Transportation Research Part A 66 (2014) 173–184

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Energy efficiency and time charter rates: Energy efficiency savings recovered by ship owners in the Panamax market

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ARTICLE INFO

Article history:
Received 24 August 2013
Received in revised form 25 March 2014
Accepted 9 May 2014
Available online 12 June 2014

Keywords:
Energy efficiency
Panamax
Dry bulk
CO_2 emissions
Time charter
EEDI

ABSTRACT

This paper presents the first analysis on how financial savings arising from energy efficient ships are allocated between owners and those hiring the ships. This as an important undertaking as allocation of financial savings is expected to have an impact on the incentives faced by ship owners to invest in more energy efficient vessels. We focus on the dry bulk Panamax segment as it contributes to around 50 Mt (5%) of total CO_2 emissions from shipping in 2007 and therefore its importance in terms of environmental impact should not be neglected. The time charter market represents a classical example of the principal–agent problem similar to the tenant–landlord problem in the buildings sector. We discovered that on average only 40% of the financial savings delivered by energy efficiency accrue to ship owner for the period 2008–2012. The finding that only part of the savings are recouped by shipowners affecting their incentives towards energy efficiency could consequently have implications on the type of emission reduction policies opted at both, global and regional levels.

1. Introduction

As the energy efficiency of a ship, i.e. the amount of fuel consumed per unit of transport supplied, is a function of both the technical specification and the way in which a ship is maintained and operated, one can distinguish between "technical efficiency" which refers to some baseline conditions, and "operational efficiency" which takes into account the practicalities of the voyage, variability in environmental conditions and commercial realities of operations. One example of the former is the Energy Efficiency Design Index (EEDI) (Buhaug et al., 2009) while a measure of operational efficiency can be obtained by taking measurements of fuel consumption and work over a period of time (IMO, 2005).

Energy efficiency is expected to be an important feature for a firm operating a ship, as it influences its overall costs and revenues. There are a number of different markets in shipping where energy efficiency might be reflected in prices: the new build market, the second hand market and the charter markets, both voyage and time charter. In the voyage market, charterers hire ships on a given route and pay a fixed amount, which includes fuel consumption, while in the time charter market the daily price for hiring a ship excludes the fuel costs which are additionally borne by charterers. This article focuses on the time charter market as it represents a classical example of the principal–agent problem, also known as split incentive and tenant–landlord problem (Blumstein et al., 1980; Brown, 2001 and Graus and Worrel, 2008; Vernon and Meier, 2012 in the transport sector), although the verification of the agency problem on the level of investments is not tackled as the data

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http://dx.doi.org/10.1016/j.tra.2014.05.004
0965-8564/

do not enable us to compare the optimal and the observed level of investments. In the time charter vessel owners (agents) decide the level of technological energy efficiency, while charterers (principals) bear the costs associated with agent's chosen level of energy efficiency, i.e. the fuel bill in the case of the shipping market. This paper quantifies the extent to which the fuel savings related to energy efficiency ships are captured by ship owners through higher charter rates using a linear regression of about 2000 fixtures in the Panamax dry bulk market observed between 2007 and 2012. This is an important endeavour, as this issue directly impacts the revenues of ship owners and therefore their incentive to invest in energy efficiency. Panamax refers to ships with deadweight (payload capacity) of approximately 60,000–80,000 tonnes which are designed to have maximum capacity whilst being able to transit via the Panama Canal, although according to the taxonomy of the database used in this study Panamax ships range between 60,000 and 100,000 tonnes. We selected the Panamax dry bulk sector to carry out our analysis because of its reputation for being competitive (Stopford, 2009). This sector was attributed a total of about 50 $MtCO_2$ in 2007, i.e. about 5% of total sea transport emissions, a considerable quantity which is expected to increase due to higher demand for shipping services (IMO, 2009).

The paper is structured as follows. Section 2 discusses econometric analyses of the time charter market, rewards of energy efficient investments in the shipping sector and the way energy efficiency can be defined. Section 3 describes the data we use in this article while Section 4 discusses the estimation and the result presented in this study. Section 5 draws the conclusions and the policy implications of our work before presenting recommendations for further work which could help take the analysis in this paper forward.

2. Literature review: econometric studies and the impact of energy efficiency on charter rates

Econometric studies modelling time charter and voyage rates can be grouped into two categories, i.e. those addressing the relationship among different rates, and those exploring the drivers influencing time charter and voyage rates. The existence of a relationship between time charter rates of different durations or between time charter and voyage rates is explained by the fact that a charterer has the option of entering into a single time charter contract for the whole period he needs a ship for, any mixture of time charter and spot contracts, or a number of voyage rates covering the routes they need to journey. Veenstra and Franses (1997) found the existence of a stable long-term relationship between the prices of six routes, three being served by capesize, the other by Panamax ships, all driven by one common trend. Berg-Andreassen (1997) reports that the conventional explanation of the time charter rates setting process is essentially correct: spot rate changes matter but spot rate levels do not. With regard to the studies discussing the drivers influencing time charter and voyage rates, fuel price has received considerable attention, which can partly be attributed to the debate on the use of market-based instruments to address CO_2 emissions in the shipping sector (Vivid Economics, 2010) and to the fuel costs estimated to be about 60% of ships' costs in the current climate of high fuel prices and low charter rates (Lloyd's List, 2012a). As voyage rates comprise costs related to fuel consumption, the relationship between these rates and fuel prices give an idea of the extent to which changes in fuel price are either absorbed by ship owners or passed to charterers. According to UNCTAD (2010), owners of ships used in the iron ore trade passed changes in the fuel price entirely to charterers while only a third of the changes was passed in the wet bulk market, both findings being confirmed by Vivid Economics (2010). In the case of grains, Vivid Economics (2010) reports that only 20% of the changes in fuel costs are passed on, about half the value estimated by Lundgren (1996) on the USA-Europe route. Findings discussed for the coal market in Chowdhury and Dinwoodie (2011) depend on the type of coal, the size of ships, i.e. Panamax or capesize, and the route. The average of all estimated models is very close to full transfer of fuel costs, considerably higher than the 40% estimated by Lundgren (1996) on the USA-Europe route.

On the basis that most of the variables affecting voyage rates are likely to affect time charter rates, it is interesting to discuss the models estimated for voyage rates. The model in Chowdhury and Dinwoodie (2011) and Vivid Economics (2010), for example, include bunker prices, trade volume and fleet size. An increase in trade is expected to cause an increase in the voyage rates through an increase in the demand for ships while an increase in the fleet is expected to cause a decrease in the rates. The model in Lundgren (1996) includes lay-up and change in trade, as supply and demand factor, respectively. The specification used in UNCTAD (2010) and Tsolakis (2005) introduces the commodity price among the variables used to explain voyage rates. The coefficient is found to be negative and statistically significant in UNCTAD (2010) but positive in Tsolakis (2005) for both the Panamax and capesize bulk carrier.

As the effect of energy efficiency on time charters has not been explored by the academic literature, our literature review utilises anecdotal evidence derived from news articles and industry reports. Kollamthodi et al. (2008), based on an interview with the Norwegian Shipowners Association, claim that charterers are willing to pay higher rates for fuel efficient ships. In the container sector, a recent poll of twenty brokers showed that fuel efficiency was the single most important factor for the hiring of vessels on time charters, and that more efficient vessels obtain rate premiums compared to standard vessels (Sustainable Shipping, 2012). Maersk Line, one of the leading container companies, recently stated their willingness to pay for the retrofit of the vessels they charter in, as this results in a lower fuel bill for the company (Lloyd's List, 2012b). This suggests that charters are willing to trade lower fuel bills for increased costs in the chartering of ships. In fact, analysts have argued for some time that a two-tier market is emerging, with charterers willing to pay more for efficient vessels and older and less fuel-efficient vessels losing out to modern tonnage (Sustainable Shipping, 2012 and Lloyd's List, 2012c). In the tanker sector, oil companies are reported to prefer newer vessels even if they are slightly more expensive (Lloyd's List, 2012d).

It is however unlikely that energy efficiency is fully reflected in the charter rates. Barriers, such as lack of reliable information on costs and savings from an energy saving measure as well as uncertainty as to whether the market will pay a premium for fuel efficient ships will result in sub optimal levels of investment. Based on a survey of five operators and seven other maritime stakeholders, Faber et al. (2011) conclude shipowners investing in fuel efficiency cannot recoup their investments, unless they either operate their own ships or have long term agreements with charterers. Wang et al. (2010) point out that charterers may be unlikely to pay a premium to reflect energy efficiency due to the diversity of the charter markets, where each sector comprises several subsectors reflecting cargo capacity, dimensions and other vessel characteristics, and to the difficulty in verifying fuel consumption claim made by the owners, a key factor in the split incentive problem discussed above. Interviews conducted by one author of this paper pointed to similar conclusions. Three ship owners/operators and a management company showed scepticism to the notion that charter rates reflect a premium for energy efficiency and notion that investments in energy efficiency sustained by the ship owners could be recouped (Rehmatulla, 2014).

An argument for investment in energy efficiency is that it increases the success rate of winning contracts and therefore provides better utilisation rates of the ships, which may be an important factor particularly in an oversupplied market like the current one (Wang et al., 2010; Rehmatulla, 2014). According to a large bulk shipping owner, the company would still invest in energy efficiency even if not remunerated through charter rates as many major charterers require ships to comply with a certain level of environmental performance (Rehmatulla, 2014). This view has been recently confirmed by Lloyd's List (2012b), according to which, Maersk and other operators in the container market, as well as operators of other vessel types that hire ships on long charters may not be willing to pay premiums for energy efficient vessels but they feel compelled to take in the better ships first, where owners of vessels with a lower performance are forced to start accepting lower rates or shorter contracts. It is interesting to note that less energy efficient ships are forced to accept lower rates, as discussed in Lloyd's List (2012b), contradicts the statement that energy efficient is not remunerated through charter rates.

3. Descriptive analysis of the data

Data on the fixtures between January 2007 and September 2012 were taken from the Clarksons Ship Intelligence Network (SIN). The SIN database contains information on date of the fixtures, name of the ship being chartered, build year, deadweight tonnage, start and end of laycan period, daily charter rates and length of the charters. Ships involved in the fixtures were matched, based on their IMO number, to the information from the Clarksons World Fleet Register (WFR) database which contains information on gross tonnage of a ship, installed power, fuel consumption, bunker capacity, the build year and speed. It is worth stressing that all technical data in this dataset describes the design characteristics of ships rather than their operational performance. From the variables above we computed a simplified EEDI as described below. Next, we used the following variables from SIN to describe the state of the economy and the shipping industry: quantity of commodities carried by Panamax, fuel prices (HFO380 in Rotterdam), the size of the Panamax fleet, and an index describing the rate prevailing in the market for one annual time charters. The quantity of traded commodity carried by Panamax has been computed by multiplying the total seaborne iron, grain and coal by the share carried by Panamax ships out of the quantity carried by all ship types. Information on the share of each commodity, taken from Stopford (2009), is based on data from 2001 to 2002 and is assumed to stay constant across the period covered by our dataset, as we did not have access to data from more recent years. Finally, we computed the price of the mix of commodities carried by Panamax from the World Bank Pink Data. The price of each commodity was weighted by using its share out of the total cargo transported by Panamax ship in 2010. Data on the shares was sourced from UNCTAD (2011).

Calculating a ship's technical energy efficiency requires measurement of both fuel consumption and performed transport work. Whilst the EEDI regulation has made verified calculation of technical energy efficiency for new ships compulsory since 1st January 2013 (IMO, 2011), there is no definitive database for the existing fleet, as ship owners and charterers have to work with estimates of energy efficiency computed from the key ship parameters. In fact, estimates of the fleet have been used to form the baseline curves stipulated in the IMO MARPOL Annex VI amendment (IMO, 2011) while a similar approach is taken in the formation of the Existing Vessel Design Index (EVDI) (Rightship, 2012). The formula applied in both instances is

$$EFF = \frac{0.75P_{me}.sfc_{me}.C_f + P_{ae}.sfc_{ae}.C_f}{V \bullet dwt} \tag{1}$$

where P_{me} and P_{ae} are the installed power of the main and auxiliary engine, C_f the carbon factor of the fuel, sfc_{me} and sfc_{ae} the specific fuel consumption of the main and auxiliary engine, respectively, V the vessel's speed and dwt the vessel's deadweight. Databases, such as Clarksons World Fleet Register, list most of the input data for the calculation, but are often poorly populated for the sfc_{me}, P_{me}, P_{ae} and sfc_{ae}. This paper adopts (1) to compute a simplified EEDI, as described in IMO (2011).

In time charter markets, the energy efficiency of ships is mainly communicated by ship owners through the fuel consumption and speed information (both for ballast and laden legs) provided during the negotiation process and ultimately reported in the contract. Actual performance can deviate from the values listed in the contract due to a number of factors such as weather, deterioration of the hull (fouling), deterioration of the engine (wear), quality and calorific content of the fuel. Due to the difficulty of verifying information about a ship's fuel consumption prior to engaging it in a charter, the charterer is normally protected by a guarantee which stipulates the acceptable range for speed and fuel consumption (Veenstra and Dalen, 2011). During or on completion of the time charter, data can be collected to verify whether the advertised energy efficiency was achieved.

As increased energy efficiency implies reduced energy consumption and therefore fuel bill for the charters, one would expect this to be a desirable attribute for somebody looking to hire a ship thus ship owners may overstate claims related to energy efficiency to attract business (Veenstra and Dalen, 2011). In order to limit unsubstantiated claims, claims can be made against the guarantee. In addition, reputation in the industry to ensure repeat business, either for a specific ship or for the company owning and operating the ship may constrain short-term benefits from overplaying the energy efficiency of a ship. Unfortunately, energy efficiency performance is difficult to verify, even at the end of the charter, and claims against the guarantee can be difficult to pursue successfully (Williamson, 2012). Fuel performance measurements are normally limited to collecting data about fuel consumed over a long period of time but very detailed information is required (e.g. weather data) to assemble sufficient evidence to effectively pursue claims against the guarantee Some reduction in the uncertainty in energy efficiency and fuel consumption of a prospective charter can be obtained through the use of third party data. The recently introduced mandatory calculation of the EEDI will increase the quality of the data available to charterers for ships built after 2013, while some data is already publicly available for existing ships through tools such as the EVDI (Rightship, 2012) and other broker-held sources.

After data cleansing, our dataset contains about 2000 observations. Filters to cleanse data were based on the characteristics of the ships from the Panamax market, e.g. dwt not falling between 60,000 and 100,000 or showing different values for any variables present in both datasets from where the data were sourced. The empirical distributions of the ship and fixture specific variables can be seen in Fig. 1. From the first histogram in Fig. 1a, one can see that the dataset used in this study comprises mainly relatively short fixtures, as testified by the peak in the distribution for contracts ranging between 100 and 200 days. Because of the changing market conditions in the years covered by the sample, the rates of the fixture do not show a distribution similar to the one of the duration of the contracts. As can be seen in the figure, most of the rates vary between 10,000 and 80,000 dollars per day but a significant right tail well into the 100,000 $/day can be noticed. In terms of the number of days between the signing of the contract the start of the laycan period, most contracts start relatively soon after the signing date. Ships chartered out in the fixtures in the dataset were built relatively recently when compared to the 25 year average lifetime of a ship (Faber et al., 2011). A reduction in the number of ships built in the last three years or so can be noticed in the figure. The distribution of the deadweight tonnage of the ships in the dataset reflects the market segment analysed in this study, with most of the ships size falling between 70,000 dwt and 75,000 dwt. Finally, in the last graph in Fig. 1a, bunker capacity shows quite a disperse distribution with values ranging between 1500 and 4500 tonnes, with three peaks near the 2100, 2700 and 3200 values.

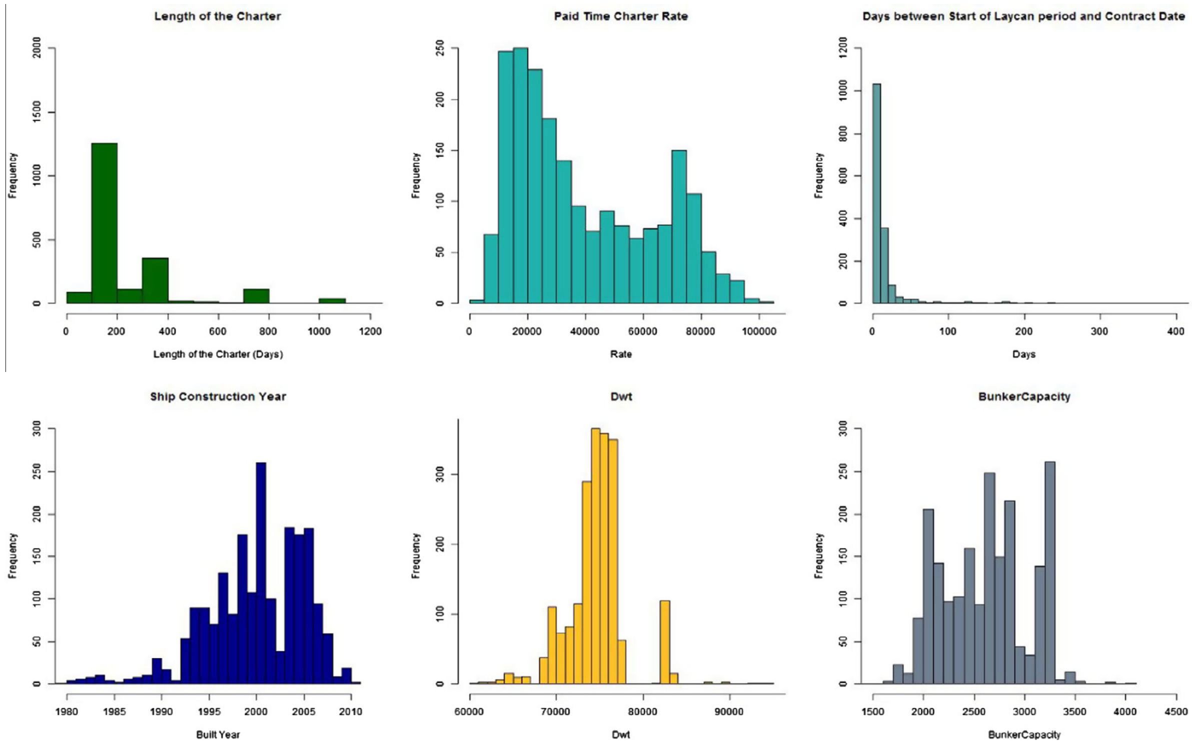

Fig. 1a. Empirical distribution of ship-specific and fixture-specific variables used in this study.

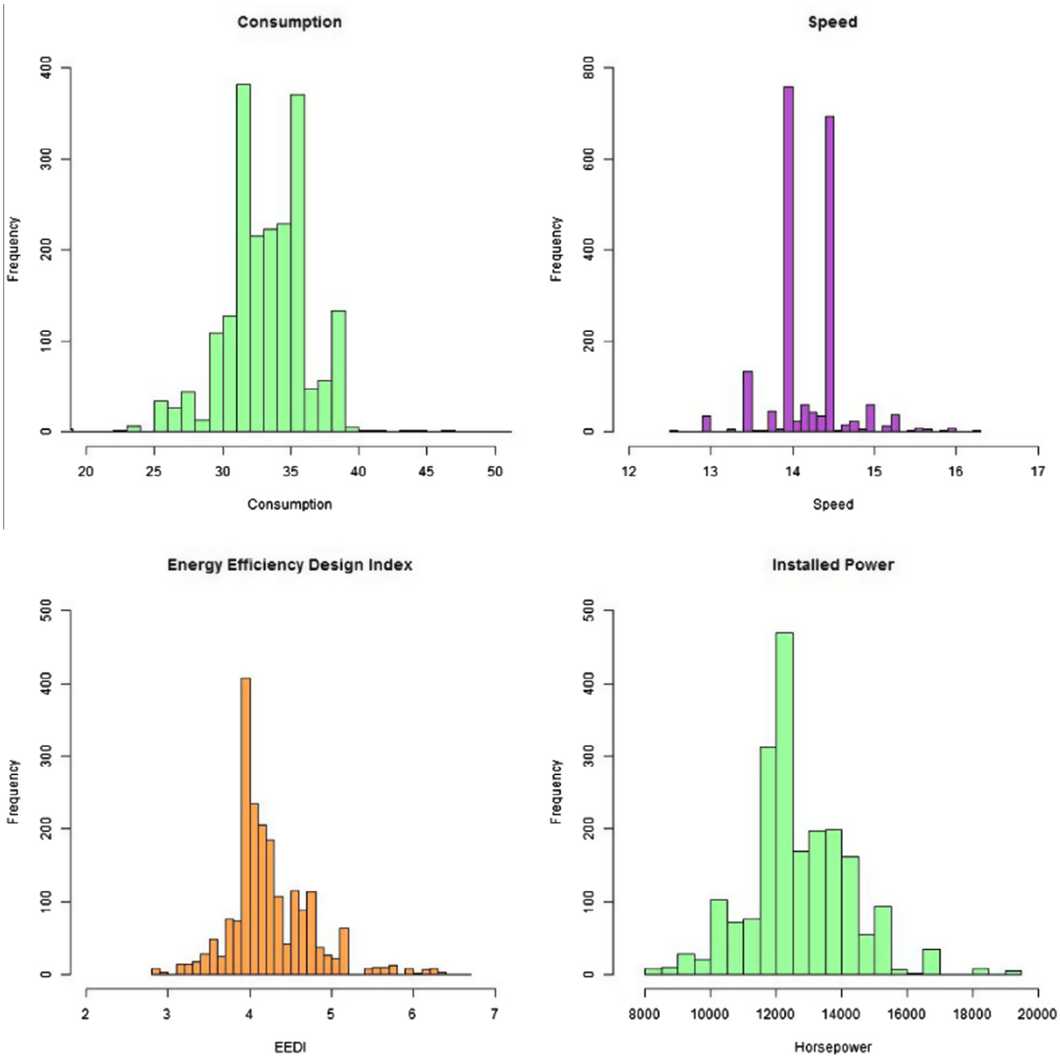

Fig. 1b. Empirical distribution of ship-specific and fixture-specific variables used in this study.

In Fig. 1b, one can notice that the consumption of most ships falls between 30 and 40 tonnes per day. In the next graph one can see that design speed takes mainly two values, 14 and 14.5. Finally, in the last two graphs in Fig. 1b, one can notice the similarity in the distributions of the simplified EEDI and installed power. Considering a correlation of 0.86 between the two variables in our dataset, one can conclude that information conveyed by the simplified EEDI index is of limited additional value compared to the information conveyed by installed power in the case of the Panamax dry bulk market.

Fig. 2 shows the variables representing the condition of the economy and of the ship sector used in this study. Panamax fleet size has increased by about a third since January 2007, and so did the quantity of commodities carried by Panamax ships, although this increased demand is not reflected in the average time charter which collapsed in the last quarter of 2008 before bouncing back slightly in 2010 and falling again in the remaining part of the sample. The bunker price has fully recovered from the crash in the last quarter of 2008, with the price now close to the maximum in the sample. At a consumption of 32 tonnes per day, recent bunker price implies a daily fuel bill of about 19,000 dollars, nearly twice the recent charter rates on one-year contract. Finally, one can notice the similarities between the plots of the commodity carried by the Panamax ships and the bunker price.

4. Estimation procedure and results

Estimation of the effect of energy efficiency on the time charter rates is carried out using the cross-section dimension of the dataset described above. We adopt the established General-To-Specific methodology (Campos et al., 2005) which starts from a very general model likely to include irrelevant variables and narrows it down based on the statistical significance of

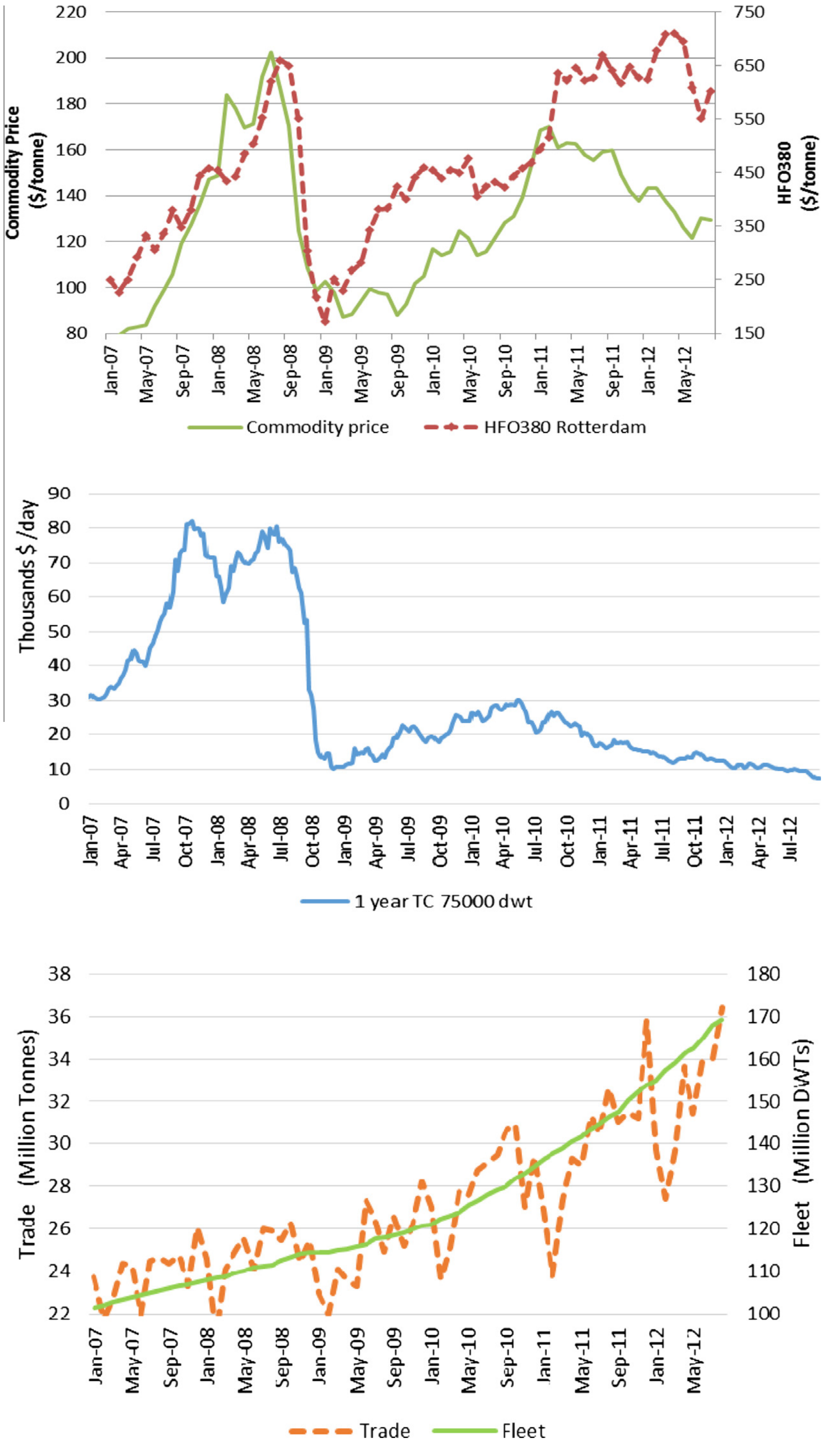

Fig. 2. Time plots of the variables representing the condition of the economy and the shipping industry used in this study.

the estimated parameters. The full list of variables includes age of the ship when the contract was signed (called Age in the tables below); its gross tonnage (Gross Tonnage in the tables), installed power on the ship measured in horsepower (Horsepower), consumption of fuel measured in tonnes per day (Fuel Consumption), quantity of fuel which can be loaded onto the ship (Bunker Capacity), design speed of the ship (Speed); simplified EEDI, as described above (EEDI), the fuel price in Rotterdam (Fuel Price); fleet size measured in total dwt (Fleet), price of the commodity carried by Panamax ships (Commodity Price), traded quantity carried by Panamax ships (Trade), number of days where loading of the cargo is allowed without

Table 1
Estimated values, standard error in parentheses, and statistical significance of the coefficients. Key for statistically significance of coefficients: **=1%, *=5%.

Variables	Model 1	Model 2	Model 3	Model 4
Intercept	230,220**	162,230**	190,657.44**	150,170**
	(23,901)	(3815.90)	(3388.76)	(4316.80)
Age	−349.09**	−352.10**	−346.55**	−295.14**
	(78.28)	(52.63)	(54.58)	(83.68)
Gross Tonnage	−0.84**			
	(0.30)			
Horsepower	2.27*			
	(1.01)			
Bunker capacity	−2.58**	−2.43**	−2.48**	−1.96*
	(0.61)	(0.60)	(0.64)	(0.98)
Speed	−2485.10*			
	(1076.80)			
EEDI	−6689.80*			
	(2888.20)			
Fuel price	96.06**	96.37**	151.96**	
	(5.30)	(5.30)	(3.11)	
Fleet	−1895**	−1898.70**	−2002.54**	−1412.40*
	(36.42)	(36.13)	(34.76)	(45.52)
Commodity price	188.02**	187.94**		
	(12.87)	(12.93)		
Trade	1715.70**	1712.50**	1074.19**	2347.80**
	(137.37)	(137.82)	(123.93)	(219.75)
Forward start	−61.86**	−61.83**	−62.47**	−42.58**
	(6.43)	(6.39)	(6.99)	(7.90)
R^2	78.38%	78.33%	76.37%	42.91%
AIC	43,674	43,675	43,849	45,641

the need of paying the charter rate; length of the charter and number of days between the signing of the contract and the start of the charter (Forward Start), and in the case of relative models the 1 year time charter rate for Panamax ships (Time Charter Benchmark Rate). Estimated models have been judged on the basis of their fit, on whether the sign of the coefficients conform to theory, and on the basis of the comparison between the effect of energy efficiency imputed by the model and the maximum rational effect. Both models with variables in logarithms and levels have been estimated although only models with variables in levels are discussed as taking the logarithms of the variables did not reduce the heteroscedasticity of the residuals while making the interpretation of the results less intuitive. The imputed effect of fuel efficiency is computed by using the estimated coefficient on the variable of interest and the difference between the value of the variable representing energy efficiency for a specific ship and the average value in the fleet. The maximum rational effect is computed by multiplying the fuel price observed at the contract date by the difference between a ship's fuel consumption and the average in the fleet. Overall, one would expect imputed effect to be smaller than the maximum rational effect and the two effects to have the same sign for most of the fixtures observed in our dataset.

4.1. Absolute models including the energy efficiency design index

Table 1 shows the coefficients of the estimated models. Model 1 comprises a number of variables referring to technological characteristics of the ships. Unfortunately, we discard this model as:

- it includes Gross Tonnage rather than the more meaningful Dead Weight Tonnage, and the sign on the former variable is contrary to expectations. As higher values of Gross Tonnage enable a bigger cargo, one would expect a positive effect of this variable on the charter rates;
- ship-based variables in the model, with the exclusion of Age, act as a single block as a consequence of the correlation across them and estimated coefficients.[1] As soon as one ship-based variable is dropped, the significance of the whole block of variables falls apart, and the coefficient on the intercept decreases to compensate for the change. Dropping these non-statistically significant technological variables with the exception of EEDI leads to this variable becoming non-statistically significant, and the value of the coefficient being just 2% of the value in Model 1;
- the model delivers implausible results in terms of imputed effect of energy efficiency. Average between imputed and maximum rational effects is −1.5 rather than being positive and smaller than one, as one would expect, while the percentage of fixtures for which the sign of the imputed and the maximum rational effects agree is a very low 53%.

[1] The value of the correlation between EEDI and Horsepower is very high, 0.86, while the correlation between EEDI and GT and between EEDI and Speed is very similar, −0.15 and −0.13, respectively. Similarly, correlation between GT and Horsepower and between GT and Speed is 0.26 and 0.24, respectively. By multiplying the values of the technological variables across ships by the coefficients in Model 1, one obtains a very uniform value across ships. The cumulative density of the computed value is very concentrated with 70% of the observations falling between −76,200 and 73,400.

Continuing the search specification delivers Model 2 in Table 1. As can be seen in the table, no significant changes between the coefficients in Model 1 and Model 2 can be observed, with the exception of the intercept.

In Model 2 and Model 3, the latter obtained after dropping commodity price, an increase in the age of the ship decreases the time charter, each additional year decreasing the rate by about 350 dollars per day. The amount of fuel which can be loaded onto a ship is a negative attribute, probably because it reduces the cargo carrying capacity, with each additional tonne decreasing the time charter by about 2.5 dollars per day. Large fleet size causes a decrease in the time charter rates because of increased supply of shipping services, with each additional Million DWT causing a decrease of 2000 dollars per day. Trade has a positive effect on time charter rates, as a consequence of increased demand for shipping services, with each additional Million Tonne causing an increase ranging between 1700 and 1000 dollars per day. With regard to the start of charter period, charters seem to have a preference for early starts, each day between the signing of the contract and the start of the laycan period causing a decrease of 60 dollars in the charter rate.

Model 2 in the table includes the price of the commodity carried by Panamax ships. Commodity prices are incorporated in Tsolakis (2005) and UNCTAD (2010), although these articles disagree on the sign of the coefficient. The rationale for including commodity price is that the rate is correlated with the value of the cargo, according to UNCTAD (2010), while commodity price is said to act as a proxy for transportation demand according to Tsolakis (2005). With regard to fuel prices, it is not entirely straightforward why time charter rates are positively influenced by this variable, as it occurs in Table 1, with a possible explanation, as suggested by a referee, related to the fact that high prices would encourage slow steaming and therefore a larger demand for tonnage caused by increased journey time. Both coefficients on the commodity and fuel price take somewhat high values. In Model 2, an increase in the fuel price of 10 dollars per tonne increases the time charter rates by about 1000 dollars per day even though the average increases in fuel expenditure for Panamax ship would be only about 350 dollars. In the same model an increase in the commodity price of the same amount would result in an increase in the rate of about 2000 dollars per day. Dropping the commodity price from Model 2 causes a substantial increase in the coefficient on the fuel price in Model 3, which is expected considering the correlation between the two variables – see Fig. 2.

In order to cast some light on these two issues Model 2 has been estimated on rolling and on recursive samples. After ordering the dataset according to the contract date, the first method implies estimating Model 2 on the first 1000 observations, shifting the sample by 200 observations, i.e. adding the next 200 observations while dropping the first 200, and

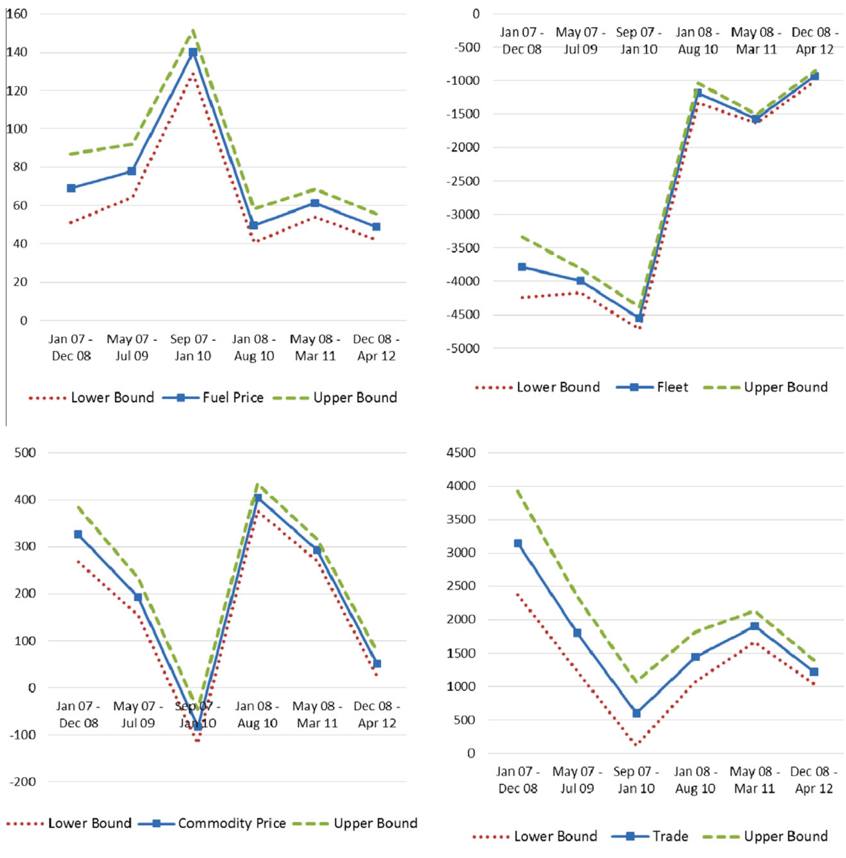

Fig. 3. Value of coefficients and 95% confidence bounds for Fuel Price, Fleet, Commodity Price and Trade from Model 3 in Table 1estimated on rolling samples containing observations between the dates on the ticks in the horizontal axes.

re-estimating the model. This is repeated until there are no observations left to add. Recursive sampling differs from the procedure above as no observations are discarded when new ones are added. If the relationship between fuel price and commodity price on one side, and time charters on the other is spurious we would expect the value of the coefficient to show considerable instability across samples. As one can see in Fig. 3, estimated coefficient on fuel price is fairly stable across rolling samples with the exception of the spike observed when using only observations between September 2007 and January 2010. The same can be said in the case of trade coefficient, although the spike is observed in the first sample. In the case of the fleet variable one has the impression that two very different market conditions are incorporated in the dataset, the values of the coefficient in the first three samples being almost three times the values in the remaining samples in Fig. 3, a fact which may be explained by the rigidity of supply function described in Koopmans (1939). Finally, the value of the coefficient of commodity price is rather unstable, confirming the divergence reported by Tsolakis (2005) and UNCTAD (2010). As one can see in Fig. 3, estimated coefficient is about 300 or 50 units either side away from zero. Recursive estimation, not shown in the figure, delivers much more stable values in the coefficients across samples due to the increasing number of observations which smooth out the impact of additional data points.

Bearing in mind the instability in Fig. 3, one may be reluctant to include commodity price in the equation determining the value of time charter rates. The argument on the correlation between value of the cargo and charter rates, as discussed in UNCTAD (2010), may hold across commodities but it does not seem very stable across time, at least in the case of the dataset discussed in this study. The estimation of the coefficient on fuel price is relatively stable across rolling and recursive sample therefore making spurious relationship unlikely. A positive coefficient on fuel price could be explained by this variable acting as a proxy for the economic activity and inflationary expectations in the economy. In term of model fit one can notice that dropping the commodity price does not have a considerable effect on the value of the adjusted R^2 and Akaike Information Criterion – compare Model 2 and Model 3 – while dropping fuel price decreases the values of the adjusted R^2 by about 30 percentage points – compare Model 3 and Model 4. It would seem desirable to assess whether the fuel price has a legitimate role in the equation of the time charter rates or whether the results in Table 1 are an artefact of the time span used in this study. This is clearly an undertaking requiring a dataset spanning a much longer timespan than that used in this study.

4.2. Absolute models not including the energy efficiency design index

Based on feedback from industry practitioners and the results discussed above, we dropped Gross Tonnage and EEDI, respectively, from the general model from where the search specification is started. After doing so, we still faced the issue of whether commodity and fuel price should be included in the model delivered by the search specification, as discussed above. In the models including fuel and commodity price or fuel price only, the estimated coefficient on consumption is about -150 implying an average of the ratio between imputed savings and maximum rational savings of 38%. We decided to discard these models, as the coefficient on consumption is not statistically significant across rolling samples. In the case of the model incorporating neither the fuel nor the commodity price, the coefficient on fuel consumption is about three times the values discussed above. Average of the ratio between maximum rational savings and imputed savings is very close to unity, implying full transfer of fuel savings realised by more efficient ships to ship owners. Unfortunately, in about a third of the fixtures, imputed savings are higher than maximum rational savings. In addition, adjusted R^2 decreases by about 30 percentage points when fuel price is not used in the estimation. These two reasons lead to these models being discarded.

4.3. Relative models

The remainder of this section discusses models estimated based on a relative rather than an absolute approach. In the former, that has been adopted so far, independent variables, including a proxy for energy efficiency, explain time charter rates in the fixtures. In the relative approach, one introduces among the independent variables a benchmark, which captures common factors affecting all fixtures, e.g. conditions of the industry and the economy, while the remaining independent variables explain the difference between this benchmark and the rate in each fixture. If variables related to the condition in the economy and the industry still have an effect on a certain fixture, one would expect a smaller coefficient compared to those in Table 1, as part of their effect is being captured through the introduction of the benchmark.

We have estimated models incorporating variables based on fuel consumption and fuel expenditure, the latter measured by the difference between fuel expenditure of a ship and the average in the fleet, or the average in the ships with similar design speed. As similar results have been obtained regardless of the variable used in the model, only models using fuel expenditure are presented, on the grounds that one can read directly the percentage of monetary savings passed on to ship owners from the coefficient in the model. As it is not a priori clear whether variables describing the conditions of the shipping industry and the economy should have an influence on the differential between a fixture rate and the benchmark, we decided to incorporate all the variables discussed so far in the general model from which search specification was started. The second column of Table 2 shows the model obtained by dropping all non-statistically significant variables. Surprisingly, fuel and commodity price are preferred to fleet size and trade, i.e. the variables traditionally used to represent the conditions of demand and supply in the shipping industry. Estimated coefficients on fuel and commodity price are much smaller than those in Table 1, confirming our expectations above. As we do not have strong prior views on whether variables describing the condition of the economy and the shipping market should be influencing the charter rates in a relative approach, we have estimated a model with ship-specific variables only (Model 2) and a model incorporating fleet and trade as proxy for supply

Table 2
Estimated values, standard error in parentheses, and statistical significance of the coefficients from models based on the relative approach. Key for statistically significance: **=1%, *=5%.

	Model 1	Model 2	Model 3
Intercept	−3897.80**	1697.40**	1436.00**
	(4677.10)	(4565.10)	(4707.00)
Age	−265.44**	−337.65**	−280.17**
	(42.94)	(42.93)	(45.75)
Dead weight tonnage	0.20**	0.09	0.17**
	(0.06)	(0.06)	(0.06)
Bunker capacity	−1.07**	−1.24**	−1.16**
	(0.29)	(0.31)	(0.30)
Time charter benchmark rate	1.05**	0.99**	0.96**
	(0.01)	(0.01)	(0.01)
Fuel price	11.72**		
	(1.58)		
Commodity price	−92.90**		
	(7.48)		
Fleet			−136.85**
			(14.55)
Trade			383.65**
			(66.27)
Forward start	−83.91**	−81.25**	−82.08**
	(8.09)	(7.05)	(7.21)
Difference from average fuel expenditure	−0.43**	−0.39**	−0.40**
	(0.11)	(0.12)	(0.12)
R^2	95.34%	94.82%	94.97%
AIC	40,552	40,766	40,707

and demand (Model 3). While the Akaike Information Criterion points to Model 1, there is almost no difference across models according to the adjusted R^2. In addition, the value of the coefficient on the difference from average fuel expenditure is about 0.40 across all models in Table 2, implying that about 40% of the financial savings arising from reduced fuel consumptions are recouped by the owners through increased charter rates. It is worth stressing, as discussed above, that a similar figure was found in the specifications obtained when following the absolute approach discussed in Section 4.2. While those models were discarded because the coefficients were not robust across samples, all models in Table 2 display statistically significant coefficients across recursive and rolling samples.

It is interesting to discuss how the value of the coefficients on the difference between a ship's fuel expenditure and the average in the fleet changes across time in presence of the very different market conditions. As shown in Fig. 4, one can see an overall decreasing pattern in the absolute value of the size of fuel savings captured by shipowners, starting at about 50% and almost halving when using samples geared toward the ending period of our data. The value in this graph have been used by implementing the recursive and rolling sample procedure discussed above. This decreasing pattern in the fuel savings captured by shipowners can be justified by a number of factors:

- when market was tight fuel efficient ships were rewarded through price premium, while in a market with considerable spare capacity they might be increasingly rewarded through higher utilisation rates;

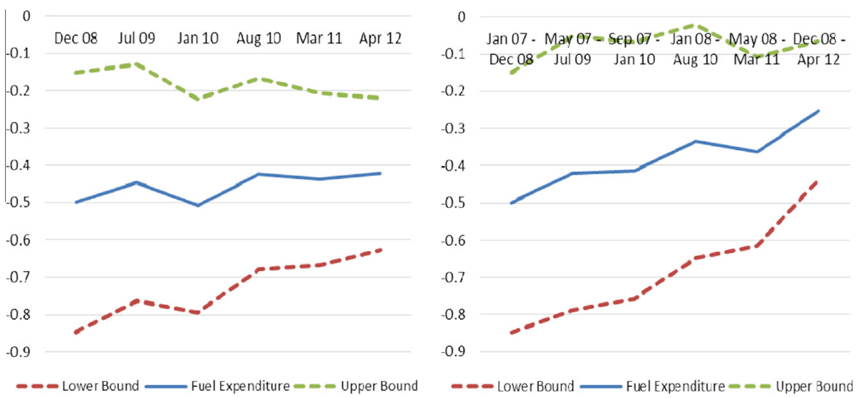

Fig. 4. Value of coefficient, and upper and lower 95% confidence interval bounds for the difference between a ship's fuel expenditure and the average in the fleet estimated on recursive samples containing observations from January 2007 up to the month on the ticks (left figure) and on rolling samples containing observations between the dates on the ticks (right figure).

- as fuel efficient ships becomes more common, their relative premium decreases if potential charters have more and more fuel efficient ships to choose among, as pointed out by a referee;
- slow-steaming has become more common in an environment characterised by high fuel prices and low charter rates. As is widely known, the difference in fuel consumption between a fuel efficient ship and one with a standard design is much smaller when slow steaming than at design speed. For this reason one would expect a decreasing trend in the size of the fuel savings evaluated at design speed, i.e. the variables in our study, incorporated in the time charter market. As savings computed at design speed overestimate the effective values captured when slow steaming, the coefficient in the model needs to decrease even though the percentage of savings captured by the shipowners stats constant.

It is finally worth mentioning that our findings in relation to the size of fuel savings across time are rather disappointing for ship owners of fuel efficient ships, bearing in mind the caveat mentioned above. In fact, before the time charter crash they benefited from higher rates and higher percentage of fuel savings incorporated in the charter price. Unfortunately, both income streams decreased after the market crash.

5. Conclusions and policy implications

This paper presents the first estimation in the literature of the extent to which energy efficient ships are rewarded in the market place for the fuel savings they deliver. Confirming evidence form the press industry, we discovered that only part of the financial savings from energy efficiency accrues to ship owners. More specifically, we found that on average only 40% of the financial savings based on design efficiency accrue to the vessels' owners, i.e. the party deciding the efficiency level of the ships, with the estimated percentage showing a decreasing trend going from 50% when using the oldest using only the first 1000 fixtures in our sample to 25% when using the most recent 1000 fixtures. From an environmental perspective, this is discouraging because ship owners will not invest in energy efficiency as much as they would if they could retain the whole amount of savings. As this is likely to be due to the lack of information and difficulty in verifying fuel consumption claims made by ship owners, we believe that any policy facilitating the flow of information on energy efficiency between charterers and owners, would incentivise the level of investment in energy efficiency in the shipping sector and consequently reduce emissions from the sector.

CO_2 emissions from the shipping sector have considerably increased over the last decade, and with the rising influence of Asian countries and their exports, they are likely to continue to do so. Considering the limited decarbonisation options available, increasing energy efficiency is a valuable contribution to reducing emissions in the shipping sector. Our findings are important against the background of the current climate policy in the shipping sector and the policies encouraging the uptake of energy efficiency. If energy efficiency is not adequately rewarded, then it can be introduced only by mandatory standards (command and control instruments) which have to be abided by. On the other hand, if more energy efficient ships can charge a premium on the market, owners will have an incentive to invest in reducing fuel consumption. In the latter case, the market will help achieving carbon reduction by rewarding environmentally-sound behaviour.

The fact that savings delivered by energy efficiency do not accrue entirely to the ship owners can have two explanations. The first is related to the fact that economic benefits of each transaction are shared between the seller and buyer depending on bargaining power. Any savings due to energy efficiency will be naturally divided between ship owners and charters according to how strong demand for ships is compared to available supply. In fact, our rolling estimation confirms that our estimate of the percentage of the savings accruing to the owner decreases as observations from the peak of the market are dropped from the estimation sample, as can be seen in Fig. 4. In a tight market ship owners have increased bargaining power and therefore those with more energy efficient ships are more likely to be fully rewarded for the saving enjoyed by charters. From a policy point of view, there is not much one can do about this, as it seems inadequate to advocate a tight shipping market for the benefit of the uptake of energy efficiency.

The second explanation of our findings is related to the enforcement of contractual clauses. As fuel consumption clauses included in the time charter contract may be difficult to verify, charterers may find it difficult to enforce the fuel consumption guarantee on the contract due to the related legal expenditure. In these settings, it would seem perfectly reasonable for time charterers to be reluctant to pay the full premium for energy efficient ships. To the extent to which our results are caused by this factor, policy has a considerable role to play. Any instrument facilitating the diffusion of information or reducing the costs of holding ship owners accountable to their energy efficiency claims will help increase the maximum amount that time charterers are willing to pay for the increased energy efficiency and stimulate the uptake of energy efficient investments. Any type of policy facilitating the communication between charters and owners such as the EEDI is helpful to increase the revenues accruing to owners of energy efficient vessels. Other helpful policy measures may be related to the provision of operational data which can be used by charters to verify fuel consumption such as weather data. As the operational energy efficiency of a ship is also influenced by conditions of the ship, such as the deterioration of the hull and engine, any labelling scheme signalling to potential charters the operational performance of a ship will be helpful in facilitating the uptake of energy efficiency investments. Similarly, setting up a registry or database detailing consumption of the ship in previous charters can help potential charters quantify the financial savings which can be expected.

Throughout the discussion in this paper it is easy to identify several areas where further work would be beneficial. It is possible that dubious relationships within the variables in the model are caused by variables not considered in the model, for example it is possible that the positive relation between fuel price and charter rate can be explained by more slow-steaming and thus a larger demand for tonnage. Capturing this relationship would require additional data sources and one potential data source is the satellite automatic identification system (S-AIS) with which it is possible to determine the operating speed of ships. Secondly, we discussed that the key finding of this paper, i.e. the percentage of savings recovered by shipowners is directly related to market supply and demand and the extent to which this is captured in the modelling. Possible improvements and refinements can come from and extended data set covering a longer period of time, to even out the supply demand imbalances witnessed in the period used in this paper. Unfortunately the Clarkson's data set does not go beyond that which has been used in this paper and alternative sources such as IHS Fairplay (Sea-web) are also for a shorter period.

Acknowledgments

The authors would like to thank two anonymous referees whose comments have improved the quality of the analysis discussed in the paper.

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