-3.162	-27.579**	-3.059
N	175		175		175		175		176		176		262		262		262		270		398		398.000	
Adj. R squared	0.9244		0.9241		0.9244		0.9249		0.9256		0.9260		0.9229		0.9223		0.9201		0.9191		0.9275		0.928	

Note: Significance levels are respectively 0.1% (***), 1% (**), 5% (*) and 10% (.). Standard errors are Newey-West heteroskedasticity and serialcorrelation consistent.

6.3   Cross validation results

The initial split between the training-set and the test-set is set to 50/50 in order to both feed the model with sufficient data and secure wide observation windows. Hence, our test-set consists of the transactions 1207-2412 for Handysizes and 200-398 for VLCCs, which is equivalent to the timespan of July 2005 – March 2015 and April 2006 – March 2015, respectively. Predictions of second-hand prices in the test-set are calculated based on our specific model specifications for both Handysizes (8) and VLCCs (11). The figure 6.3 display the estimated residuals both in absolute values and relative to observed prices from our one-step-ahead expanding cross validation procedure.

Figure 6.3 Prediction error
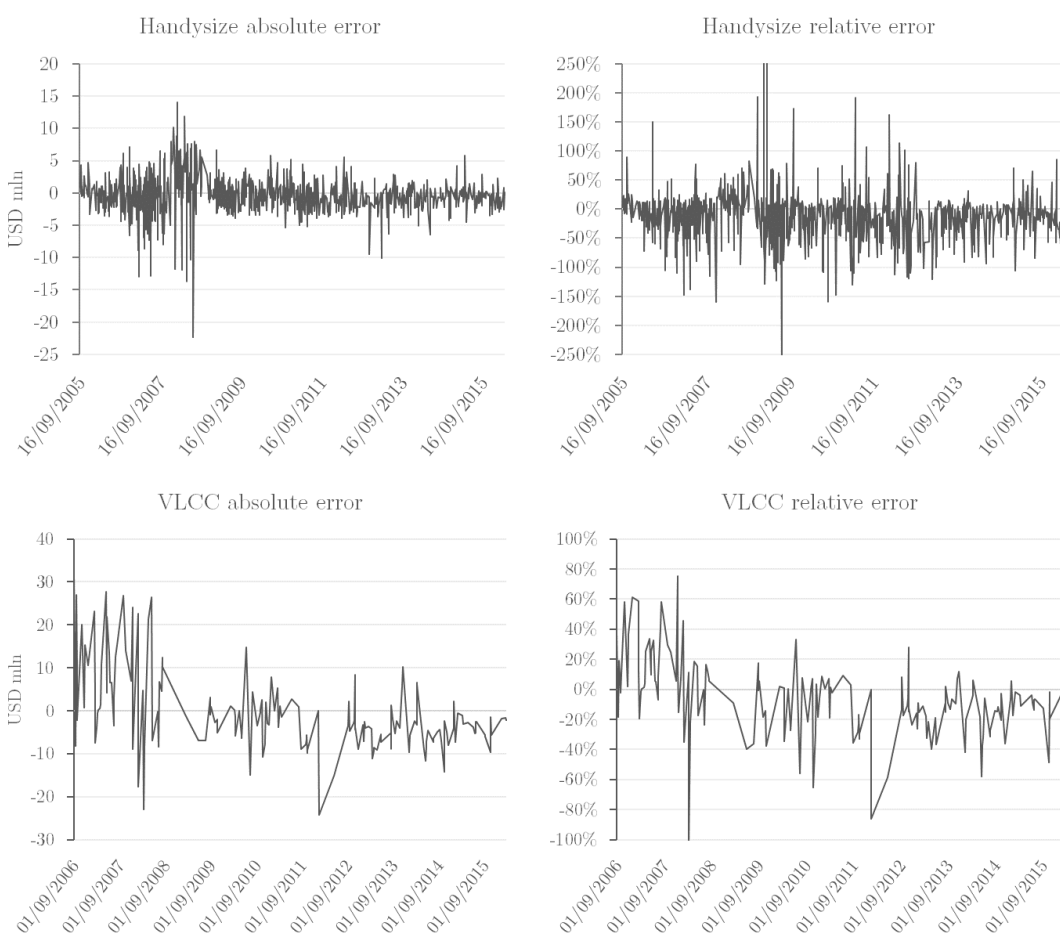
There are a number of inferences to be drawn based on the estimated residuals for both Handysizes and VLCCs. Firstly, we observe that our specific models predict some outliers. By default, the OLS model goes through the sample mean, from which issues regarding the variables arise. For instance, the discount for a Chinese built vessel should in absolute terms decrease with the depreciation of the vessel. However, in our model the discount remains the same and increase in relative terms to the observed price, as the vessel ages, creating outliers. Secondly, the boom in the years 2003-2008 led to a rapid increase in vessel values, from which we observe greater absolute deviations. The deviations do not necessarily mean that the models make worse predictions in boom markets, as we observe the pattern is much less evident in the residuals relative to observed prices. Thirdly, we observe that there are a high number of outliers for Handysizes and that they are on the downside. One possible explanation could be that our models do not sufficiently account for the heterogeneity in ship sizes. However, when we plot the residuals of the observed prices and the market rate index together with DWT, we see no clear evidence of non-linear patterns or a two tier linear regime for Handysizes. Please refer to appendix A.1. As such, we argue that there might be unobserved factors that our model does not account for. Finally, we argue that the residuals for VLCCs follows the cycle with peaking residuals in the euphoria of 2008 and a coinciding trough for both the market and residuals in 2012, before a gradual shift towards higher residuals throughout 2015. The cyclical pattern suggests that our model is unable to incorporate the full cyclical nature of the business. However, we emphasize that our sample of VLCCs is limited and that the pattern is much less evident with Handysizes, albeit we observe a peak and trough for the Handysize model residuals in 2008, and 2015-2016, respectively.

Finally, we test whether our specific models, including microeconomic price determinants, are more accurate in terms of RMSE than the market models. The comparison of the results allows us to infer whether adding the heterogeneity in microeconomic characteristics improves the accuracy of our models predictive power of unseen data. Figure 6.4 displays an overview of the initial split between the training-set and the test-set together with the varying test-sets and their corresponding RMSE for both our specific models and the compared market rate models.

Table 6.4 RMSE

Cross validation	Root Mean Square Error	
Handysize	Specification (8)	Market rate model
50/50	2.77	3.30
60/40	2.82	3.35
70/30	2.02	2.26
80/20	2.01	2.24
90/10	1.71	2.29
VLCC	Specification (11)	Market rate model
50/50	9.15	8.92
60/40	7.24	6.95
70/30	6.56	6.73
80/20	6.16	7.48
90/10	4.84	6.72

The Handysize model specification (8) dominates the market rate model for all test-sets, which suggest that the included micro determinants clearly add predictive power to our model. The same clear results do not apply for the VLCCs; where we observe that the market rate models dominate for the observation windows 50/50 and 60/40, while the specific model dominate for shorter test-sets. The poor performance of the specific VLCC model could be explained by the sample being too small, and that the training-set has insufficient information to make good predictions. Other explanations could be that there are shifting trends in the microeconomic variables, higher market volatility and omitted variables, which influence the model estimations. As discussed earlier, South Korean built vessels might provide a discount in the training-set and a premium in the test-set. Furthermore, hull type is not fully incorporated through the market, and the market volatility is generally higher for VLCCs. Lastly, the table 6.4 display improving predictions in terms of RMSE as the training-set expands. We conclude that the model utilizes the new data to produce predictions that are more accurate.

6.4 Model uncertainties

There are potential weaknesses that might rise criticism against this paper. Firstly, Roumpis and Syriopulos (2006) found that the average sales rate for VLCC's and Handysizes were 1.95 and 12 each month for all ages, respectively. The few VLCC transactions might not be sufficient to make credible monthly estimates on 0-year-old, 5-year-old, 10-year-old and 15-year-old vessels. Thus, the Clarkson's second-hand estimates on VLCC is likely a result of 'guesstimates' from brokers or an internal valuation model, introducing new biases to our model. Secondly, a drawback of linear models is that in reality, most systems are not linear. The OLS-model does not account for the possible non-linear relationships between price and vessel characteristics that could cause functional misspecification. Thirdly, OLS regression can underperform when the dataset has some excessively large or small values of the dependent variables. As OLS is trying to minimize the sum of the squared error, these outliers will have a disproportionately large effect on the constants that it solves for. Lastly, the OLS-model does not control for potential time-constant effects that could be an issue in our data. One might expect that specific ship-owners might have extensive experience with deals, which results in both premiums for sales and discounts for purchases. Furthermore, if there are many defects with a certain vessel, both the vessel itself and its sister ships might be subject to investor badwill.

7   Conclusion and further research

The purpose of this thesis was to investigate the microeconomic determinants of Handysize dry-bulk carrier- and VLCC tanker second-hand prices. We utilize a parametric approach, which has the potential to reveal more in limited datasets, at the expense of some general model assumptions. Using raw sales data on conducted second-hand transactions in the period 1996-2016, we find that: (1) the market rate index for a standard vessel account for most of the explained variance in vessel prices. (2) Ship-specific microeconomic factors for both ship-classes, contribute in the explanation of second-hand prices. Overall, the results generally support the findings in the literature, with some new added insights regarding the determination of prices.

For Handysize dry-bulk carriers, the market rate index, term structure, DWT, speed, number of holds, country of build and the fuel efficiency proxy affects prices. Out of which increased speeds, DWT carrying capacity, number of holds and fuel efficiency translate into premiums in the market. On the other side, the term structure as well as vessels built in China and other countries yields a discount. Moreover, we find that DWT and speed are especially attractive in booming markets and that conversely to our expectations, fuel-efficiency show a significant discount in market troughs. The cross validation analysis conclude that a weak cyclical pattern is observable in our prediction errors, which suggests that our model do not fully account for the cyclical nature of the industry. In addition, the Handysize specific model (8) outperforms the market rate model, and improves its own predictive power as the size of the training-set increases.

For VLCC tankers, our findings suggest that the market rate index, DWT, number of pumps and country of build all affect prices. Increased DWT capacity and South Korean built vessels command a premium, whereas Chinese built vessels and number of pumps provides a discount. The effect of country of build is relative to the reference builder, Japan. The cross validation analysis displays a cyclical pattern suggesting that our model do not fully comprehend the market cyclicality. For the VLCC specific model (11) we observe deviating results depending on the size of the training-set, in the comparison with the market rate model. By increasing the training-set, the

model does not only predict more accurately than the market rate model, but also improves its own predictive power.

Finally, we suggest two topics for further research that could extend the literature on second-hand valuation. Firstly, it would be interesting to investigate whether buyer/seller and their relationship affect the second-hand price. Adland et al. (2016) finds evidence that charterers, owners and the interaction between them, play an influential part in the determination of the freight rate in individual contracts for Capesizes and VLCC's. As such, one could expect corresponding results for second-hand vessel prices. Secondly, we believe it could be of interest to compare parametric, non-parametric and semi-parametric models on the same ship-class and sample through cross validation techniques.

8 Appendices

8.1 Appendix A

Table A.1 Correlation Matrix Handysize

	Price	Market rate	Term Structure	Age	Dwt	Speed	Grain Capacity	Cubic utilization	No Holds	HP	Fuel Consumption	FEP	Bunker Cost	FEI	d_Japan	d_S.Korea	d_China	d_Other	d_HFO	d_IFO	d_sulzer	d_B&W	d_Mitsubishi	d_other
Price	1																							
Market rate	**0.94**	1																						
Term Structure	-0.51	-0.51	1																					
Age	**-0.61**	**-0.64**	-0.07	1																				
Dwt	0.11	-0.06	0.03	0.02	1																			
Speed	-0.08	-0.11	0.02	0.13	0.16	1																		
Grain Capacity	0.15	-0.02	0.03	-0.03	**0.96**	0.15	1																	
Cubic utilization	0.12	0.13	-0.01	-0.16	-0.07	-0.01	0.16	1																
No Holds	-0.04	-0.13	0.04	0.11	0.58	0.25	0.56	-0.09	1															
HP	-0.14	-0.21	0.02	0.24	0.49	0.41	0.46	-0.14	0.54	1														
Fuel Consumption	-0.24	-0.30	0.05	0.32	0.39	0.59	0.36	-0.14	0.49	**0.81**	1													
FEP	-0.27	-0.17	-0.10	0.24	-0.44	0.33	-0.45	-0.09	-0.09	0.25	0.46	1												
Bunker Cost	0.29	0.34	-0.17	0.08	0.03	-0.08	0.05	0.09	-0.07	-0.13	-0.21	-0.24	1											
FEI	-0.33	-0.23	0.03	0.28	-0.57	0.17	-0.58	-0.16	0.21	0.45	**0.79**	-0.22		1										
d_Japan	-0.02	-0.08	0.03	0.05	-0.06	-0.14	-0.05	0.09	-0.34	-0.33	-0.26	-0.19	-0.03	-0.16	1									
d_S.Korea	0.10	0.09	-0.02	-0.07	0.03	0.01	0.05	-0.02	0.05	-0.01	-0.03	0.05	0.05	-0.16	**-0.73**	1								
d_China	0.17	0.25	-0.05	-0.25	-0.03	0.03	0.01	0.00	-0.04	0.00	0.15	-0.02	-0.02	-0.16	-0.42	-0.35	1							
d_Other	-0.14	-0.12	0.00	0.14	0.07	0.18	0.05	-0.14	0.03	0.37	0.34	-0.09	0.06	0.09	-0.01	0.17	0.17	1						
d_HFO	-0.25	-0.25	0.04	0.26	-0.01	-0.03	-0.03	0.03	0.09	0.24	-0.09	0.16	-0.11	0.16	0.01	-0.05	-0.11	0.09	1					
d_IFO	0.25	0.25	-0.04	-0.26	0.01	0.03	0.04	-0.03	-0.09	-0.16	0.16	-0.11	0.11	-0.16	-0.01	0.05	0.11	-0.09	**-1.00**	1				
d_sulzer	-0.20	-0.26	0.00	0.31	0.32	0.19	0.26	-0.15	0.29	0.35	0.37	-0.15	0.04	0.04	-0.07	-0.06	-0.05	0.15	0.11	-0.11	1			
d_B&W	0.11	0.15	-0.02	-0.15	-0.11	-0.03	0.01	0.03	-0.15	0.02	-0.03	0.06	0.09	0.07	-0.23	0.17	0.17	0.07	-0.07	0.07	-0.56	1		
d_Mitsubishi	0.14	0.14	0.01	-0.18	-0.15	-0.16	-0.24	0.08	-0.35	-0.34	-0.21	0.08	-0.14	-0.25	0.34	-0.12	-0.14	-0.25	-0.03	0.03	-0.37	-0.47	1	
d_other	-0.10	-0.06	0.02	0.07	-0.16	-0.04	-0.18	-0.09	-0.05	-0.06	-0.10	-0.06	0.12	-0.19	0.07	0.01	0.00	-0.01	0.01	0.03	0.03	-0.18	-0.12	1

Table A-2 Correlation matrix VLCC

	Price	Market rate	Term Structure	Age	Dwt	Speed	HP	Pumps Total No	Pump Cap	Barrels	Fuel Consumption	FEP	FEI	d_Japan	d_S.Korea	d_China	d_Other	d_HFO	d_IFO	d_B&W	d_Sulzer	d_Mitsubishi	d_Other	d_SingleSkin	d_DoubleHull
Price	1																								
Market rate	**0.95**	1																							
Term Structure	-0.52	-0.53	1																						
Age	**-0.80**	**-0.82**	0.16	1																					
Dwt	0.25	0.17	-0.03	-0.14	1																				
Speed	0.20	0.15	0.01	-0.19	0.23	1																			
HP	0.29	0.24	0.05	-0.22	**0.66**	0.43	1																		
Pumps Total No	0.01	0.02	-0.02	0.09	0.19	-0.11	0.18	1																	
Pump Cap	0.04	0.01	-0.08	0.08	0.27	0.13	0.15	0.20	1																
Barrels	0.13	0.07	-0.01	0.00	**0.81**	0.21	0.54	0.11	0.23	1															
Fuel Consumption	-0.20	-0.25	0.11	0.37	0.48	0.20	0.53	0.13	0.20	0.50	1														
FEP	-0.07	-0.08	-0.01	0.15	0.02	0.15	0.23	0.00	0.05	0.08	**0.84**	1													
FEI	-0.35	-0.37	0.14	0.50	-0.02	-0.08	0.21	0.08	0.05	0.09	**0.70**	**0.74**	1												
d_Japan	-0.40	-0.36	0.04	0.33	-0.29	-0.12	-0.42	0.01	0.11	-0.16	-0.04	0.02	0.07	1											
d_S.Korea	0.48	0.41	-0.09	-0.43	0.27	0.32	0.41	0.00	-0.09	0.19	-0.11	-0.16	-0.28	**-0.78**	1										
d_China	0.14	0.23	0.10	-0.22	0.00	-0.28	0.01	-0.03	-0.08	-0.01	-0.03	0.05	-0.20	-0.19	-0.19	1									
d_Other	-0.23	-0.27	0.01	0.34	0.05	-0.14	0.02	0.02	-0.03	0.28	0.28	0.33	-0.26	-0.20	-0.25	-0.06	1								
d_HFO	-0.02	-0.04	0.12	-0.07	0.07	0.05	-0.03	-0.18	0.02	0.04	0.05	0.03	0.02	0.01	-0.05	0.07	0.02	1							
d_IFO	0.02	0.04	-0.12	0.07	-0.07	-0.14	-0.05	0.18	-0.02	-0.05	-0.03	-0.02	0.02	-0.01	0.05	-0.07	-0.02	**-1.00**	1						
d_B&W	0.22	0.26	-0.09	-0.33	0.05	-0.02	0.03	-0.08	-0.02	-0.05	0.18	0.28	0.33	-0.31	0.22	-0.07	-0.25	0.06	-0.06	1					
d_Sulzer	0.11	0.06	-0.05	-0.02	-0.02	0.14	0.08	0.12	0.01	-0.12	-0.06	-0.05	-0.02	-0.13	0.20	0.07	-0.02	-0.06	0.06	**-0.62**	1				
d_Mitsubishi	-0.19	-0.16	0.08	0.13	-0.15	-0.15	-0.30	-0.08	-0.03	-0.19	0.01	-0.31	-0.35	-0.16	-0.05	0.22	-0.25	-0.04	0.04	-0.06	-0.06	1			
d_Other	-0.32	-0.34	0.14	0.43	0.12	-0.01	0.15	0.04	0.06	0.21	-0.03	**0.68**	**0.70**	0.07	0.37	-0.21	0.32	0.06	-0.06	-0.38	-0.23	-0.13	1		
d_SingleSkin	-0.54	-0.53	0.07	**0.61**	-0.22	-0.23	-0.39	-0.05	0.08	-0.02	0.30	0.30	0.44	-0.44	0.37	-0.44	0.22	0.09	-0.09	-0.23	-0.12	0.10	0.46	1	
d_DoubleHull	0.54	0.53	-0.07	**-0.61**	0.22	0.23	0.39	0.05	-0.08	0.02	-0.30	-0.30	-0.44	0.44	-0.37	0.44	-0.22	-0.09	0.09	0.23	0.12	-0.10	-0.46	**-1.00**	1

Table A.3 Summary of macroeconomic descriptive statistics

	Handysize bulkcarriers						VLCC tankers					
	No.	Mean	Median	Min	Max	SD	No.	Mean	Median	Min	Max	SD
Avg. scrap age by year	20	29	29	25	35	3	18	23	24	18	29	3
Weekly bunker price	1375	243,74	146,5	50,5	720	193,12	---	---	---	---	---	---
Monthly TC earnings												
6-month	240	11 969	8 200	4 788	48 125	8 500	---	---	---	---	---	---
1-year	240	11 538	8 233	5 088	40 800	7 591	190	41 603	40 000	18 000	90 000	16 596
3-year	240	10 523	8 719	6 025	28 375	4 808	169	37 914	36 000	22 000	70 000	10 548
Monthly second-hand prices												
Resale	113	29	25	18	57	10	131	115,6	105	80.0	195.0	26.0
5-year	243	19,2	17	9,3	54	9, 3	243	79,6	71	50.0	165.0	26.0
10-year S/H	---	---	---	---	---	---	41	33,5	25	23.0	60.0	12,5
10-year	243	15	13	6	47	9	173	65,1	58	34.0	135.0	25,6
15-year S/H	---	---	---	---	---	---	122	30	23,9	14.0	60.0	13,1
15-year	173	13	12	4	38	8	69,	30, 4	28	22	45	6
20-year	173	9	8	2	33	6	---	---	---	---	---	---
1977/1976 built	74	3	2	1	5	1	71,	9, 3	8, 5	5,	15	3,1
Scrap value	240	2	2	1	5	1	240	12, 7	13, 5	3, 8	28,4	6,3

Figure A.1 Handysize DWT residual plot
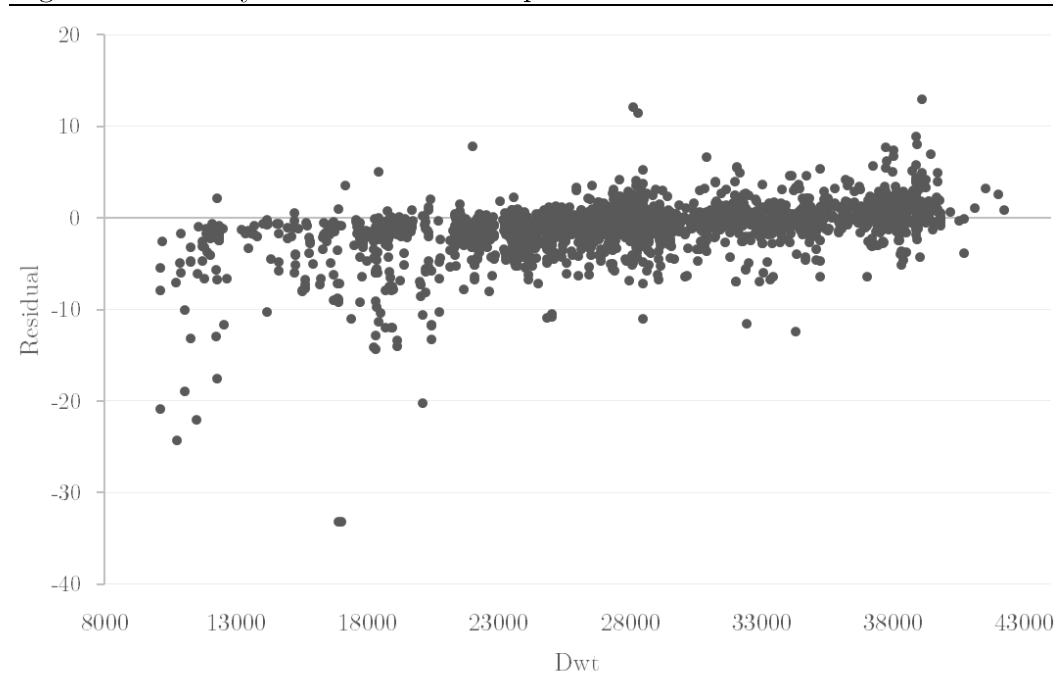
Table A.4 Robustness tests and diagnostics

Test diagnostics	Handysize specification (8)	VLCC Specification (11)
Breuch Pagan test		
BP	422.26	10.428
df	8	5
P-value	1E-16	0.064
Breusch-Godfrey test		
LM test	141.03	19.093
df	1	1
P-value	1E-16	0.000
Shapiro-Wilk test		
W	0.87743	0.95128
P-value	1E-16	1E-16

Table A.5 Variance inflation factors

Variables	VIF
Handysize specification (8)	
Market rate index	1.65
Term Structure	1.49
Dwt.1000	2.18
Speed	1.32
No.Holds	2.03
d_China	1.11
d_Other	1.40
Fuel.efficiency.Proxy	1.88
VLCC specification (11)	
Clarksons.Proxy	1.57
Dwt.1000	1.58
d_S.Korea	1.56
d_China	1.47
d_OtherCountry	1.11

8.2   Appendix B

```
#                                  ____REGRESSION_CODE_IN_R____


### LOAD PACKAGES ###
library(xlsx)
library(plm)
library(zoo)
library(lmtest)
library(car)
library(plyr)
library(lme4)
library(Hmisc)
library(dynlm)
library(orcutt)
library(sandwich)
library(forecast)


######################################################################
############################## LOAD DATASET ##########################
######################################################################

## Loads HANDYSIZE dataset ##
HANDY <- read.csv('handy7.csv')
attach(HANDY)

## Load VLCC dataset ##
VLCC <- read.csv('vlcc8.csv')
attach(VLCC)




######################################################################
######################### OLS REGRESSION VLCC #######################
######################################################################

## Choice of market proxy ##
OLS <- lm(Price ~ Theoretical.Price)
OLS <- lm(Price ~ Clarksons.Proxy)

## Regression model wide to narrow ##
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + HP + Pumps.Total.No + Pump.Cap +
d_S.Korea + d_China + d_OtherCountry + d_Sulzer + d_Mitsubishi + d_OtherEngine + d_IFO + d_singleskin2000.2010 +
Fuel.Consumption)
OLS <- lm(Price ~ Clarksons.Proxy + Term.Structure.1000 + Dwt.1000 + Speed + HP + Pumps.Total.No + Pump.Cap + d_S.Korea +
d_China + d_OtherCountry + d_Sulzer + d_Mitsubishi + d_OtherEngine + d_IFO + d_singleskin2000.2010 + Fuel.Efficiency.Proxy)
OLS <- lm(Price ~ Clarksons.Proxy + Term.Structure.1000 + Dwt.1000 + Speed + HP + Pumps.Total.No + Pump.Cap + d_S.Korea +
d_China + d_OtherCountry + d_Sulzer + d_Mitsubishi + d_OtherEngine + d_IFO + d_singleskin2000.2010 + Fuel.Efficiency.Index)

OLS <- lm(Price ~ Clarksons.Proxy + Term.Structure.1000 + Dwt.1000 + HP + Pumps.Total.No + Pump.Cap + d_S.Korea + d_China +
d_OtherCountry + d_Sulzer + d_Mitsubishi + d_OtherEngine + d_IFO + d_singleskin2000.2010 + Fuel.Efficiency.Index)
OLS <- lm(Price ~ Clarksons.Proxy + Term.Structure.1000 + Dwt.1000 + HP + Pumps.Total.No + Pump.Cap + d_S.Korea + d_China +
d_OtherCountry + d_Sulzer + d_Mitsubishi + d_OtherEngine + d_singleskin2000.2010 + Fuel.Efficiency.Index)
OLS <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + HP + Pumps.Total.No + Pump.Cap + d_S.Korea + d_China + d_OtherCountry +
d_Sulzer + d_Mitsubishi + d_OtherEngine + d_singleskin2000.2010 + Fuel.Efficiency.Index)
OLS <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + HP + d_S.Korea + d_China + d_OtherCountry + d_Sulzer + d_Mitsubishi +
d_OtherEngine + d_singleskin2000.2010 + Fuel.Efficiency.Index)
OLS <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + HP + d_S.Korea + d_China + d_OtherCountry + d_Sulzer + d_Mitsubishi +
d_OtherEngine + Fuel.Efficiency.Index)
OLS <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + HP + d_S.Korea + d_China + d_OtherCountry + Fuel.Efficiency.Index)
OLS <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + d_S.Korea + d_China + d_OtherCountry + Fuel.Efficiency.Index)
OLS <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + d_S.Korea + d_China + d_OtherCountry)

OLS <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + d_S.Korea + d_China + d_OtherCountry + Interaction.Boom.Dwt +
Interaction.Trough.Dwt)
```

```
###########################################################################
######################### OLS REGRESSION HANDY ############################
###########################################################################

## Choice of Market Proxy ##
OLS <- lm(Price ~ Theoretical.Price)
OLS <- lm(Price ~ Clarksons.Proxy)

## Regression model wide -> narrow ##
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_S.Korea + d_China + d_Other +
d_sulzer + d_Mitsubishi + d_other + d_IFO + HP + Grain.Cap.Dwt + Fuel.Consumption)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_S.Korea + d_China + d_Other +
d_sulzer + d_Mitsubishi + d_other + d_IFO + HP + Grain.Cap.Dwt + FEI)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_S.Korea + d_China + d_Other +
d_sulzer + d_Mitsubishi + d_other + d_IFO + HP + Grain.Cap.Dwt + Fuel.efficiency.Proxy)

OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other + d_sulzer +
d_Mitsubishi + d_other + d_IFO + HP + Grain.Cap.Dwt + Fuel.efficiency.Proxy)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other + d_sulzer +
d_Mitsubishi + d_other + d_IFO + HP + Fuel.efficiency.Proxy)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other + d_sulzer +
d_Mitsubishi + d_other + d_IFO + Fuel.efficiency.Proxy)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other + d_IFO +
Fuel.efficiency.Proxy)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other +
Fuel.efficiency.Proxy)

OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other +
Fuel.efficiency.Proxy + Interaction.Boom.Dwt.1000 + Interaction.Trough.Dwt.1000)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other +
Fuel.efficiency.Proxy + Interaction.Boom.Speed + Interaction.Trough.Speed)
OLS <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other +
Fuel.efficiency.Proxy + Interaction.Boom.Fuel.Efficiency.Proxy + Interaction.Trough.Fuel.efficency.proxy)

###########################################################################
######################### TESTS AND REMEDIES ##############################
###########################################################################

## Test for Multicollinearity with Variance Inflation Factors ##
vif(OLS)
sqrt(vif(OLS))

## Test for Heteroskedasticity with Breusch-Pagan ##
bptest(OLS)
# Fix e.s.e using white heteroscedaticity-corrected covariance matrix
coeftest(OLS, vcov.=hccm(OLS))

## Test for Autocorrelation with Breusch-Godfrey ##
bgtest(OLS)
## Test for Autocorrelation with Durbin Watson ##
dwtest(OLS)
# Fix e.s.e. with vcovhac, neweywest or kernhac
coeftest(OLS, vcov. = NeweyWest)
coeftest(OLS, vcov. = kernHAC)
coeftest(OLS, vcov. = vcovHAC)

## Test for Normality with Shapiro Wilk ##
res1=residuals(OLS,type="response")
res2=residuals(OLS,type="pearson")
res3=rstudent(OLS)
res4=rstandard(OLS)
shapiro.test(res1)
shapiro.test(res2)
shapiro.test(res3)
shapiro.test(res4)
```

```
###########################################################################
######################### CROSS VALIDATION HANDY ##########################
###########################################################################
handy <- as.data.frame(HANDY)
attach(handy)
n       <- length(handy[,1])
train  <- floor(0.50*n)
test   <- n - train

pricepredictor.1 <- matrix(0,test,1)
pricepredictor.2 <- matrix(0,test,1)
realprice         <- Price[(train+1):n]
SSE1            <- 0
SSE2            <- 0
error1          <- 0
error2          <- 0

for (i in 1:test)
{
  xdata            <- handy[1:(train+i-1),]
  ols.test1              <- lm(Price ~ Clarksons.Proxy + Age.2 + Term.Structure.1000 + Dwt.1000 + Speed + No.Holds + d_China + d_Other +
Fuel.efficiency.Proxy, data=xdata)
  ols.test2              <- lm(Price ~ Clarksons.Proxy, data=xdata)

  newdata              <- handy[train + i,]
  pricepredictor.1[i]  <- predict.lm(ols.test1, newdata = newdata)
  pricepredictor.2[i]  <- predict.lm(ols.test2, newdata = newdata)

  SSE1              <- SSE1 + (pricepredictor.1[i] - realprice[i])^2
  SSE2              <- SSE2 + (pricepredictor.2[i] - realprice[i])^2
  error1            <- error1 + (pricepredictor.1[i] - realprice[i])
  error2            <- error2 + (pricepredictor.2[i] - realprice[i])
  }

RMSE1 <- sqrt(SSE1/test)
RMSE2 <- sqrt(SSE2/test)
MAE1 <- error1/test
MAE2 <- error2/test

###########################################################################
############################# CROSS VALIDATION VLCC #######################
###########################################################################
vlcc <- as.data.frame(VLCC)
attach(vlcc)

n       <- length(vlcc[,1])
train  <- floor(0.50*n)
test   <- n - train
pricepredictor1 <- matrix(0,test,1)
pricepredictor2 <- matrix(0,test,1)
realprice         <- Price[(train+1):n]
SSE1            <- 0
SSE2            <- 0
error1          <- 0
error2          <- 0

for (i in 1:test)
{
  xdata              <- vlcc[1:(train+i-1),]
  ols.test.1            <- lm(Price ~ Clarksons.Proxy + Dwt.1000 + d_S.Korea + d_China + d_OtherCountry, data=xdata)
  ols.test.2            <- lm(Price ~ Clarksons.Proxy, data=xdata)
  #ols.test.2            <- lm(Price ~ Theoretical.Price, data=xdata)

  newdata              <- vlcc[train + i,]
  pricepredictor1[i]  <- predict.lm(ols.test.1, newdata = newdata)
  pricepredictor2[i]  <- predict.lm(ols.test.2, newdata = newdata)

  SSE1              <- SSE1 + (pricepredictor1[i] - realprice[i])^2
  SSE2              <- SSE2 + (pricepredictor2[i] - realprice[i])^2
  error1            <- error1 + (pricepredictor1[i] - realprice[i])
  error2            <- error2 + (pricepredictor2[i] - realprice[i])
  }

RMSE1 <- sqrt(SSE1/test)
RMSE2 <- sqrt(SSE2/test)
MAE1 <- error1/test
MAE2 <- error2/test
```

```
############################################################################
############################## PLOTS ########################################
############################################################################

## Normality of residuals ## (qq plot for studentized residuals)
qqPlot(OLS, main='QQ Plot')
sresid <- studres(OLS)
hist(sresid, freq=FALSE,
    main="Distribution of Studentized Residuals")
xfit<-seq(min(sresid),max(sresid),length=40)
yfit<-dnorm(xfit)
lines(xfit, yfit)

## Outliers ##
outlierTest(OLS) # Bonferonni p-value for most extreme obs
qqPlot(OLS, main="QQ Plot") #qq plot for studentized resid
leveragePlots(OLS) # leverage plots

density.default(x=rstudent(OLS))
plot(density.default(x=rstudent(OLS)))

qqPlot(OLS, distribution='norm')

############################################################################
```

9 Bibliography

Adland, R., & Jia, H. (2015). Shipping Market Integration: The Case of Sticky Newbuilding Prices. *Maritime Economics and Logistics 17*, 389-398.

Adland, R., & Koehn, S. (2008). multivariate semi-parametric approach to desktop valuation chemical carriers.

Adland, R., & Koekebakker, S. (2004). Market Efficiency in The Second-hand Market for Bulk Ships . *Maritime Economics & Logistics 6*, 1-15.

Adland, R., & Koekebakker, S. (2007). Ship Valuation Using Cross-Sectional Sales Data: A multivariate Non-Parametric Approach. *Maritime Economics and Logistics 9*, 105-118.

Adland, R., Alger, H., & Banyte, J. (2015). *Does fuel efficiency pay? Empirical evidence from the drybulk timecharter market revisited.* Norwegian school of Economics, Department of Economics, Bergen.

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

Adland, R., Jia, H., & Strandenes, S. (2006). Asset bubbles in shipping? An analysis of recent history in the drybulk market. *Maritime Economics & Logistics 8*, 223-233.

Alizadeh, A. H., & Nomikos, N. K. (2006). Trading strategies in the market for tankers. *Maritime Policy & Management, 33:2*, 119-140.

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

Beenstock, M. (1985). A theory of Ship Prices. *Maritime Policy & Management 12*, 215-225.

Beenstock, M., & Vergottis, A. (1989a). An econometric Model of the World Shipping Market for Dry Cardgo, Freight and Shipping. *Applied Economics*, 339-356.

Beenstock, M., & Vergottis, A. (1989b). An econometric model of the World tanker market. *Journal of Transport Economics and Policy 23*, 263-280.

Beenstock, M., & Vergottis, A. (1992). The interdependence between the Dry Cargo and Tanker Markets. *Logistics and Transportation Review 29(1)*, 3-38.

Breusch, T., & Godfrey, L. (1981). A review of recent work on testing for autocorrelation in dynamic simultaneous models. In D. Currie, A. Nobay, & D. Peel, *Macro-economic Analysis; Essays in Macroeconomics and Econometrics* (pp. 63-110).

Breusch, T., & Pagan, A. (1979). A simple test for heteroskedasticity and random coefficient variation. *Econometrica, Vol 47, No. 5*.

Campbell, J. Y., & Shiller, R. F. (1988). Stock prices, earnings and expected dividends. *Journal of Finance 43*, 661-676.

Chai, T., & Draxler, R. R. (2014). Root mean square error (RMSE) or mean absolute error (MAE)? - Arguments against avoiding RMSE in the literature. *Geoscientific Model Development*, 1247-1250.

Charemza, W., & Gronicki, M. (1981, 01 01). An econometric model of world shipping and shipbuilding. *Maritime Policy and Management 8*, 21-30. Retrieved 02 20, 2016, from http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade

Clarksons. (2011, 1 13). *Tradewindsnews.* Retrieved from http://www.tradewindsnews.com/weekly/243788/gambles-ahead

Clarksons. (2016, 4 10). Retrieved from http://wfr.clarksons.net/wfr/

Federal Reserve Bank of St. Louis. (2016, 05). *Economic Research.* Retrieved from https://research.stlouisfed.org/fred2/

Fulford-Smith, R. (n.d.). *Marine Money Offshore.* Retrieved from https://www.marinemoneyoffshore.com/node/5803

Geman, H. (2007). *Mean reversion versus Random walk in Oil and Natural Gas Prices.*

Glen, D. R. (1997). The market for second-hand ships: Further results on efficiency using cointegration analysis. *Maritime Policy & Management* , 245-260.

Hale, C., & Vanags, A. (1992). The market for second-hand ships: Some results on efficiency using cointegration. *Maritime Policy and Management 19(1)*, 31-39.

Hendry, D. F. (2000). Econometric Modelling.

Hoover, K. D. (2005). The Methodology of Econometrics. *Palgrave Handbook of Econometrics, voulme 1: Theoretical Econometrics*, 25-30.

IMO. (2016). Retrieved from International Maritime Organization: http://www.imo.org/en/OurWork/Safety/Regulations/Pages/OilTankers.aspx

Kavussanos, M. G., & Alizadeh, A. H. (2002). Efficient pricing of ships in the dry bulk sector of the shipping industry. *Maritime Policy & Management 29:3*, 303-330.

Köhn, S., & Thanopoulou, H. (2011). A gam assessment of quality premia in the dry bulk time–charter market. *Transportation research part E 47*, 709-721.

Louis, F. R. (2016, 05 15). *Federal Reserve Bank of St. Louis.* Retrieved from Economic Research: www.stlouisfed.org

Newey, W. K., & West, K. D. (1978). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica, vol 55, No. 3*, 703-708.

Pruyn, J. F., Voorde, E. v., & Meersman, H. (2011). Second han vessel value estimation in maritime economics: A review of the past 20 years and the proposal of an elementary method. *Maritime Economics & Logistics 13*, 213-236.

Research, D. M. (2013). *Ship Operating Costs Annual Review and Forecast.*

Roumpis, E., & Syriopoulos, T. (2006). Price and volume dynamics in second-hand dry bulk and tanker shipping markets. *Maritime Policy and Management* , 497-518.

Shapiro, S. S., & Wilk, M. B. (1965). An Analysis of Variance Test for Normality (Complete Samples). *Biometrika, Vol 52, No. 3/4*, 591-611.

Sødal, S., Koekebakker, S., & Adland, R. (2009). Value based trading of real assets in shipping under stochastic freight rates. *Applied Economics* , 2793-2807.

Stopford, M. (2009). *Maritime Economics.* Routledge.

Stopford, M. (2009). *Maritime Economics 3e.*

Strandenes, S. (1984). *Price Determination in the time charter and second-hand markets.* Norwegian School of Economics, Bergen, Norway: Discussion paper 0584.

Strandenes, S. (1986). *Norship: a simulation model of markets in bulk shipping.* Bergen, Norway: Norwegian School of Economics.

Strandenes, S. (1998). *The shipbroking function and market efficiency.* Stiftelsen for samfunns- og næringslivsforskning.

Strandenes, S. (2002). Economics of the markets for ships. In C. Grammenos, *The Handbook of Maritime Economics and Business* (pp. 217-220).

Tsolakis, S. D., Cridland, C., & Haralambides, H. E. (2003). Econometric Modelling of Second-hand Ship Prices. *Maritime Economics and Logistics 5*, 347-377.

Veenstra, A. W. (1999). Quantitative analysis of shipping markets. *T99/3 TRAIL Thesis Series.*

Wiljnolst, & Wegeland. (2009). *Shipping Innovation.*

Wooldridge, J. M. (2009). Introductory Econometrics: A modern Approach 4e.