Original Article

Second hand vessel value estimation in maritime economics: A review of the past 20 years and the proposal of an elementary method

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Abstract The past 20 years (1991–2011) have brought us in total 11 papers on the pricing of second hand vessels. It is a subject not often investigated, but it is of importance when considering the capital costs of a vessel. It also reflects the topics generally researched by (maritime) econometrists at the time of publication. The first 10 years are dominated by testing for the Efficient Market Hypothesis. The current ideas focus on a micro-economic valuation of the vessel, incorporating particulars such as DWT, age, speed, horsepower, hull type and many others.

Maritime Economics & Logistics (2011) **13**, 213–236. doi:10.1057/mel.2011.6

Keywords: second hand market; vessel pricing; modelling; review; efficient market; shipping

Introduction

The costs of operating a vessel are for a large part depending on financing costs. Stopford (2009) estimates that roughly 40 per cent of the costs of operating a vessel are capital costs. The depreciation and the interest rate are seen as the

major contributors to the capital costs. Both have a direct link with the price of the vessel when it was purchased and the way the vessel was financed. Outside a period in the beginning of the life of a vessel, the second hand value of a vessel can be proxy for the capital costs incurred, when considering the entire fleet. For the period at the beginning the newbuilding price is a much better proxy to base these costs on.

A large influence on the interest costs is the way of financing the vessel, with the extremes of 100 per cent debt and 100 per cent equity. Interest is paid on the loan taken to purchase the vessel and is a cost. Equity does not incur these costs. The provider of equity will, however, expect to earn a profit on his money invested. Assuming a vessel is financed by debt entirely will provide a profit provision for the equity part of the financing of the vessel and will side step the discussion on the average part financed by equity. A minimal profit is taken into the cost calculation when applying it to a marginal cost model of the freight rates however.

Although the discussion on financing is an interesting one, the ability to determine the second hand vessel price needs to be solved first. This article will provide an overview of the past 20 years in research on the estimation of second hand vessel value and price. We conducted this literature research as the first part of our exploration of a proper way to determine individual second hand vessel prices. In 1993, Beenstock and Vergottis published their book on maritime economics (Beenstock and Vergottis, 1993). It was one of the most complete structural models and at the same time the last of its kind. Roughly half the book is used to present an overview of the modelling efforts of the 60 years preceding the publication. Owing to the extensive descriptions of previous models in this book, this overview will start with this book and consider all research done on the second hand vessel price since then.

All of the models described by Beenstock and Vergottis including their own were structural models. Their main contribution to the field of maritime economics was the use of asset value models to calculate ship prices. This choice, and especially the idea of treating new build prices and second hand prices the same, was much debated afterwards. The introduction of new statistical techniques into the field of maritime economics around the time of their publication together with the availability of much more detailed time information (monthly/weekly versus yearly) sparked interest in new types of models. ARMA, ARIME, ARCH GARCH[1] were all to be explored and brought new insights. Their main use is the exploration and prediction of the freight rates, or demand for transport. Applications for the second hand prices were also developed, but on a smaller scale.

In retrospect, a large part of these two decennia has been devoted to establishing whether the Efficient Market Hypothesis (EMH) holds in the

second hand market for vessels or not. This discussion will be detailed in the next section. Evaluation of the results and forces that fuelled the discussion are given in the section after that. In the past 10 years another approach has come up as well, the non-parametric approach. Time is left out of the equation and a nonlinear, multi dimension link is established between the second hand value and factors such as size, age and freight rate. A presentation and review of the results in this area is presented in the subsequent section. A last aspect investigated in the past by several authors is the relation between the market price and the volume traded. The discussion of these results will be done in the penultimate section. In the final section the lessons learned will be summarized and an approach for future research will be suggested.

The suggested approach is based on our review of 20 years of research on second hand vessel pricing. For a future model the following explanatory variables should be considered as a minimum: newbuilding price level, order-book size, profit (or earnings and bunker/fuel consumption costs), age and DWT. Next to these five, there are two other elements, but these might not be so easily taken up in a larger model, such as speed and horsepower of the vessel sold. Still, it has been shown these factors have explanatory powers when looking at individual sales. The elements country of building and classification society were already discarded as a significant influence on price in the papers reviewed.

The Period Focussed on the Validity of the EMH

Right around the time Beenstock and Vergottis publish their book, the discussion about second hand prices started to focus on whether the market for these vessels was efficient. The EMH was first formulated by Fama (1965) and concerns the stock market. He states that a market is efficient if '..., given the available information, actual prices at every point in time represent very good estimates of intrinsic values.' In this case, the expectations of the market about the future are rational and represent all available information at that time. This theory is strongly linked to the random-walk theory of stock prices first used by Jules Regnault, a French broker, in 1863. This theory states that consecutive price movements in time are independent of each other and can therefore be approached by a series of random shocks, a random walk. Fama states that the only way to outperform a buy-and-hold strategy in such a market is if an analyst is consequently able to correctly predict both events and their influence on the price. In that paper, he tests whether there has been a company able to do so, but cannot find one.

The discussion on the validity of this theory in second hand vessel prices was held with varying results over a 15-year period from 1992 to 2006. Over time, the complexity of the models increases and the debate shifts to the underlying assumptions. This section will focus on presenting that research as it was. In the next section, we will evaluate the results based on the knowledge currently available.

The EMH in this context is for the first time applied by Hale and Vanags (1992). In their paper, Hale and Vanags criticize Beenstock and Vergottis for implicitly assuming the EMH to be true in a paper they published before the final book (Beenstock, 1985). They investigated whether the EMH holds by testing the second hand value of three different bulker sizes for co-integration. Their argument here is that if co-integration exists, one price Granger causes the other and therefore one price can be expressed as a function of the other, with error correction. This can be seen as an inefficient market, as one commodity determines the price of another one. The idea for testing for inefficiency in markets is taken from McDonald and Taylor (1988), who apply it at the London metal exchange.

Within their research, Hale and Vanags use the data available from Lloyd's Shipping Economists for the period October 1979–July 1988, with total 104 observations. They investigate the price movements of 30 000 DWT, 70 000 DWT and 120 000 DWT bulkers. The time series are stationary at the first difference I(1) and tested for pair-wise co-integration and Granger causality. Although the first test did not yield positive results, the second one could not reject (5 per cent level) the causality for the smaller two ship sizes. As a final test, co-integration was tested for a three-variable regression. Here also, the results are positive. They reach the conclusion that prices of vessels are driven by two exogenous forces. Although they suggest two potential forces, no proof is provided that they actually would cause the movements in price. Still they see this as proof that the market for second hand vessels is not efficient. With the market being inefficient, all previous (structural) models would be based on false assumptions and therefore obsolete.

Several years later, Glen (1997) revisits the study of Hale and Vanags. Within their research they not only look at a longer time series, but also include tankers in the mix. Glen specifically states that he is investigating EMH as it has been formulated by Fama (1976), which states that market efficiency is present if and only if current asset prices fully and instantly reflect all available information. This implies that the behaviour of one asset cannot be influenced by information on the behaviour of another asset. In other words, two distinct assets cannot be co-integrated. In the 5 years between the two papers, a new technique to assess co-integration has become known to maritime economics, Johansen's maximum likelihood (Johansen, 1988) and that is applied here.

In the study of Glen, all series are stationary at I(1). Stationarity is a pre-requisite for both the Engle and Granger two-stage co-integration analysis and the Johansen method. A side step was made to also test for seasonality, using monthly dummies, no proof of this was found, hence this influence was discarded in the final test. Their data source is also Lloyd's Shipping Economist, though the range is now from October 1979 until July 1995, giving 190 observations for six vessels types. The same three bulker sizes are considered; 30 000 DWT, 70 000 DWT and 120 000 DWT. Next to that, three tanker sizes are also evaluated; 32 000 DWT, 80 000 DWT and 250 000 DWT, though these series go until August 1988, as the represented vessels have been changed after that issue.

The autoregressive models, a current value explained by its lagged values, of the vessel prices yields acceptable results for the bulkers, but not very satisfying results for the tankers. The largest tanker performs best; strangely the largest bulker is the worst performer of its kind. With the functions determined by auto-regression, the co-integration is tested first for the same sample as Hale and Vanags, but this time using Johansen's theory. The results already suggest co-integration on the pair-wise test, a completely different result than that of Hale and Vanags. When looking at the entire available dataset, there is also strong pair-wise co-integration for all pairs. The model rejects the presence of two co-integrating vectors as proposed by Hale and Vanags. At most, one such vector is present according to Glen. The conclusions on EMH of Glen are unresolved; strong co-integration exists, rejecting EMH, but it seems more likely that it is of an external stochastic form, than true integration of the prices. A suggestion for further research of this aspect is made, linking freight rates, trade growth and asset price behaviour.

This theory of one external driving the maritime industry is supported by a paper from Veenstra and Franses (1995), who conclude on investigating freight rates in the tanker and bulker market, that there is a single factor driving them, though this factor itself is stochastic and unpredictable in nature. In his PhD thesis, Veenstra (1999) devotes a small chapter to the second hand prices of vessels. In his discussion, he assumes the value of the vessel to be linked to the discounted sum of its future income. Implicitly, this would mean accepting that the EMH holds, though no mentioning of this assumption is made.

Kavussanos and Alizadeh (2002) return to the subject of EMH in second hand prices in 2002. The paper defines EMH as proposed by Fama, though in different papers (Fama, 1970, 1991). EMH explicitly assumes rational behaviour, meaning the price of an asset is equal to its discounted future earnings, the discounting factor set to a market accepted value. When EMH holds, investors cannot make an arbitrage profit, by buying vessels below their rational value and selling them above it. While earlier papers focussed on co-integration as

measure to accept or reject EMH, Kavussanos and Alizadeh focus on four methods for testing the hypothesis, using excess profits as proposed by Campbell and Shiller (1988). They extend this methodology to make it applicable to real assets with a finite economic life. They also extend the data series (for bulkers) from January 1976 until December 1997 resulting in 262 observations. Their first method is to test the restrictions on the VAR model as would be imposed by the EMH. The second test is a variance ratio test, checking if the variances of the predicted and real price are similar (at log difference level). The third test checks if excess holding periods returns are unpredictable and their final test identifies whether a time varying risk premium is present.

For their estimation of excess return not only a values time series is required, but also newbuilding and scrapping price time series. These were all collected from Lloyd's Shipping Economist. The exact sizes of the vessels are not disclosed, only the class (being Handysize, Panamax and Capesize). To calculate the profit, time charter rate series were obtained from Clarkson and operating costs were estimated in the form of $OC = a^* e^{bt} + u_t$. They are assumed to have little short-term variance and to grow at an inflationary rate. Before starting their test the data are evaluated and the log values of the data are found to be I(1) again. No indication of seasonality was discovered, which is in line with previously described research.

In order to perform the first two tests, three scenarios were applied to their model (buying/selling); newbuilding/second hand (5-year old), newbuilding/scrap (20-year old) and second hand (5-year old)/Scrap (20-year old). In the first case, EMH is not rejected for Handysize vessels. In the second case, EMH is rejected at the 10 per cent confidence level, but not at the 5 per cent confidence level. In the third case the EMH is rejected for all sizes at the 5 per cent level of confidence. The variance test is also performed on these scenarios, comparing the empirical distributions, constructed using bootstrap methods. If the 95 per cent confidence interval includes 1 (EMH would require this value), then the EMH is said to hold. They reject the EMH in all but one case, that of the 5-year old Panamax sold/scrapped after 15 years.

After this, they are testing their model for both 1-month and 3-month excess holding. The paper demonstrates that the sample means for the 1-month excess holding are statistically zero, while those of the 3-month holding set are significantly different from zero and higher, except for the handysize vessels. This leads to a rejection of the EMH. The failure of EMH, they argue, can be explained by time-varying risk perception of the investors. Kavussanos and Alizadeh investigate this claim using GARCH-M (Engle *et al*, 1987) and find the GARCH-M(1,1) specification appropriate in all cases. The risk premium is increasing, both with size and holding period, although for Capesize it decreases with holding period. According to them, this appeals to common sense, as with

a larger size, larger sums are involved and the risk of unexpected events is higher when the period increases. Still its presence is a reason to discard EMH.

The autocorrelation present in the excess returns of the different series is then finally explained by two possibilities. First, the aggregation of stochastic data might induce autocorrelation, which they refer to (Working, 1960). Second, there might be thin trading. This could result in the sale of one vessel influencing the sale price of the next.

A new view on EMH is introduced by Adland and Koekebakker (2004). They also apply the idea of no excess profit as proof of the EMH, though they investigate it in a different way than Kavussanos and Alizadeh did. They investigate 693 technical trading rules. These rules are either based on filter rules, moving averages or support and resistance levels. The goal of all these trading rules is to predict the future. The EMH can be seen as stating that no prognosis of the future can be made, based on the past only, as it incorporates all information available at the time, so also the current information. When any trading rule is able to predict the future, this proves the EMH not to hold. The new element incorporated by Adland and Koekebakker is the addition of transaction costs and market illiquidity.

They give an extensive overview of the history of trading rules in academics, which leads the reader to conclude that when trading costs and buy-and-hold benchmarks are considered, they yield no benefits significantly above normal. Another aspect discussed is data snooping; a given dataset is used more than once for inference or model selection. It forms a sort of self-fulfilling prophecy, where good results are published and bad results are discarded, making one trading rule more popular than the other by pure 'luck'. Lo and MacKinlay (1990) not only investigate the effect of data snooping in financial asset pricing models, but also suggest a relatively simple test to cure the potential problem; a 10-year out-of-sample performance experiment. This method will also be applied as a test by Adland and Koekebakker.

Their focus is on the four larger ship bulker sizes; VLCC, Aframax, Capesize and Panamax. Data collected is monthly average spot earnings, operating costs, scrap values and 5-year-old values for all types for the period January 1976–May 2003, a total of 329 observations. When running their model, the total amount of wealth of an investor/trading rule is tracked, using four basic assumptions:

1. The investor starts with the amount of cash equal to the value of the vessel at the start time. This start time is set to be month 18, while at that time all trading rules have sufficient data to generate a signal.
2. No short sales of vessels are possible.

3. A broker commission of 1 per cent is incurred upon selling.
4. Any surplus cash is invested in the money market at 1-month LIBOR.

Their period for selecting the best trading rules is set from January 1976 to December 1994 ($n=228$) leaving 101 observations for testing. They mention that their treatment of profits ignores the waiting time and off-hire time and is therefore biased towards the buy-and-hold benchmark strategy as profits are larger than would in reality be the case.

Their results show that trading rules outperform the financial market in the selection period. The selected rule (per category) is tested out of sample against the buy-and-hold benchmark, in both the wet bulk categories, the trading rule fails to outperform the benchmark. In the bulker section, the trading rule yields far better results however. They attribute this to market trends that were upwards for tankers and downwards for dry bulkers.

A second test is performed after this to correct for the illiquidity of the market. They argue that the second hand market is active, but not with a large choice every month. Buyers might not be able to purchase the vessel right away and sellers cannot get rid of their vessel right away. A month is assumed to be a valid delay. If the trading signal is still active in that month, the change will be executed. Again the best trading rules are selected on the basis of the selection period, though performance is already less, as would be expected. These rules are tested against the out of sample period. In this case, only the Panamax category buy-and-hold benchmark is out-performed by a trading rule.

In their conclusions, it is mentioned that the results favour the EMH, though two issues need to be considered. The selection of trading rules is based on cumulative wealth in the test period, though it only also includes operating profit in the out-of-sample test. Second, these profits are overestimated, potentially by as much as 15 per cent. They state that this could easily overturn their results.

In what appears to be the last paper published on this subject, Sødal *et al* (2006) investigate whether the EMH holds when comparing investments in dry bulkers and tankers. To test the potential benefits of market switching, they apply a theoretical real options model, as identified by McDonald and Siegel (1986). For their investigation, they make use of the concept of relative pricing and an empirical study on pairs trading by Gatev *et al* (2005). Pairs trading is a strategy where two items are selected that have moved together in the past. Once they deviate from their common path, buy the cheap one and sell the expensive one. If history is to repeat itself, prices will converge again and a profit is made. This concept is applied to the two integrated markets of bulkers and tankers.

They refer to Beenstock and Vergottis (1993), who argue that the tanker and bulker markets are integrated through a common newbuild and scrap market.

Next to that, the link is strengthened by the presence of Oil-Bulk-Ore (OBO) carriers, who can switch between the two markets. All this ensures that freight rates cannot move too far apart. This is a different assumption than commonly held before, when size categories were investigated as independent markets. The differential between the two freight rates is the key parameter in their model and is modelled by an Ornstein-Uhlenbeck (mean-reverting) process.

In the efficient and competitive market, the freight rate differential will remain inside the hysteresis band. This band exists because the transaction costs form an irreversible fee for switching. If the freight rate moves outside this band, there is room for excess profit in one of the two markets. There are three theoretical ways to model such a (perfect) market; stochastic demand process, stochastic with barriers and mean reverting price process. The first two imply some technical challenges and the data to fill them are scarce, according to the authors. This is the reason they choose for the O-U process. Other assumptions made are as follows:

1. An investor owns exactly one vessel; this is either a Capesize bulker or a Suezmax tanker (both roughly 150 000 DWT).
2. Buying and selling takes place in the second hand market only.
3. All ships have infinite life time (for example all ships can be sold at 5-year value).
4. Discount rate is constant.
5. Brokerage fee is constant.

The weekly spot rate data are used from January 1990 until January 2004, to estimate the factors of the O-U process. Together with the assumptions and monthly info for newbuild and second hand prices for the same period, the upper and lower barriers for the spot rate differential are estimated. These form the switching trigger and in a perfect market the spot rate differential would not exceed these barriers. Within the estimation, consideration is given to the fact that spot rates have become increasingly volatile over time and the estimation period is taken as 3 years, deemed to be the average newbuilding delivery time.

In three cases within their test period, the spot rate moves outside these bounds and this is in line with different boom (timings) in the two markets. This would indicate that the market was a little slow to react. The hysteresis band widens fast, so reaction of the market is seen by them, but just with a small delay, allowing excess profits to be made.

In the end, sensitivity analysis is performed on the discount rate and the fixed brokerage fee, but these do not significantly alter the conclusions made earlier. In their conclusions, several remarks on the validity of the model results are made. These concern the fact that there is no test to determine the

significance of a switch, that the spot rate differential might not adequately pick up uncertainty and that the O-U representation might not aptly describe the spot rate differential.

In Table 1, the papers above are summarized using year of publication, method adopted, markets used, data period investigated, costs incorporated and if EMH holds or not. Several papers perform more than one test and each test occupies one line in the overview.

Evaluation of Results of the EMEH Validity Testing

The papers above are mainly summarized, but no evaluation has been done yet. A first conclusion is that the validity of EMH seems to hold in one paper, while being discarded in another. This section will evaluate them as a whole as many objections hold for each paper, while also contradictions can be found between them. The following elements will be evaluated in this section: market independence, using co-integration as a test for EMH, biases towards buy-and-hold and data used. Still, the first observation holds, even after looking outside the second hand market, the EMH validity remains undecided at the end of this chapter.

A first observation made is a clear disagreement in the assumption of independence of the markets. Where Glen, Adland and Koekebakker and Kavussanos and Alizadeh assume the different size segments to be sufficiently independent, Sødal *et al* assume that both the tanker and bulker market are integrated, using the same arguments as Beenstock. While it is unclear if either or both assumptions are not justified, at least one group will discover issues of correlation due to insufficient independence or lack of integration of the investigated commodities.

The earlier papers use co-integration to test for EMH. Kellard (2001) and Brenner and Kroner (1995) challenge the simple test on co-integration as a measure of failure of the EMH. Brenner and Kroner provide a theoretical framework in their paper for testing on a commodity market, where the spot rates are random walk and the future rates are priced by an arbitrage system. Owing to irregularities in the commodities market three tests will have to be done:

1. Are spot prices and lagged future prices co-integrated $(1, -1)$?
2. Testing for serially uncorrelated residuals in u. Interest as levels is non-stationary and most likely influences the test results.
3. Test whether the spot rate, lagged future rate and lagged interest rate are co-integrated $(1, -1, 1)$.

Table 1: Overview of the papers on the efficiency of the second hand vessel market

Author	*Year*	*Method*	*Markets*	*Data period*	*Data source*	*Costs*	*EMH holds*
Hale and Vanags	1992	Testing for co-integration (Granger causality)	Dry bulk: 30.000, 70.000 & 120.000 DWT	October 1979–July 1988	Lloyd's Shipping Economist	None	Not for the 30.000–70.000 and for the three-variable regression.
Glen	1997	Testing for co-integration (Johansen's Maximum likelihood)	Dry bulk: 30 000, 70 000 and 120 000 DWT Tankers: 32 000, 80 000 and 250 000 DWT	Dry bulk: October 1979–July 1995 Tankers: October 1979–August 1988	Lloyd's Shipping Economist	None	Co-integration is present for all pairs, though no clear rejection of the EMH.
Kavussanos and Alizadeh	2002	Buy-and-hold in VAR model in excess holding	Handysize, Panamax and Capesize;	January 1976–December 1997	Lloyd's Shipping Economist and Clarkson	None	EMH holds only for Handysize vessels.
		Buy-and-hold with a variance ratio test	Handysize, Panamax and Capesize;	January 1976–December 1997	Lloyd's Shipping Economist and Clarkson	None	EMH holds only for 5-year old Panamax sold for scrap in 15 year.
		Unpredictable 1- and 3-months excess holding profits	Handysize, Panamax and Capesize;	January 1976–December 1997	Lloyd's Shipping Economist and Clarkson	None	EMH is rejected.
		Presence of time varying risk premium	Handysize, Panamax and Capesize;	January 1976–December 1997	Lloyd's Shipping Economist and Clarkson	None	EMH is rejected.
Adland and Koekebakker	2004	Evaluation of excess profit achieved by technical trading rules	VLCC, Aframax, Capesize and Panamax;	January 1976–May 2003	Lloyd's Shipping Economist and Clarkson	Trans-action costs	EMH holds in the tanker markets but fails in the bulker markets.
						Transaction costs and market illiquidity	EMH fails only for Panamax vessels.
Sødal *et al*	2006	Excess profit through pairs trading	Tanker and bulker market (150.000 DWT)	January 1990–January 2004	Lloyd's Shipping Economist	Brokerage fee and discount rate	EMH failed for three short periods.

Rejection of the last test will imply long run market efficiency, though one would expect if tests 1 and 2 are not rejected, test 3 would be rejected; Kellard shows that the before mentioned irregularities might result in different results. The last two tests were not performed within the papers focussing on co-integration and perhaps would have altered the results.

In later comparative studies, the authors assume that the investor will only hold one ship at a time. In both cases this results in previous profits staying within the money market against LIBOR. In both cases profits are not maximized and no evidence is provided that the money market performs at least equally to the shipping profits. Their results are therefore further biased towards buy-and-hold than they account for in their conclusions. Sødal *et al* further consider spot rates as a representation of profit. They do compensate this for the increased capital costs of double hull tankers, but spot rates are also highly sensitive to bunker prices among others. Their method of looking at the difference would compensate for this, given that both rates show a similar elasticity to bunker prices, no evidence of this was provided. UNCTAD (2010) shows that the elasticity for bunker prices in freight rates determined by OLS for iron ore are either 0.149 or 0.095, while for crude oil tankers this is 0.445. Although no statistics were checked for significance of the difference, the standard deviations are small enough to not allow an overlap in the 95 per cent interval. This would indicate a distinct difference in elasticity for (one type of) dry bulk and wet bulk. A possible explanation for this difference could be that oil is also used as fuel and that an increase in the price promises a higher profit in the sales of the product. The entire chain will probably want to benefit of this, resulting in higher freight rates.

The final comment on the papers presented concerns the data used in all of them. All research refers to either Clarkson's or Lloyd's Shipping Economist as their source. However, they do provide monthly estimates for vessel prices and weekly/daily prices for spot and charter rates on the basis of for example the Baltic Exchange. Although in a yearly overview Clarkson (2009) reports 1223 sales in 2008 and 1894 in 2007, which results in a total monthly sales volume of roughly 100–150 ships per month of all types and all ages. Syriopulos and Roumpis (2006) investigate actual sales in the bulker market and report an average of about two sales for both the Capesize and VLCC vessel categories. Only Handysize (dry) bulkers have a substantial monthly transaction number (± 12), all others do not exceed five sales per month (for all ages). One can only conclude that the monthly sales are spread to thin to accurately reflect a market for 5-year-old, 10-year-old and 20-year-old vessels. These values are mostly filled by 'guestimates', estimates of a number of knowledgeable brokers. They most likely have their internal models for coming to this price, introducing biases in the data. Another aspect that would seem to influence the data series,

but is not always picked up on, is the fact that over time, the representative vessel of a certain group has changed in size. This was done in line with market trends, though older estimates were not re-evaluated by the companies providing the data.

Kavussanos and Alizadeh are the only ones to assume vessels to have a finite life and to depreciate in value over time. While most others investigate the 5-year-old curve, even selling vessels back for the same price, which outside the range of a couple of months would not hold in reality. The lack of continuous data over all ages of the vessel limits the realism in their study. It does demonstrate that techniques applicable to stocks and stock markets are not always directly transferrable to real assets such as ships, which deteriorate with age.

Veenstra and Van Dalen (2008) mention similar problems with the collection of freight rate data. First published fixtures represent about 70 per cent of the total fixtures, with a severe deficiency in the longer contract durations (+2 years). They mention that Laulajainen (2006) claims that shippers feel the fixtures published do represent the market developments correctly. Second, there is no filter on the fixtures published, they could be guesses or estimates, hearsay or deliberately incorrect. Next to that, purely speculative intermediate deals are also present. Lastly the number of fixtures closed fluctuates strongly over the period. For aggregate data, there will be enough information available, but for disaggregated data on size, route and cargo type, insufficient data or even no data are available. This might induce models to produce unexpected outcomes and data leading to wrong conclusions.

In their paper, Merikas *et al* (2008) introduce the relative price ratio second hand/newbuild (SH/NP) as an investment trigger and they study the movement of this ratio. A low SH/NP ratio would indicate that the age depreciation is rated above the appreciation of the vessel, the market is weakening and asset play becomes interesting. In the other case, a high SH/NP ratio would indicate that the asset is valued higher than its depreciation by age and the market is strengthening, a signal that operation of the vessel is interesting. The third reason for purchasing a vessel, replacement of an existing one, is not really dependent on the market. They test the influence of various indicators on their ratio (including newbuild price itself). In their conclusions, they stress the usefulness of this ratio for investors for timing their decision. They, however, fail to recognize that it is more likely they modelled market expectations, rather than market behaviour, due to the data problems described above.

Looking at the more recent developments in financial economics (Shiller, 1999; Lim *et al*, 2006; Oh *et al*, 2007; Fox, 2009), its days of influence are ending. There is a new stream of economists like Shiller, explaining bubbles and other market events by herd theories and other theories borrowed from the field

of psychology. Asian economists like Lim and Oh also find far less indicators of an efficient (stock) market in Asia, due to lower liquidity of these areas. This would make the theory primarily suited for western markets, yet here Fox shows how the market itself has lost fate in the EMH, as it failed to prevent or even has propelled us into the last two bubbles of dotcom and housing. They argue that there is no rational market to begin with. Still the essence of the EMH, that is one cannot beat the market, is still subscribed and held as true today.

While the above described papers are all focusing on checking if EMH can be accepted to explain market behaviour, all tests were flawed by a number of problems in assumptions and data. The first one is that the design of the test itself was not always suited to test for EMH. The biggest one is that it is more likely that brokers' expectations were tested rather than real market behaviour, due to the lack of sufficient underlying data points. The absence of continuous age lines further complicated the testing of the EMH. Finally the assumptions on market integration were inconsistent over time.

The results remain inconclusive at best. It is the opinion of the authors that EMH and rational behaviour does serve an important role in helping us understand markets, as well as baselines against which inefficiencies of the market (due to irrational behaviour) can be discovered and explained. While in this and other fields non-structural models did provide important new insights, the data behind it in the case of second hand vessels should be considered flawed. In areas where more transactions occur per unit of time, this should be less of a problem. In order to investigate the market of second hand vessels, however, studying the actual data rather than the provided (flawed) indicators could be a solution. The next section of this paper will discuss research that did this.

Research on Second Hand Vessel Pricing Using Concluded Sales Data

Tsolakis (2005) in his PhD thesis propagates a move back to the structural market models, incorporating lessons learned from the VAR and other non-structured models such as described by Kavussanos (1996); Glen (1997); Veenstra (1999); Wright (1999); Kavussanos and Alizadeh (2002).

He argues from a perspective of a supply and demand function, where demand depends on the time charter rate, second hand price, newbuild price and LIBOR. On the other side, the supply depends on the size of the orderbook compared to the current fleet and on the second hand price. Setting demand equal to supply (market equilibrium), one can derive a function for second hand price. This price will depend on time charter rate, new build price, LIBOR.

Although he discusses research on the second hand price and EMH that was mentioned here as well, he does not incorporate that in his model. He also does not build further on the notion of Veenstra that sales have two purposes; replacement and speculation.

The more common notion in maritime economics, since the model proposed by Beenstock and Vergottis, is that the newbuild market should be seen as a futures market, rather than a direct replacement market. This does not mean that the price of these futures cannot influence the second hand price, but one should be careful with the interpretation. Another important aspect left out of his equation is the age of the vessels. As the heritage of the more detailed data availability, a new structural model should take this up. Tsolakis also still makes use of the Lloyd's shipping economists and Clarkson's data series though it seems at a yearly level, therefore most complications are less relevant.

In their paper Adland and Koekebakker (2007) do take up most of the comments made here earlier on the EMH. They investigate ship valuation using a non-parametric multivariate approach. In this approach, they incorporate three factors for price determination: Deadweight, time-charter rate and age. The relatively new aspect here is that they do not concern themselves with time series and market expectations, these are left out. Their multivariate density estimation (MDE) assumes there is a relation between the investigated variable (price) and a small number of other economic and fundamental factors. Although many factors can be named to influence vessel price, only a very limited number can be selected, as the properties of the MDE deteriorate quickly with more variables in the equation.

On the basis of the depreciation of vessel value over its economic life, age is taken up to be important when deciding on the price of a vessel. As measure for the state of the freight rate, they take the 1 year Time Charter Rate (TC-rate), though this duration was based mostly on availability rather than any other reason. Lastly they select size as it can influence the price a vessel obtains within its class, for example a large Panamax versus a much smaller vessel will obtain a higher price. The subgroup chosen was the handysize, mainly because of the volume of the second hand market of this subgroup. One thousand eight hundred and fifty two data points were left for estimation of the model after clearing it of abnormalities such as damaged vessel sales, auctions and so on.

On the basis of a comparison of their model performance and the broker estimates provided by Clarkson's for the 30 000 DWT 5-year-old bulker, they conclude that volatility of their model is smaller and attribute this both to the market sentiment and the smaller number of young vessels being sold. Also the downward trend in the prices is not captured by the model. This trend is attributed to a decline in newbuild price in that era, an aspect the model did not incorporate.

While one could argue to add newbuild costs to the model, there could also be pursued another approach. The lower newbuild costs would effectively lower the capital costs of the 5-year-old vessel and with the same TC-rate, this would increase the profit. Estimating the model not on TC-rates, but on profits (Profit = TC-rate−Opex) might also work. This way, newbuild price is incorporated in the model, but correctly, rather than implementing the movement of future contracts in the stock movement. It could also be that the authors intended to use the newbuild price of the vessel sold. In this case, both conceptions should lead to similar results with the younger vessels. With older vessels, the newbuild price might quickly loose its significance due to several resales of the vessel.

Continuing in this line of thought of using 'micro'-economics to determine vessel prices is Köhn's (2008) PhD. This thesis is focused on the use of Generalized Additive Models (GAM) to various aspects of the maritime economics. There are several benefits of this approach over that of Adland and Koekebakker, discussed before. GAMs allow taking nonlinear relationships in a combination with parametric components, such as dummy variables. A second benefit of these semi-parametric frameworks is that reliable results are provided using moderately sized samples. The limited dimensions issues that Adland and Koekebakker ran into does not occur here. These benefits do come at a cost; both the representation of the smooth terms and the degree of smoothening have to be chosen.

The representation chosen by Köhn is the Thin Plate Regression Spline and basing the selection of the smoothening factor on Generalized Cross Validation. The following choices come at an extra cost concerning significance; *P*-values can only be approximated using a Bayesian approach. Typically the *P*-values calculated this way are on the low side, as they are conditional on the smoothening parameter, which is usually uncertain.

The dataset used is the Purchase and Sales data of Clarkson for chemical tankers from October 1990 till March 2005. After cleaning 736 observations are left, that is substantially less than Adland and Koekebakker. The following data were collected for potential inclusion with smoothness terms: price, newbuild price, earnings, age, size, number of tanks, number of pumps, pump capacity, speed and horsepower. Next to that, there was also data collected for inclusion in dummy variables: country of build, classification society, engine type, coating, hull information and IMO standards.

Next, a set of eight equations is set up to estimate the price. All contain at least the newbuild price, the earnings, the size and the age. Hull type is present in all except one, as the difference between single and (partial) double hulls is expected to make a large difference on the price. Also a measure of cargo diversity is often present, either type of coating, number of tanks or the multiplication of these two.

Going over the results of his GAM estimations, the basic model establishes that all four elements (newbuild price, earnings, size and age) are significant and highly nonlinear. A discussion of the other results follows, but concerning our own data is less relevant. Köhn concludes that nonlinearity is an important aspect to be taken into account in at least price determination. Several elements were displaying a low level of correlation, but when applied nonlinear showed high significance.

In Table 2, the most important aspects of the three papers discussed above are summarized; author, year of publication, markets investigated, data period investigated, data sources used and explanatory variables. Tsolakis clearly went back to the old structural models, but did not implement the lessons learned from the EMH discussions at all, limiting the applicability of his solution. On the other hand Köhn takes a very similar approach to the normal vessel valuation process by a broker. This idea was started by Adland and Koekebakker, but Köhn provides a mathematic technique that requires half the data points for estimating five times as many dependant variables as they did. Both also are able to take nonlinear trends into account, which seems especially relevant when looking at the influence of age on vessel price. The beginning and end of this curve are flattened. It is our conclusion that the GAM approach provides the most potential for future research. The selection of variables to take into account will depend on the goal of the model, but opens a whole new field to be researched in the future.

Price–Volume Relations in the Second Hand Market

All papers discussed have focused determining the price of second hand vessels. This section concerns a variable that might influence the price as well, but has not been considered in any of the papers described so far; the trading volume of the second hand vessel market. The two papers described here investigate the relation between trading volume and price. An important aspect to test here would be if price follows or drives volume. In the last case the previous models did not overlook a determining factor, though in the first case this might be a variable to take up. They explicitly do not model the second hand vessel price, but still discuss a potentially important variable and should therefore not be left out of this review.

Both Alizadeh and Nomikos (2003) and Syriopulos and Roumpis (2006) investigate the several aspects of the relationships between price of the vessels and volume of the second hand vessels traded. The 2003 paper focuses only on the dry bulk market, while the 2006 paper focuses also on the tanker market and extends the time period, August 1991–June 2002 and

Table 2: Overview of the papers using a structural model for second hand vessel pricing

Author	*Year*	*Method*	*Markets*	*Data period*	*Data source*	*Variables*
Tsolakis	2005	Supply and demand function	VLCC, Aframax, Handymax, Capesize, Panamax and Handysize	1968–2001	Time series from Clarkson	Newbuild price level, time charter rate, LIBOR and orderbook/fleet
Adland en Koekebakker	2007	Non-parametric multivariate density estimation (MDE)	Handysize	January 1993–October 2003	Individual secondhand vessel sales from Clarkson	Deadweight, time charter rate and age.
Köhn	2008	Generalized additive model (GAM)	Chemical tankers	October 1990–March 2005	Individual secondhand vessel sales from Clarkson	Price, newbuild price level, earnings, age, size, number of tanks, number of pumps, pump capacity, speed, horsepower, country of build, classification society, engine type, coating, hull type, IMO rating.

September 1991–November 2004, respectively. Research on the financial markets shows a positive relation between price and volume. Two theories are mentioned, which can explain this phenomenon; Mixture of Distribution Hypothesis (MDH) (Clark, 1973) and Sequential Information Flow(Copeland, 1976). The first one assumes that information on supply and demand is disseminated symmetrically and all traders view this information simultaneously, resulting in immediate equilibrium restoration. The second one assumes asymmetrical information release, at random and sequentially. Market equilibrium is therefore restored gradually.

Both papers investigate the relation in three steps: correlation, Granger causality and volume-volatility. Although the number of sales is absolute and based on raw reported data, the second-hand value is taken as the 5-year-old vessel price estimation from Clarkson. Results of the first test show that for all cases for the bulkers, a significant positive relation between price and volume is reported, except for the Capesize vessels, there the relation is negative and insignificant (5 per cent level). For tankers, the relation is positive for Handysize, Aframax and VLCC, but not significant at the 5 per cent level. At the 10 per cent level, only the VLCC remains insignificant. The Suezmax has a negative relation, significant at the 10 per cent level. Although the authors assume a lengthy sales process (1–3 months) to help in the correlation, we also see another indication of the risk of using data series. In the three classes with dubious results the amount of months with less than four sales is definitely more than 60 per cent of the time. This raises doubt on the correctness of the estimated value of a 5-year-old vessel and the validity of the results of their correlation estimation. This does further support their conclusion that volume and price in second hand vessels are correlated, as they are found to be in other markets as well.

The results of the Granger causality tests, using VAR models where the lag-length p has been chosen on the basis of SBIC, indicate that a volume does not Granger cause price in either the tanker or the bulker market. In the smaller classes (Handysize (Wet & Dry), Panamax and Aframax), price changes are Granger causing the trading volume in these markets. This result is consistent with the MDH on the assumption that past return influences the trading level of the market. Higher capital returns seem to lead to increased trading as more people want to get a piece of the pie.

An EGARCH-X model is estimated for each category to investigate the volatility, using lagged volume as an explanatory variable. Here their findings from this model are limited to the volume–volatility relation. Bulkers for all three classes present a negative sign (at 5 per cent significance), which indicates that volatility diminishes when the trade volume increases. Tankers, however, present a different picture; it is negative, like the bulkers, in the Aframax and

VLCC markets, though not significant at the 5 per cent level. In the Handysize and Suezmax market the relation is positive, though smaller and only significant for the Handysize.

This difference is explained through thin trading. In a modified version of the MDH by Tauchen and Pitts (1983), thin trading will result in a negative relation, while mature markets will cause the relation to be positive. The explanation is that with thin trading, as the volume of transactions rises, more information becomes available and mis-pricing is less likely to occur. In mature markets, the relation is positive, as in the original MDH model, more trading leads to more volatility.

In Table 3, the results are summarized stating the author, year of publication, testing method, markets investigated, time period considered, data sources used and results of the tests. As in three tests were performed in both papers, the results are presented in six rows, though results are the same for both papers for each test. Their final conclusions are that trade volume information can provide additional information on the status of the market, when the prices are obscure or not clearly giving a direction. It also has been proven that volume does not drive price and that the other papers discussed did not miss an important explanatory variable.

Final Conclusions

This review is performed over the past 20 years of developments in second hand vessel price modelling. The goal was to find out how to best model these prices.

The majority of the time was spent on testing the validity of the EMH for the second hand vessel market, though results remain inconclusive. When the market model is extended with elements such as broker fees and illiquidity the EMH does seem to hold, or at least not fail seriously. This research into the EMH was started by the availability of more detailed data series. The materialization that these series were for a large part based on estimations and expectations ended this period. The data still have many uses, but it does not represent the market unbiased on a monthly level. If we consider the EMH to hold, in the more complex cases, this means that consecutive price changes are independent. When modelling the second hand price, past values of the price should therefore not be used as an explanatory variable.

Currently, research focuses on the underlying data and micro-economy for determining the price of the vessel. Non- and semi-parametric models perform a key function in this development. In a sense, this is a move back to the more structured models, defining *a priori* which elements could influence the outcome,

Table 3: Overview of the papers investigating the price-volume relation in the second hand vessel market

Author	*Year*	*Method*	*Markets*	*Data period*	*Data source*	*Results*
Alizadeh and Nomikos	2003	Correlation	VLCC, Suezmax, Aframax, Handymax, Capesize, Panamax and Handysize	August 1991–June 2002	Time series from Clarkson	For Panamax, Handysize, VLCC, Aframax, Handymax the relation is (significantly) positive. For Capsize and Suezmax the relation is negative.
Syriopulos and Roumpis	2006			September 1991–November 2004		
Alizadeh and Nomikos	2003	Granger causality	VLCC, Suezmax, Aframax, Handymax, Capesize, Panamax and Handysize	August 1991–June 2002	Time series from Clarkson	For Aframax, Handymax, Panamax and Handysize prices granger cause the trading volume. In no case volume granger causes price.
Syriopulos and Roumpis	2006			September 1991–November 2004		
Alizadeh and Nomikos	2003	Volume-volatility	VLCC, Suezmax, Aframax, Handymax, Capesize, Panamax and Handysize	August 1991–June 2002	Time series from Clarkson	Negative relation for Capesize, Panamax, Handysize, VLCC and Aframax. Positive relation for Suezmax and Handymax. This is explained by mature markets versus thin trading markets.
Syriopulos and Roumpis	2006			September 1991–November 2004		

though not assuming any clear linear link between them. Currently, the following elements have been considered that are applicable to all ship types: newbuilding price level, orderbook size (relative to the fleet), earnings/time charter rate, age, size/DWT, speed, horsepower, country of build, classification society. Unfortunately these have not yet been considered in one model and also the increase of bunker costs on earnings has been left out.

In the last part of the review, the price–volume relation was investigated. In several sub-markets, price does seem to influence the volume traded, though volume did not seem to influence price. This eliminates volume as a variable in the determination of the price, which is in line with observations in other markets.

On the basis of our review of 20 years of research, a future model for second hand vessel pricing should consider the following explanatory variables: newbuilding price level, orderbook size, profit (or earnings and bunker/fuel consumption costs), age and DWT. There are two other elements, but these might not be so easily taken up in a larger model, such as speed and horsepower. However, in a future research these should be considered. The elements 'country of build' and 'classification society' were already discarded as a significant influence on price in the papers reviewed.

Note

1 ARMA: Autoregressive Moving Average Model (future values of a time series are the results of external shocks and internal trends). ARIMA: Autoregressive Integrated Moving Average Model (when time series are not stationary, differencing is applied to make them stationary, after which an ARMA model is estimated for the stationary series). ARCH: Autoregressive Conditional Heteroskedasticity (variance is time (and history) dependant). GARCH: Generalized Autoregressive Conditional Heteroskedasticity (error variance is represented by an ARMA model).

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