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Explaining price differences between physical and derivative freight contracts

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Abstract

Physical time-charters (TC) and Forward Freight Agreements (FFAs) represent two hedging approaches that differ in terms of risks and physical access to transportation. We investigate the determinants of the time-varying TC-FFA freight rate differential in the dry bulk market. We find that TC and FFA prices are co-integrated but TC rates are generally priced higher than FFAs. The differential is explained by the level and slope of the term structure, a measure of economic 'stress' as well as vessel specifications and contractual terms. Finally, the TC-FFA differential is related to default risk premium and the potential convenience yield.

Keywords: *FFAs, time-charter, basis risk, convenience yield, default risk.*

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1. Introduction

Agents and participants in the international shipping market have developed and utilised different types of contracts and tools to control freight market risk. These include long-term period timecharter contracts, contracts of affreightments and, more recently, freight derivative contracts such as forward freight agreements (FFA) and freight options.[1] The main difference between physical and financial contracts relates to flexibility and access to transportation. Physical contracts such as time charters ensure access to a transportation service and a vessel, but they are not flexible because the underlying vessel cannot be changed, their termination could be costly, and they are bilateral contracts that are subject to default or counterparty risk. FFA contracts are flexible in terms of trading and have virtually no default risk when they are cleared, but they do not provide access to a vessel or transportation service. Nevertheless, both period and FFA contracts are used for managing spot freight rate exposure by shipowners and charterers.

A large body of the literature has been devoted to investigating different aspects of the FFA and physical market including Kavussanos and Visvikis (2004a and 2004b), Kavussanos, Visvikis and Menachof (2004), Kavussanos, Visvikis and Batchelor (2004), Batchelor et al. (2007), Alizadeh (2013), among others (see Section 2). For instance, Kavussanos, Visvikis and Menachof (2004) investigate the unbiasedness of FFA prices in relation to determination of future spot rates and conclude that forward freight rates are unbiased predictors of spot freight rates. Other studies such as Kavussanos and Visvikis (2004a and 2010) and Alizadeh et al. (2015) focus on evaluating hedging performance and the interaction between FFA and spot rates. They use different hedging techniques including constant and time-varying hedge ratios when hedging spot freight market exposure with FFAs. The general finding here is that the hedging performance of FFAs is substantially worse than for other commodity and financial markets, a

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[1] The forward freight agreement (FFA) contracts were developed and evolved over time to enable agents involved in international shipping to manage risks that arise from fluctuations in freight rates (see Kavussanos and Visvikis, 2004 and Alizadeh and Nomikos, 2009) and vessel prices (Alizadeh and Nomikos, 2012). A FFA is defined as a cash-settled contract between two counterparties to settle a freight rate for a specified quantity of cargo or hire rate for a type of vessel in one (or a basket) of the major shipping routes in the dry bulk, tanker and container shipping sectors for a specified future time period. The underlying asset of the FFA contracts can be any of the routes (or basket of routes) that constitute the freight indices produced mainly by the Baltic Exchange or by other providers of freight market information (see Kavussanos and Visvikis, 2006 and Alizadeh and Nomikos, 2009, for a full description of FFAs and their applications for hedging).

fact which is typically attributed to the non-storable nature of spot freight rates and the corresponding lack of a cost-of-carry relationship between spot and forward prices.

These early studies (Kavussanos and Visvikis, 2004a and b, and Kavussanos, Visvikis and Menachof, 2004) were undertaken at a point in the dry bulk FFA market development where the most active contracts were related to individual routes such that the hedging of spot exposure was indeed the *modus operandi*. Within the past decade, such contracts have effectively ceased trading, with liquidity now focused on longer FFA contracts (quarters or calendar years) settled on a global weighted average spot rate per vessel size, the Baltic TC averages (Adland and Jia, 2017). The hedging of freight market exposure using such FFA contracts is, by definition, more akin to using physical TCs, where owners and operators lock in time-charter-equivalent earnings per vessel for a prolonged period of time.

In this study, we therefore examine, for the first time, the statistical relationship between physical TC and FFAs. While both alternatives lock in a fixed freight rate for a defined period, the two approaches carry very different types of risks. Firstly, a time-charter (TC) is a physical contract that gives the charterer commercial control over a vessel and access to a transportation service, while a FFA contract is a purely financial cash-settled contract for the difference between a Baltic Index and the agreed contract rates. If secure access to transportation has value (a “convenience yield”) then we would expect that TCs are, on average, priced higher than FFA contracts for the same ship size and period. We would also expect that this differential is positively related to the state of the freight market, because secure access to transportation will have a lower value (convenience) during periods of oversupply of ships and low freight rates. This is a general concept for the forward pricing function in commodity markets, where the underlying asset is storable and the marginal convenience yield is a decreasing function of stocks held (Brennan, 1958).

Secondly, there are multiple potential sources of cash flow differences (basis risks) due, for instance, to a) different vessel specifications between the physical vessel and the standard Baltic type vessel underlying FFA contracts, b) different trading patterns of the physical ship, c) higher default risk for a single charterer in a TC than the clearing houses standing behind FFA contracts and d) timing differences in the start and end-dates of the contracts, particularly when TC contracts have embedded extension options. These sources of risk are likely to be time-varying and dependent on market conditions and the financial standing of the charterer.

Our paper has three primary objectives. Firstly, we want to assess whether there is a (potentially time varying) differential between TC rates and corresponding FFA prices. We assess this relationship by comparing the standardized fixed-duration TC rates as supplied by shipbrokers and the FFA prices for an equivalent duration. Secondly, we want to assess whether such differential is caused by known differences in risks and cash flows (e.g. different vessel specifications). Thirdly, we want to evaluate whether the differential is dependent on freight market conditions such that it can be interpreted as a convenience yield in the physical forward market. For the latter two research questions, we evaluate the differential between realized individual TC fixtures in the dry bulk market and the FFA price for the corresponding period.

Addressing the above questions are important for several reasons. First, from a theoretical point of view, a better understanding of the FFA and time-charter markets and their interaction can be used to specify better models and produce more accurate forecasts for these variables. Second, from a practical point of view, improved knowledge of the relationship and differences between time-charter rates and FFAs can help ship-owners, operators and charterers to assess freight trading tactics, formulate better hedging strategies and enhance the efficiency of their risk management process. For instance, market participants can use the information on the difference between FFA and TC contracts to determine the value of period contracts (e.g. time-charter or contract of affreightment) using FFA curves. Third, shipowners, operators and charterers can use the results to assess whether apparent arbitrage opportunities between the physical and "paper" forward freight markets are real or simply a result of time-varying risk premia or physical basis risks. Fourth, our research is closely related to the important question of default risk in physical time-charters. Adland and Jia (2008) show conceptually that default risk is strongly related to freight market conditions and contract duration, with longer contracts fixed during strong markets at greater risk. By comparing TC rates with "risk free" FFA prices we are able to uncover a similar risk profile, supporting earlier results in the literature. Finally, the results reveal important information regarding the adjustment of hedge ratios according to vessel and contract specific factors when FFAs are used to hedging a vessel's earnings.

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature, Section 3 describes our data and methodology, Section 4 contains our empirical results and Section 5 discusses the implications of our findings. Section 6 summarises the findings and concludes with suggestions for future research.

2. Literature review

The maritime economic literature typically treats pricing in the freight derivatives and physical forward markets separately, even though the dynamics of spot freight rates is the main driver of both markets. Studies on freight derivatives focus on three main issues: the hedging efficiency of the contracts (Thuong and Visscher, 1990; Haralambides, 1992; Kavussanos and Nomikos, 2000a, 2000b; 2000c; Kavussanos and Visvikis, 2010; Goulas and Skiadopoulos, 2012), price discovery and the unbiasedness of forward prices in relation to realized spot rates (e.g. Kavussanos and Nomikos, 1999; Kavussanos and Nomikos, 2003, Kavussanos and Visvikis, 2004a) and causality viz-a-viz spot freight rates (see, Kavussanos et al, 2004a; 2004b; Kavussanos and Visvikis, 2004b; Alizadeh et al., 2014). Performed on both the defunct BIFFEX freight futures and the FFA market, these empirical studies broadly conclude that freight derivatives have overall poor hedging efficiency, even when allowing for time-varying hedge ratios, and represent unbiased forecasts only in the short run (1 – 2 months out).

A related branch of the literature focuses on the modelling of spot freight markets using stochastic models. Examples are the logarithmic mean reverting process proposed by Tvedt (1997), the stochastic partial equilibrium models of Tvedt (2003) and Adland and Strandenes (2007) and the non-parametric mean reverting model of Adland and Cullinane (2006). Prokopczuck (2010) compares the appropriateness of the one and two factor models proposed by Gibson and Schwartz (1990) and Schwartz (1997) for modelling freight rates. Nomikos et al (2013) suggest jump diffusion models that can capture the fat tails of freight rate logarithmic returns. Benth and Koekebakker (2016) further extend these models to account for short-term autocorrelation, stochastic volatility and non-Gaussian increments in spot rate log-returns, and investigate whether the theoretical forward curves from this model can recreate observed FFA curves. Yin et al (2016) apply Vector Error Correction models (VECM) to investigate the interaction between spot and forward rates in the dry bulk market and includes exogenous fundamental variables in the model.

Separately, researchers have investigated the determinants of TC rates at the micro level (i.e. for individual fixtures). Köhn and Thanopoulou (2011) use Generalised Additive models to assess the impact of variables such as place of delivery, lead time, charter duration, vessel size and fuel consumption in a non-linear framework. Their empirical results support the notion of price differentiation based on vessel quality. Agnolucci et al (2014) investigate the existence of a freight rate premium for fuel efficiency in the Panamax dry bulk TC market during the period 2008 – 2012 and find that owners recoup approximately 40% of the fuel savings through higher rates. Adland et al (2017) perform a similar study on the determinants of dry bulk TC rates for a much larger sample and find that fuel efficiency is only rewarded in poor market conditions.

An important issue in this context that is not yet well understood, is the influence of time-varying risk premia in forward freight pricing, both for the physical and derivatives markets. As discussed in Kavussanos and Alizadeh (2002) this risk premium is thought to arise because operation in the spot and forward markets involves different levels of risk. Adland and Cullinane (2005) present a theoretical argument for rejecting the expectations theory for forward freight pricing and argue that the risk premium must be time varying and depend on the state of the freight market in a systematic manner. Adland and Jia (2008) present a conceptual model for how TC default risk how charter market default risk will vary with freight market conditions, charter duration, and the financial situation of the charterer. Alizadeh et al (2007) show that while the unbiasedness hypothesis holds for implied forward rates in the physical market (that is, implied forward rates are unbiased predictors of realized future TC rates), there exists chartering strategies that profit from capturing cyclical predictable components in the residual. Koekebakker and Adland (2004) investigate the dynamics of the term structure of freight rates and its volatility structure.

Overall, the literature review presented here suggests that that the relationship between spot rates, FFA prices and physical time-charter fixtures represents a complex interplay between time-varying risk premia, volatility structures and basis risk such as differing vessel and contractual specifications. Until now, there has been no attempt at investigating the dynamic relationship between forward rates in the physical and freight derivative markets or its determinants. From a theoretical point of view, the two must be co-integrated based on an arbitrage argument. If FFA rates are substantially higher than the TC rate for an equivalent period and ship, a ship-operator can sell the FFA contract, charter in the vessel on the TC contract and sublet it in the spot market or on an index-linked time-charter[2]. Conversely, if TC rates are substantially higher than FFA prices, a ship-operator can charter in a vessel on an index-linked contract, charter it out on a TC and buy the FFA contract. We note that due to the various sources of basis risk, as detailed in Adland and Jia (2017) and Alizadeh and Nomikos (2009), these strategies would not

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[2] An index-linked time-charter differs from the traditional fixed-rate TC in that the daily rate for the vessel is "floating" and follows, typically, the same Baltic index used for the settlement of FFAs.

represent arbitrage opportunities in the true sense, but “statistical arbitrage” opportunities where the expected profit is positive. Specifically, Adland and Jia (2017) show that the cash flow from physical operation will never mimic that of the spot indices underlying the FFA market, even for a large fleet with a geographically diversified trading pattern, due to the lag-effect imposed by fixed-rate charters.

Our paper fills this gap in the literature based on the following three contributions. Firstly, we test whether TC rates and FFA prices are co-integrated as a result of their interchangeable use for freight market hedging. Secondly, we evaluate empirically the dynamics of the differential between time series of FFA prices and TC rates, addressing the characteristics of the time-varying risk premium or convenience yield that this differential represents from a theoretical point of view. Thirdly, we investigate the determinants of the differential for individual fixtures by controlling for vessel specifications and contractual terms, shedding light on the importance of physical basis risks in this context.

3. Methodology

According to the Efficient Market Hypothesis (EMH) and the notion of no arbitrage, the discounted cash flows from a time-charter contract and the equivalent FFA contract - which covers the duration of the time-charter - should be equal (ignoring, for now, the differences in risks). Mathematically, we can write the argument as

$$\sum_{t=0}^{P} e^{-rt}(TC_t^P) = \sum_{t=0}^{P} e^{-rt}(FFA_t^P) \tag{1}$$

where TC_t^P is a P period time-charter rate, FFA_t^P is a portfolio of FFA contracts covering P period, and e^{-rt} is the discount factor.

In reality, FFAs and physical TCs are close substitutes for freight market hedging, but they are not identical in terms of risks and “convenience”. There are at least four key reasons for this. First, a physical contract provides secure access to transportation (i.e. effectively commercial control over a vessel) while a FFA contract does not. Such a “convenience” should give rise to a premium in TC rates which is higher in strong freight markets when there is potentially scarcity of tonnage (Adland and Cullinane, 2005). Second, a time-charter is a bilateral contract with inherent counterparty risk, compared to FFAs which are cleared. Adland and Jia (2008) show from a theoretical point of view that the TC default risk is higher in strong freight markets and for longer duration contracts. However, shipowners tend to do their credit check and due diligence work on the counterparty before entering the agreement, select the best and most reputable charterers, and avoid charterers with poor credit record. In addition, under a time-charter contract the payment is made on a fortnightly basis and the shipowner can exercise a lien on the cargo in case charterers default, or even terminate the contract in case of default. Nevertheless, there is always a counterparty risk and potential financial loss due to default in the physical time-charter contract. Third, current and expected market conditions as well as expected volatility affect the demand for hedging and speculation (Alizadeh, 2013; Alizadeh et al, 2014) and, consequently, the liquidity in each market. Fourth, time-charter and FFA differentials could also be related to differences in the specification of the physical asset compared to the standard ship used to assess the underlying freight for the FFA contract such as size, age, speed and consumption, delivery and redelivery locations, and extension options embedded in physical time-charter contracts.

Consequently, we expect that the TC-FFA price differential reverts towards some (potentially time-varying) mean in the long run, resulting in an overall stationary process. This co-integration behavior follows from the fact that the two hedging instruments are substitutes. Accordingly, large price differentials would affect their relative supply and demand and bring prices back into line.

To statistically test the for the co-integration of the time-charter and FFA rates we employ the Johansen (1988) cointegration test and perform Likelihood Ratio tests on the restriction implied by the EMH. Let tc_t represent the log of TC rate at time t and ffa_t represent the log of the equivalent FFA price for the corresponding period. Then the Johansen cointegration test between physical TC rates and FFA prices can be specified as:

$$\Delta tc_t = a_{0,1} + \sum_{i=1}^{P} a_{1,i} \Delta tc_{t-i} + \sum_{i=1}^{P} a_{2,i} \Delta ffa_{t-i} + \phi_1 (\beta_1 tc_{t-1} + \beta_2\, ffa_{t-1} + \beta_0) + \varepsilon_1 \qquad (2)$$

$$\Delta ffa_{t-1} = b_{0,1} + \sum_{i=1}^{P} \alpha_{1,i} \Delta tc_{t-i} + \sum_{i=1}^{P} b_{2,i} \Delta ffa_{t-i} + \phi_2 (\beta_1 tc_{t-1} + \beta_2\, ffa_{t-1} + \beta_0) + \varepsilon_2$$

where tc_t and ffa_t represent the log of physical time-charter and FFA rates (for the same maturity) at time t, respectively, $(\beta_1 tc_{t-1} + \beta_2\, ffa_{t-1} + \beta_0)$ is the long run cointegrating relation, and ϕ_1 and ϕ_2 are the coefficients representing the speed of adjustment to long run equilibrium. While the cointegration relation between the physical TC and FFA is a necessary condition for the EMH, it is not a sufficient condition (Hakkio and Rush, 1989). To test for equality of TC and FFA, one has to further test restrictions on the cointegrating relation which imply one-to-one movement between the two series in the long run with no significant spread between the two. In other words, the validity of the restriction $(\beta_1 = 1 \quad \beta_2 = -1 \quad \beta_0 = 0)$ on cointegrating vector should also be assessed.

The next step after establishing whether the physical TC and FFA prices are co-integrated, is to assess the differential between the two series and its time-varying dynamics. In the setting where both FFA prices and TC rates refer to a standard vessel (i.e. where there are no time-varying basis risks due to vessel specifications), we expect the differential to be mean reverting, though not necessarily with a zero mean due to the differing sources of risk (and risk premia). A good starting point in our discrete-time framework is an autoregressive-moving-average model with added linear terms describing the average – an ARMA-X process.

Based on the preceding discussion of market practice and maritime economic theory, it seems reasonable to postulate that the TC-FFA differential could be related to the following three factors which are expected to capture the main sources of risk. The first is the level of the freight market, which is expected to incorporate changes in ‘convenience yield’, or transportation security, as well as default risk. The second is expectations about the future, as reflected in the slope of the term structure of freight rates. The third is the level of uncertainty or risk in the general economy, which will affect both counterparty default risk and liquidity risk premia.

We therefore specify the following ARMA(p,q)-X process for the logarithmic difference between physical time-charter and FFA rates with duration K at time t, $ldiff_t^K = \ln(TC_t^K) - \ln(FFA_t^K)$

$$ldiff_t^K = \beta_0 + \beta_1 lTC_t^K + \beta_2 SL_t + \beta_3 DEF_t + \sum_{i=1}^{p} \gamma_i ldiff_t + \sum_{j=1}^{q} \delta_j \varepsilon_{t-j} + \varepsilon_t \tag{3}$$

where, lTC_t^K is the log of TC rate with duration K at time t, SL_t is the slope of the forward curve (log difference between Current Quarter and 2 Quarter ahead FFA), and DEF_t represents the market default premium calculated as the difference between the yield on BBB corporate bonds and the yield on the 10-year Treasury bond. We assume DEF_t is a proxy for world economic conditions and credit risk, henceforth we call this variable default probability[3]. The optimal number of lags (p, q) is determined according to the Schwarz Bayesian Information Criterion (SBIC).

For the investigation of the differential between realized individual TC fixtures and FFA prices we base our variable selection on the recent literature on the determinants of TC rates at the micro level. In particular, we follow Adland et al (2017) and include the following variables in a multiple log-linear regression with three sets of variables reflecting vessel-specific, contract-specific and market variables, respectively:

$$\begin{gathered} ldiff_{t,i} = \beta_0 + \beta_1 AGE_i + \beta_2 AGE_i^2 + \beta_3 DWT_i + \beta_4 SP_i + \beta_5 CON_i + \gamma_1 TCD_i + \gamma_2 LC_i \\ + \gamma_3 OP_i + \gamma_4 PD_i + \gamma_5 ID_i + \lambda_1 SL_t + \lambda_2 DEF_t + \lambda_3 BP_t + \varepsilon_{t,i} \end{gathered} \tag{4}$$

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[3] There are different proxies proposed in the literature as market stress and default probability including the Market Stress Index published by the Federal Reserve Bank of St Louis, and the market default likelihood index (MDLI) by Andreou (2015). We choose the yield premium of BBB corporate bonds on 1-year Treasury bonds as a proxy for general market condition and default risk because it is widely used in the literature (from Chen, Roll and Ross, 1986, to Perez-Quiros,and Timmermann, 2002 and Campbell & Diebold, 2012, amongst others), and the fact that it is a simple variable which is publicly available.

where AGE_i represents the age of the vessel at the time fixture i is reported, DWT_i is the deadweight carrying capacity, SP_i and CON_i are the design speed and consumption of the vessel in question, TCD_i is the duration of the period charter, LC_i is the laycan for the fixture, OP_i is a dummy for the presence of an extension option, PD_i is a dummy for Pacific Ocean delivery of the vessel at the start of the charter and ID_i is a dummy for Indian Ocean delivery. Finally, regarding market variables, SL_t is the slope of forward curve at time t, DEF_t is the market default premium at time t when contract i is concluded and BP_t is the bunker price at time t.

Based on our definition of the differential ($TC_t - FFA_t$) we know that any vessel- or contract-specific variable that is expected to affect the TC rate positively also will affect the differential with the FFA price positively. Following the results in Alizadeh and Talley (2011a) and Adland et al. (2017), we expect vessel age (specifically, $\beta_1 AGE + \beta_2 AGE^2$) to have a non-linear impact – positive for modern vessels and negative for older tonnage. Vessel size (*DWT*) and speed (*SP*) are expected to affect the TC rate and the differential positively, as a larger or faster vessel has greater earnings potential, all else equal. The dummies for Pacific (*PD*) and Indian Ocean (*ID*) delivery should have negative coefficients versus the Atlantic Ocean benchmark as delivery in the Atlantic positions the vessel for a higher-paying front-haul voyage. The extension option (*OP*) is a charterer's option and so should affect the TC rate and our differential positively. Finally, the duration of the charter (*TCD*) should affect the TC rate negatively, as our sample is dominated by a backwardated (downward sloping) term structure of freight rates.

4. Data

Our study is based on time series of TC rates and individual TC fixtures from Clarkson Research (2017). The weekly time-charter rates are based on brokers' assessment for a standard vessel and reported every Friday. Our sample covers 6-month and 12-month TC rates for Capesize and Panamax vessels over the period 22 July 2005 to 23 December 2016 for a total of 597 observations. For Supramax vessels the data cover the period 1 January 2006 to 23 December 2016. The sample of individual TC fixtures consists of 779 Capesize transactions, 3,224 Panamax transactions and 1,377 Supramax transactions covering the same period. The fixture data contains details on technical vessel specifications (DWT, age, design speed, fuel consumption) and contractual terms for the time-charter (duration, place of delivery, extension option etc.).

The Baltic Exchange provides daily closing prices for the nearest monthly, quarterly and calendar year FFA contracts for the corresponding sample period. As the physical TC rates relate to fixed-duration contracts commencing on the reporting date we need to create prices for the equivalent FFA contract which has the same duration. The FFA equivalent portfolio is constructed using the weighted average of FFA prices, where the weights are simply the remaining days of the current quarter and counting the days of the next quarters to cover the same time period as the TC contract. For instance, on 15 April 2010, a 6-month FFA equivalent of a 6-month time-charter is constructed as [(Q2x76 + Q3x92+ Q4*15)/182], where Q2 is the FFA price for the 2nd quarter of 2010, Q3 is the FFA price for the 3rd quarter of 2010, and Q4 is the FFA price for the 4th quarter of 2010.[4]

Table 1 shows the descriptive statistics for the FFA and TC time series data along with the differential (spread) between them. We note that the average TC rate is higher than the average FFA price across contract durations and vessel sizes, which could be taken as an early indication of a physical convenience yield, particularly as our sample includes the 2003 – 2008 period of unusually strong freight markets and high fleet utilization. Conversely, we cannot rule out that such a differential represents a risk premium, compensating, for instance, for the higher default risk inherent in a bilateral TC contract.

Insert Table 1 about here

Historical time-charter rates and FFA equivalent prices for 6- and 12-month periods along with the differential between the two rates are presented in Figures 1 to 3 for Capesize, Panamax and Supramax dry bulk carriers, respectively. We can see that the physical TC rates and FFA prices for the 6- and 12-month periods are closely aligned and move together over the long run across

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[4] We acknowledge that it may not be easy to replicate the portfolio of FFA contracts needed to exactly match the duration of a time-charter, particularly if the latter includes an extension option. There are two reasons for this. Firstly, while the minimum trade size in the FFA market is theoretically one day per month, actual trading will typically occur in multiples of 5 days. Secondly, it is generally not possible to trade a monthly contract that is in settlement beyond about the 20th day of the month, which may exclude certain contracts from the portfolio in practice. Nevertheless, we believe that our FFA-equivalent prices are representative of the implied pricing of fixed-duration contracts in the market.

all three vessel sizes, albeit with short-run deviations. In addition, the plot of the differential between the two prices seems to be highly mean reverting, relatively volatile and on average positive, for both 6- and 12-month period and across all vessel categories. The highest levels of the TC-FFA differentials and their volatilities can be observed over the period 2007 to 2008, when dry bulk freight rates were at their historical highs

Insert Figure 1

Insert Figure 2

Insert Figure 3

Table 2 shows the descriptive statistics for our TC fixture data and the FFA price for the corresponding charter duration. We also include the standard vessel specifications for the "Baltic type" vessel underlying the spot indices on which the FFAs are settled for comparison. Again, the average TC rate in the physical market is higher than the corresponding FFA price across vessel sizes. At the same time, we can observe that the technical specifications of the vessels fixed in the TC market are, on average, very similar to the standard "Baltic type" vessel. Consequently, physical basis risk due to vessel specifications appears an unlikely candidate to explain the differential.

Insert Table 2

5. Empirical results

We begin the empirical analysis by first investigating the short and long run relation between physical TC and FFA-equivalent rates, using the Johansen (1988) cointegration approach. Establishing the cointegration relation between the TC and FFA is important because it would confirm that both variables are driven by the same underlying factor in the long run and deviate from the long run equilibrium, in short periods of time, due to factors that affect each variable differently – e.g. vessel shortages in the physical market, default risk etc. The results of the Johansen test for the cointegration relation between TC rates and FFA equivalents for 6- and 12-month periods across the three dry bulk vessel classes are presented in Table 3. The appropriate lag length (=2) for the VECM model is selected by the Schwarz Bayesian Information Criterion. Both λtrace and λmax statistics suggest that there is one cointegration relation linking the physical TC and FFA rates across all vessel sizes and contract duration. The Likelihood Ratio tests on the full restriction set on cointegrating vector $(\beta_1 = 1 \quad \beta_2 = -1 \quad \beta_0 = 0)$ seem to be rejected across all vessel sizes and maturities. However, the second restriction which only implies a one-to-one movement between the TC and FFA $(\beta_1 = 1 \quad \beta_2 = -1 \quad \beta_0)$ with a non-zero spread between the two series seems to be valid at the 5% significance level for all maturities and vessel sizes, except the 12-month TC and FFA for Panamax vessels, where the restriction is valid at the 1% significant level. Therefore, the results of the cointegration and restriction tests reveal that while the TC and FFAs are cointegrated and move close to each other in the long run, there nonetheless seems to be a significant differential (premium) between the two rates. The negative sign of the estimated coefficients of the constant in the cointegrating vector suggest that physical TC rates carry a statistically significant premium over the equivalent FFA rates across all vessel types and both the 6 and 12-month maturities[5].

Insert Table 3

The estimation results of the VECM models for physical TC and FFA rates for different size dry bulk carriers are reported in Table 4. Overall, it seems that FFA rates have greater explanatory power over physical TC rates than the other way around, as indicated by the significance of lagged FFA rates in most of the TC equations. This is also evident from the higher R-bar-squared of the TC equations compared to the FFA equations. The results of the Granger-Causality tests between TC and FFA equivalents, also reported in Table 4, reveal that while there is a unidirectional causality from FFA rates to physical TC in the Capesize and Panamax markets, there is a bi-directional causality between TC and FFA rates in the Supramax market.

Insert Table 4

Having established that the physical TC and FFA rates are cointegrated, we proceed to examine the determinants of the TC premium at the macro level, where we consider only the dynamics of the differential on a time series basis (Equation 3). From Table 5 we see that the TC-FFA differentials in the Capesize, Panamax and Supramax tend to follow an ARMA-X(2,2-3) process,

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[5] To assess whether the cointegration relations between TC and FFA-equivalent rates in different sectors are stable and not affected by structural changes, we also performed the cointegration analysis and imposed parameters restrictions before and after the October 2008 financial crisis across all the sectors (Capesize, Panamax and Supramax). The results, which are not reported here but available from the authors, confirm that the cointegration relations between TC and FFA hold in both sub-periods and the results of the parameter restrictions are also consistent before and after the financial crisis, suggesting that the cointegration relation between TC and FFA-equivalents are stable and robust to possible structural change.

while the 12 month TC-FFA differential for Supramax seem to follow ARMA-X(2,0) process. The AR coefficients suggest that the differential is mean reverting towards a level which is governed by the level and slope of the physical term structure. Importantly, the coefficients of the log TC rates are positive and highly significant, which indicate that the TC-FFA differential is directly related to the level of freight rates in the market. For instance, in the Capesize segment, the estimated coefficient of lTC_t (0.231) indicates that – everything else being equal - for every \$1000/day increase in physical freight rate, the TC-FFA differential widens by \$231/day.

Moreover, the estimated coefficient of market default probability (*DEF*) is positive and significant in all equations, except for 6-month contract for Panamax vessels, which suggests that the differential is positively related to the market condition and default risk. Therefore, the empirical results support the notion that there must exist a positive and time-varying differential across all vessel sizes and TC durations. The observation that the premium is increasing with the level of the TC rate is also aligned with both the convenience yield and risk premium hypotheses. On the one hand, the physical contract provides secure access to transportation through the commercial control of a vessel, and this has greater value during times of high fleet utilization and high rates. On the other hand, Adland and Jia (2008) show that the risk premium due to default risk in bilateral TC contracts is increasing with the level of TC rates, a risk which does not exist for FFA contracts which are traded through a clearing house. It follows that the observed increase in the TC-FFA premium during strong markets may also be compensation for higher risk in the contractual structure of a time-charter. We note that it is generally not possible to disentangle the competing ‘risk premium’ and ‘convenience yield’ hypotheses in empirical work. Indeed, an alternative view of convenience yield is that it is simply a premium for the guaranteed physical access to a good, in this case sea transportation. The alternative - reliance on the spot market but hedging market risk with FFAs – comes with a risk of transportation shortage for a charterer.

Table 6 shows the estimated relationship between the observed differential for individual fixtures and the vessel-specific, contract-specific terms and market conditions. The models are estimated using the Ordinary Least Squares method and standard errors are corrected for the presence of heteroscedasticity. The reported adjusted R^2 of 52.7%, 28.8% and 33.1% for the Capesize, Panamax and Supramax markets, respectively, indicate that up to 50% of the variation of the TC-FFA differential for individual contracts can be explained by the factors considered. The estimated coefficients of the vessel-specific factors (age, size, speed and consumption) are generally significant and have the expected signs. For instance, the relationship between vessel age and the TC-FFA differential is nonlinear such that modern vessels (younger than approximately 13 years of age) command a TC premium while older vessels must accept a discount. This is in line with earlier empirical results in the literature on fixture data analysis (see, for instance, Alizadeh and Talley, 2011a and b; Adland et al, 2016; and Adland et al, 2017). Greater capacity (DWT) has the expected positive and significant impact on the TC-FFA differential and reflects the impact of differing vessel specifications between the time-chartered vessel and the "Baltic type" vessel underlying FFA pricing. Similarly, higher fuel consumption has a negative impact on the TC rate and therefore the differential, whereas higher speed tends to increase the TC-FFA differential.

The reported estimated coefficients of contract terms (duration, days to laycan, delivery location and extension option) are also significant and carry the expected signs. For instance, Pacific and Indian Ocean delivery obtains lower TC rates (and therefore a lower differential) than the benchmark Atlantic delivery, as expected. The estimated coefficient for the extension option dummy is positive and significant only in the Panamax market, where the coefficient of the TC contract duration is also significant but negative.

In relation to the estimated coefficient of variables representing market condition, the slope of forward curve is negative and significant for Supramax, but positive and significant in the Panamax model and negative and insignificant in the Capeszie model. The negative relation between the slope of FFA curve and the TC-FFA differential indicate that when the FFA market is in backwardation (i.e. high spot rates), there is a greater risk of a shortage of vessels and so having physical access to ships carries a premium (the convenience yield explanation). Similarly, a backwardated forward curve can be an indication of expected market decline and, hence, an increase in default risks and higher default premia in the TC market. The estimated coefficient of the default probability (*DEF*) is positive and significant only in the Capesize model, and it is insignificant in both Panamax and Supramax models. While the results for the Capesize model is in line with what was found in the aggregate market analysis (Table 5), the results of the Panamax and Supramax equations suggest that default probability may not be an important factor in determination of TC-FFA differential in the market for smaller vessels. The estimated coefficient for the fuel price is positive and significant across all models, which indicates that increase in fuel prices tend to widen the TC-FFA differential. This can be attributed to the fact that higher oil (and bunker) prices is an indication of increase in demand for oil and other commodities during the market recovery which in turn increase demand for transportation, freight rates and TC-FFA differentials.

6. Implications for freight trading and hedging

One practical and important implication of the results in this paper relates to the pricing of TC contracts. Theoretically, the price of TC contracts is a function of current and expected spot market rates, expected fuel prices and future market conditions (see Kavussanos and Alizadeh, 2002). In practice, however, market participants may use the FFA curve to assess and price a TC contract with some adjustment due to the contract and vessel specifications. Our model and estimated coefficients can be used to evaluate period contracts for a given forward curve (FFA equivalent), as well as contract specifics and vessel particulars. For instance, based on the estimated coefficients of the model in equation (4), Table 7 reports the calculated values of a 12-month TC contract for three 5-year old Capesize vessels of 180,000dwt, 172,000dwt and 150,000dwt, with delivery options in the Atlantic or Pacific Oceans, and the FFA equivalent level of \$10,000/day[6]. The table shows that the 12-month TC premia over the FFA equivalent can be as much as 16.9% for a 5-year old 180,000dwt Capesize delivered in the Atlantic Ocean, whereas the same vessel should earn 2.6% more than FFA equivalent if delivered in the Pacific. Similarly, a 5-year old 150,000dwt Capesize should earn 1.8% more than the FFA equivalent on a 12-month TC when delivered in the Atlantic, while the same vessel will earn 10.6% less than the FFA equivalent (\$10,000/day) if delivered in the Pacific. In addition, changes in market conditions, as proxied by the default probability (*DEF*), can affect the differential between TC and FFA contracts. For instance, in the case of the 180,000dwt Capesize vessel delivered in the Atlantic, a change of *DEF* from 1% to 2% results in an increase of \$240/day (\$11,690/day to \$11,930/day) or 2.03% in the TC rate premium due to higher default probability.

Based on the observation that the TC-FFA differential is generally positive and can widen to high levels in the short run (ref. Figures 1 to 3), it is tempting to conclude that there must exist some trading strategy that can take advantage of its dynamics by ‘arbitraging’ the physical and ‘paper’ markets. If the market is efficient, this would of course not be the case, as any apparent

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[6] Other vessel and contracts specific factors are kept constant including speed of 14knots, consumption of 50mt/day, contract period of 12 months, forward delivery period of 20 days, option to extend, 10% slope of the forward curve, default premium (*DEF*) of 1%, and fuel prices of \$350/tonne.

gains would simply be compensation for risk – both physical basis risk (i.e. differences in vessel specifications, contractual terms and cash flow timing) and default or liquidity risk. Nevertheless, as an illustration of the potential gains from following such an approach in the three vessel segments, we consider the following simple trading strategy. If the TC-FFA differential is positive on any given day, the ship-operator charters in a vessel on an index-linked TC (duration 6 or 12 months), charters it out on a fixed-rate TC and buys the FFA portfolio of equal duration. We note here that the cash flow from buying a FFA contract is equivalent to the Baltic spot index less the agreed FFA price. As a result, the two index-linked cash flows cancel out, and we are left with the TC-FFA price differential. Conversely, if the TC-FFA differential is negative on a given day, the operator enters the reverse contractual setup (selling FFA, chartering in on a fixed-rate TC and subletting on a spot index-linked TC, all with the same duration). The cumulative profit from such a freight trading strategy is simply the sum of the absolute value of all daily TC-FFA differentials[7], as shown in Figure 4 below since 1st January 2006 for 6-month and 12-month contracts in the Capesize, Panamax and Supramax segments, respectively.

Figure 4

There are a few takeaways from Figure 4. Firstly, most of the profit would have occurred in the 12 months prior to the onset of the financial crisis at the end of 2008, when the dry bulk market reached records both in terms of freight rate levels and volatility. This is consistent with the theoretical explanation that the observed differential is a compensation for risk as well as a premium reflecting the value of securing physical transportation. Secondly, the differential is generally higher for 6-month contracts than for 12-month contracts, suggesting that there are risk factors other than default risk at play here. Thirdly, the risk premium is greater for the larger vessel size (Capesize), which is consistent with the well-known greater operational leverage and volatility of larger vessel (Kavussanos, 1996). In the period with lower volatility and lower freight rates since 2009 the gains from harvesting such risk premia have largely disappeared, reflecting the general oversupply in the market. We note that "index linked" physical time-charter contracts are a relatively recent invention, such that the above trading strategy could not have been implemented throughout our sample[8].

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[7] For the purpose of illustration, we can either assume that one new vessel or a fractional vessel (1/365th or 1/183rd) enters into this contractual structure every week. Here we have assumed the latter.

[8] It may also be the case that shipowners demand a premium to the index in such charters such that the apparent profit is reduced.

Finally, turning to hedging applications, the results of this study could be important for freight risk management using FFA contracts. In this respect, ship-owners and charterers can use the estimated coefficients of the models to adjust the hedge ratio according to factors such as vessel size, age, delivery location, etc. to achieve a more effective hedge. For instance, the estimated coefficient of vessel size can be used to adjust the hedge ratio of the FFA position according to the vessel's DWT compared to the standard vessel underlying FFA contracts. The estimated coefficients of dwt in model (4) indicates that, all else equal, every 1000 DWT in vessel size above the Baltic standard vessel will increase the physical earnings of the ship by 0.46%, 0.63% and 1.40% above the FFA rate in the Capesize, Panamax and Supramax markets, respectively. Therefore, the hedgers must increase their FFA position accordingly to establish a full cover for risk for the given vessel size. Similarly, the estimated coefficients of the Pacific Ocean delivery dummy suggest that, everything else being equal, vessels delivered in the Pacific tend to earn 13.02% (Capesize), 11.40% (Panamax) and 15.36% (Supramax) less than vessels delivered in the Atlantic relative to the FFA rate for the standard vessel. Hence, the ship-owners and charterers should consider adjusting the FFA positions accordingly to avoid over- or under-hedging.

7. Concluding remarks

In this paper we have argued, from a theoretical point of view, that there should be a positive and time-varying differential between forward rates in the physical freight and freight derivative markets that is positively related to the state of the freight market. We show that TC rates and FFA prices are co-integrated and that the resulting price differential can be well described by an ARMA-X model where the linear terms (X) includes the state of the freight market and the slope of the term structure of freight rates. We repeat the investigation for individual fixtures in the TC market and show that vessel-specific and contract-specific variables (as a proxy for basis risk due to technical specifications) also act as determinants at the micro level, with the expected results. We point to two explanations for the presence of such a premium: 1) it is a compensation for known risks inherent in bilateral physical TC contracts such as default risk and 2) it is a convenience yield, as only the physical contract gives access to transportation.

Our work is an important first step in the evaluation of the determinants of the observed price differentials between the physical forward market and financial freight derivative market. However, the findings also have practical implications for risk management and operations in bulk shipping. Most importantly, we point to the possibility out that apparent ‘arbitrage’ opportunities between the two markets – which ship-operators will often claim to be able to take advantage of – may not actually exist once the differences in risks, vessel specifications and contractual terms are properly accounted for. Secondly, our proposed methodology enables risk managers to adjust physical TC rates and FFA prices for differences in periods, vessel characteristics and contract terms so as to better compare the true cost of hedging with the two alternatives.

Future research should dig deeper into the important issue of whether the magnitude of the observed time-varying differentials is consistent with likely compensation for risk, for instance along the lines of the model for default risk presented in Adland and Jia (2008). It would also be interesting to develop more complicated trading strategies for ship-operators based on the observed time-varying differentials.

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Table 1– Time series descriptive statistics

	Mean	Std.Dev	J-B	LB-Q (13)	PP Test Level	PP test changes
Capesize						
6 Month TC	40971	44275	569.18	6587.3	-1.939	-22.341
6 Month FFA	35720	40229	596.38	6560.8	-2.002	-29.612
6 Month Spread	5251	6387	5886.22	1619.2	-12.66	
12 Month TC	37907	40206	610.75	66.74.0	-1.800	-24.002
12 Month FFA	33770	36528	590.17	6675.8	-1.894	-30.254
12 Month Spread	4138	5445	13699.95	1965.3	-9.895	
Slope	0.0185	0.4430	130.18	2469.2	-4.921	
Panamax						
6 Month TC	23308	16500	464.27	6703.9	-1.840	-23.741
6 Month FFA	20150	12812	492.46	6722.7	-1.808	-28.842
6 Month Spread	3159	2613	891.66	2688.7	-11.273	
12 Month TC	21133	14500	544.97	6828.6	-1.785	-25.668
12 Month FFA	19202	12657	500.48	6772.7	-1.722	-30.018
12 Month Spread	1931	1378	3090.14	2515.7	-11.983	
Slope	0.0123	0.2578	257.87	3011.3	-4.717	
Supramax						
6 Month TC	20469	14250	464.27	6573.4	-1.730	-16.972
6 Month FFA	18391	12498	492.46	6613.4	-1.666	-27.530
6 Month Spread	2078	1682	891.66	1973.0	-11.005	
12 Month TC	18905	13000	544.97	6666.8	-1.606	-14.183
12 Month FFA	17539	12391	500.48	6653.3	-1.593	-28.433
12 Month Spread	1366	805	3090.14	2939.6	-9.679	
Slope	-0.0585	0.1718	127.25	2561.3	-4.645	
Market Stress Index	-0.3820	1.1472	1163.5	6582.2	-1.724	

- Sample period is from 22 July 2005 to 23 December 2016, a total of 597 weekly observations for Capesize and Panamax and from 1 January 2006 to 23 December 2016, a total of 580 weekly observations for Supramax vessels.
- S.D. is the standard deviation. JB test is the Jarque-Bera (1980) test for Normality. The test follows a χ^2 distribution with 2 degrees of freedom.
- LB-Q(13) is Ljung-Box (1978) tests for 13th order autocorrelation in the level of series. 1%, 5% and 10% critical values for this test are –3.9739, -3.4175 and –3.1308, respectively.
- PP test is the Philips and Perron (1988) unit root tests. 1%, 5% and 10% critical values for this test are –3.9739, -3.4175 and –3.1308, respectively.
- Slope is defined as the log of Current Quarter (CQ) over near Calendar (Cal+1) FFA contracts for each vessel size.
- Market Stress Index is the index published by Federal Reserve Bank of St Louis, representing the stress in financial markets and used as a proxy for world economic condition.

Table 2– Descriptive statistics of time-charter fixtures, vessel specifications and contract variables

		Capesize				Panamax				Supramax			
		Mean	StDev	No Obs	Baltic*	Mean	StDev	No Obs	Baltic	Mean	StDev	No Obs	Baltic
Contract Rate	$/day	49,505	44,274	765		30,216	22,151	2901		23,311	16,206	1141	
FFA equivalent	$/day	49,919	44,157	765		28,845	21,179	2901		22,536	15,766	1141	
Dwt	mt	169,878	11,881	765	172000	74,902	3,919	2901	74000	5,225	4,439	1141	52454
Age	Year	8.0	6.10	765	Max 10	8.1	5.2	2901	Max 12	6.4	5.1	1141	Max 15
Speed	knts	14.32	0.70	765	14.75	14.09	0.61	2901	14.0	14.20	0.54	1141	14.25
Consumption	Mt/d	56.59	7.31	765	56	33.57	3.58	2901	30	30.15	3.22	1141	30
Period	months	7.73	3.31	765		6.59	2.93	2901		6.31	3.10	1141	
Laycan	days	14.70	28.54	765		9.44	13.86	2901		7.31	13.87	1141	
Pacific Del Dummy		0.86	0.34	765		0.71	0.46	2901		0.60	0.49	1141	
Ind Ocean Del Dummy		0.01	0.11	765		0.08	0.27	2901		0.13	0.33	1141	
Atlantic Del Dummy		0.11	0.31	765		0.20	0.40	2901		0.26	0.44	1141	
Option Dummy		0.85	0.36	765		0.91	0.29	2901		0.82	0.38	1141	

- Sample period is from 22 July 2005 to 23 December 2016, for Capesize and Panamax and from 1 January 2006 to 23 December 2016, for Supramax vessels.
- *From Baltic Exchange (2014) Manual for Panellists. Speed is average of ballast and laden.

Table 3– Results of Cointegration tests between 6- and 12-month Time-charter rates and equivalent FFA rates for different size dry bulk ships

$$\Delta tc_t = a_{0,1} + \sum_{i=1}^{P} a_{1,i}\Delta tc_{t-i} + \sum_{i=1}^{P} a_{2,i}\Delta ffa_{t-i} + \phi_1(\beta_1 tc_{t-1} + \beta_2\, ffa_{t-1} + \beta_0) + \varepsilon_1$$

$$\Delta ffa_{t-1} = b_{0,1} + \sum_{i=1}^{P} \alpha_{1,i}\Delta tc_{t-i} + + \sum_{i=1}^{P} b_{2,i}\Delta ffa_{t-i} + \phi_2(\beta_1 tc_{t-1} + \beta_2\, ffa_{t-1} + \beta_0) + \varepsilon_2$$

	Lags	*H_0*	*H_1*	λ_{trace}	λ_{max}	*Normalised CV* *(1 β_2 β_0)*	*LR test* *β_2=-1 , β_0=0*	*LR test* *β_2=-1*
Capesize								
12month TC-FFA	*2*	*r = 0*	*r>0*	49.406	47.698	(1 -0.979 -0.339)	37.220	*2.739*
		r = 1	*r>1*	1.708	1.708		(0.000)	*(0.098)*
6month TC-FFA	*2*	*r = 0*	*r>0*	50.736	48.235	(1 -0.964 -0.528)	31.731	*3.204*
		r =1	*r>1*	2.502	2.502		(0.000)	*(0.074)*
Panamax								
12month TC-FFA	*2*	*r = 0*	*r>0*	38.488	36.910	(1 -0.959 -0.507)	27.098	*5.364*
		r = 1	*r>1*	1.578	1.578		(0.000)	*(0.021)*
6month TC-FFA	*2*	*r = 0*	*r>0*	30.178	28.100	(1 -0.963 -0.530)	21.268	*2.102*
		r =1	*r>1*	2.078	2.078		(0.000)	*(0.157)*
Supramax								
12month TC-FFA	*2*	*r = 0*	*r>0*	73.402	71.950	(1 -1.027 0.199)	48.058	*9.588*
		r = 1	*r>1*	1.452	1.452		(0.000)	*(0.002)*
6month TC-FFA	*2*	*r = 0*	*r>0*	39.480	37.649	(1 -0.992 -0.191)	26.189	*0.184*
		r = 1	*r>1*	1.831	1.831		(0.000)	*(0.668)*

- Sample period is from 22 July 2005 to 23 December 2016, a total of 597 weekly observations for Capesize and Panamax and from 1 January 2006 to 23 December 2016, a total of 570 weekly observations for Supramax vessels.
- *Cointegration tests are based on the Johansen (1988) procedure; the LR test is based on 1% significance level.*

Table 4: Results of VECM for Physical Time-charter and FFA equivalent for different size dry bulk carriers

$$\Delta tc_t = a_{0,1} + \sum_{i=1}^{P} a_{1,i}\Delta tc_{t-i} + \sum_{i=1}^{P} a_{2,i}\Delta ffa_{t-i} + \phi_1(\beta_1 tc_{t-1} + \beta_2\, ffa_{t-1} + \beta_0) + \varepsilon_1$$

$$\Delta ffa_{t-1} = b_{0,1} + \sum_{i=1}^{P} \alpha_{1,i}\Delta tc_{t-i} + + \sum_{i=1}^{P} b_{2,i}\Delta ffa_{t-i} + \phi_2(\beta_1 tc_{t-1} + \beta_2\, ffa_{t-1} + \beta_0) + \varepsilon_2$$

	Capesize				Panamax				Supramax			
	6-month		12-month		6-month		12-month		6-month		12-month	
	Δtc_t	Δffa_t	Δtc_t	Δffa_t	Δtc_t	Δffa_t	Δtc_t	Δffa_t	Δtc_t	Δffa_t	Δtc_t	Δffa_t
ECT_{t-1}	-0.182^{***}	-0.001	-0.191^{***}	0.012	-0.089^{***}	0.016	-0.111^{***}	0.004	-0.112^{***}	0.048	-0.191^{***}	0.098^{*}
	(0.034)	(0.035)	(0.043)	(0.048)	(0.024)	(0.032)	(0.025)	(0.035)	(0.024)	(0.035)	(0.033)	(0.052)
Δtc_{t-1}	-0.001	0.114^{**}	-0.108^{*}	0.049	-0.066	-0.033	-0.068	-0.081	0.093^{**}	0.179^{***}	0.187^{***}	0.281^{***}
	(0.052)	(0.055)	(0.059)	(0.067)	(0.053)	(0.069)	(0.051)	(0.072)	(0.046)	(0.066)	(0.049)	(0.078)
Δtc_{t-2}	-0.012	0.004	0.022	0.059	0.004	0.029	0.139	0.164^{***}	0.064	0.062	0.095^{**}	0.110^{*}
	(0.047)	(0.049)	(0.053)	(0.060)	(0.043)	(0.056)	(0.044)	(0.062)	(0.040)	(0.057)	(0.041)	(0.066)
Δffa_{t-1}	0.241^{***}	-0.090	0.204^{***}	-0.087	0.398^{***}	-0.005	0.273^{***}	-0.055	0.300^{***}	-0.050	0.141^{***}	-0.108^{*}
	(0.055)	(0.057)	(0.058)	(0.067)	(0.044)	(0.058)	(0.041)	(0.058)	(0.037)	(0.054)	(0.040)	(0.063)
Δffa_{t-2}	0.219^{***}	0.137^{**}	0.219^{***}	0.143^{***}	0.187^{***}	0.130^{**}	0.120^{***}	0.120^{**}	0.187^{***}	0.060	0.063^{*}	0.053
	(0.052)	(0.055)	(0.054)	(0.061)	(0.044)	(0.058)	(0.040)	(0.056)	(0.037)	(0.053)	(0.035)	(0.056)
R-bar-sq	0.177	0.033	0.144	0.037	0.271	0.018	0.232	0.049	0.351	0.047	0.327	0.077
Log-Likelihood	1081.666		1482.99		1598.18		1832.45		1784.69		2039.96	
SBIC	-3.581		-4.862		-5.595		-6.092		-6.117		-7.013	
LB-Q(8)	30.818 [0.195]		49.180 [0.002]		50.30 [0.002]		44.346 [0.010]		34.503 [098]		56.691 [0.001]	
Granger Causality												
Δtc_t --> Δffa_t	4.425 [0.109]		1.207 [0.548]		0.507 [0.776]		8.460 [0.015]		9.094 [0.011]		17.056 [0.000]	
Δffa_t --> Δtc_t	26.742 [0.000]		20.170 [0.000]		82.776 [0.000]		43.698 [0.000]		68.919 [0.000]		12.719 [0.000]	

- Figures in () and [] are standard errors and p-values, respectively.

Table 5– Determinants of physical TC premium (macro level)

$$ldiff_t = \beta_0 + \beta_1 lTC_t^k + \beta_2 S_t + \beta_3 DEF_t + \sum_{i=1}^{p} \gamma_i ldiff_t + \sum_{j=1}^{q} \delta_j \varepsilon_{t-j} + \varepsilon_t$$

	Capesize		Panamax		Supramax	
Coefficient	6-Month	12-Month	6-Month	12-Month	6-Month	12-Month
β₀ Constant	-4.520***	-2.257***	-2.722***	-1.937***	-3.534***	-0.290***
	(0.585)	(0.575)	(0.547)	(0.669)	(0.955)	(0.092)
β₁ (*ln*TC)	0.434***	0.231***	0.288***	0.218***	0.358***	0.033***
	(0.046)	(0.050)	(0.055)	(0.061)	(0.100)	(0.009)
β₂ (*Slope*)	0.073**	0.032*	-0.020	-0.101**	-0.039	-0.101***
	(0.029)	(0.018)	(0.049)	(0.039)	(0.091)	(0.031)
β₃ (*DEF*)	0.159***	0.081***	0.061	0.061*	0.099***	0.011*
	(0.056)	(0.031)	(0.039)	(0.035)	(0.036)	(0.006)
γ1	0.630***	0.555***	0.598***	0.605***	0.615***	0.465***
	(0.065)	(0.059)	(0.060)	(0.060)	(0.084)	(0.070)
γ2	0.363***	0.440***	0.392***	0.389***	0.378***	0.174**
	(0.065)	(0.060)	(0.059)	(0.058)	(0.079)	(0.074)
δ2	-0.103*	-0.249***	-0.195***	-0.199***	-0.203***	
	(0.061)	(0.078)	(0.049)	(0.066)	(0.047)	
δ3	-0.107**	-0.158**	-0.122**	-0.113*	-0.102*	
	(0.055)	(0.065)	(0.054)	(0.064)	(0.060)	
No Observations	596	596	589	589	571	571
R-Bar-Squared	0.659	0.525	0.697	0.659	0.615	0.442
SBIC	-1.953	-2.638	-2.640	-2.970	-2.909	-3.264
LB-Q(13)	12.660	9.688	11.137	9.643	9.194	10.044
	[0.179]	[0.376]	[0.266]	[0.380]	[0.420]	[0.526]
BPG Test	40.837	14.499	62.233	44.792	38.409	20.849
	[0.000]	[0.002]	[0.000]	[0.000]	[0.000]	[0.000]

- Sample period is from 8 May 2005 to 23 December 2016 for Capesize, from 22 July 2005 to 23 December 2016 for Panamax and from 16 September 2005 to 23 December 2016 for Supramax vessels.
- The order of AR and MA terms are selected to eliminate autocorrelation in residuals.
- Figures in () and [] are standard errors and p-values, respectively. *, **, and ***.indicate significance at the 10%, 5% and 1% levels, respectively.
- SBIC is the Schwarz Bayesian Information Criterion, LB-Q(13) is Ljung-Box (1978) test for 13th order residuals autocorrelation, and BPG Test is the Breusch-Pagan-Godfrey test for heteroskedasticity.
- Estimation method is Conditional Least Squares (CLS) and standard errors are corrected using Newey-West (1987) method where necessary.

Table 6– Determinants of physical TC premium (micro level)

$$ldiff_{t,i} = \beta_0 + \beta_1 AGE_i + \beta_2 AGE_i^2 + \beta_3 DWT_i + \beta_4 SP_i + \beta_5 CON_i + \gamma_1 TCD_i + \gamma_2 LC_i$$
$$+\gamma_3 OP_i + \gamma_4 PD_i + \gamma_5 ID_i + \lambda_1 SL_t + \lambda_2 DEF_t + \lambda_3 BP_t + \varepsilon_{t,i}$$

		Capesize	Panamax	Supramax
β_0	Constant	-1.3584***	-0.5926***	-1.1112***
		(0.1884)	(0.1217)	(0.2692)
β_1	AGE	0.0143***	0.0100***	0.0112***
		(0.0036)	(0.0016)	(0.0025)
β_2	AGE^2	-0.0012***	-0.0008***	-0.0008***
		(0.0002)	(0.0001)	(0.0001)
β_3	DWT/1000	0.0046***	0.0063***	0.0140***
		(0.0005)	(0.0012)	(0.0021)
β_4	SPEED	0.0212***	0.0049	0.0163
		(0.0115)	(0.0054)	(0.0159)
β_5	Consumption	-0.0004*	-0.0008	-0.0032**
		(0.0003)	(0.0008)	(0.0016)
γ_1	TC Duration	-0.0015	-0.0075***	-0.0002
		(0.0019)	(0.0012)	(0.0005)
γ_2	Time to Laycan	-0.0008***	-0.0013***	-0.0035
		(0.0002)	(0.0002)	(0.0022)
γ_3	Option Dummy	0.0039	0.0189**	-0.0231
		(0.0190)	(0.0086)	(0.0166)
γ_4	Pacific Ocean Del	-0.1302***	-0.1140***	-0.1536***
		(0.0161)	(0.0101)	(0.0151)
γ_5	Indian Ocean Del	-0.1312***	-0.0688***	-0.1450***
		(0.0470)	(0.0117)	(0.0162)
ϕ_1	Slope of FWD	-0.0179	0.0594***	-0.1672***
		(0.0149)	(0.0180)	(0.0309)
ϕ_2	Default Premium	0.0203**	0.00002	-0.0045
		(0.0090)	(0.0050)	(0.0064)
ϕ_3	Log of fuel price	0.0653***	0.0413***	0.0658***
		(0.0170)	(0.0124)	(0.0164)
No Observations		685	2920	1149
R-Bar-Squared		0.527	0.298	0.331
SBIC		-1.0844	-1.4491	-1.1906
LM Test		12.558	245.48	68.537
		[0.002]	[0.000]	[0.000]
BPG Test		62.853	480.48	137.79
		[0.000]	[0.000]	[0.000]

- Sample period is from 22 July 2005 to 23 December 2016, a total of 685 observations for Capesize, and 2901 for Panamax, and from 1 January 2006 to 23 December 2016, a total of 1149 weekly observations for Supramax vessels.
- Figures in () and [] are standard errors and p-values, respectively. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.
- SBIC is the Schwarz Bayesian Information Criterion, LM Test is the Lagrange Multiplier test tests for serial correlation in residuals and White Test is the White (1980) test for heteroscedasticity.
- Standard errors are corrected for the presence of heteroscedasticity and serial correlation using Newey and West (1987) methods.

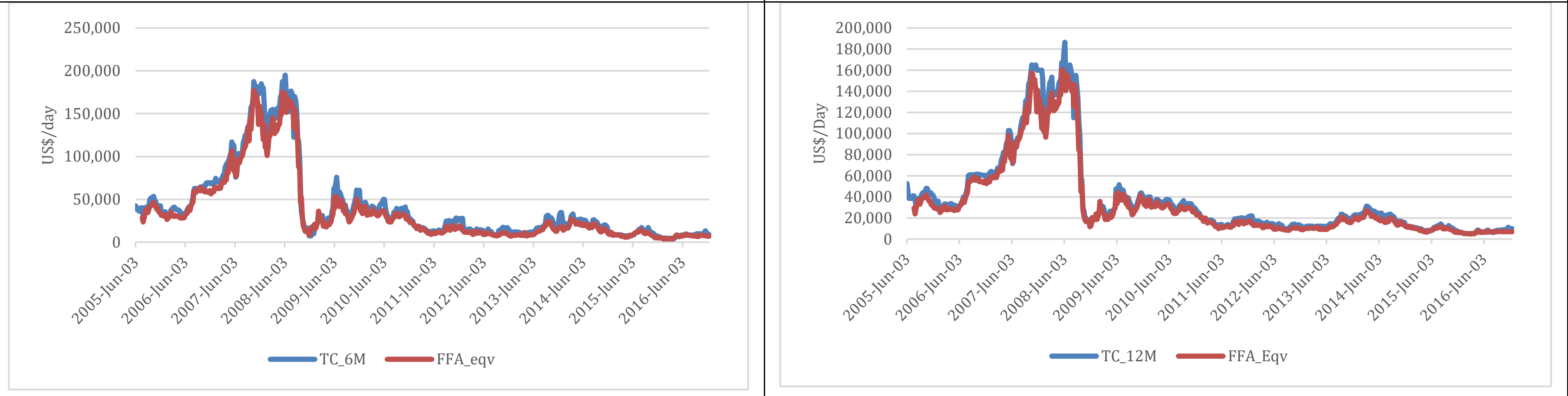
Table 7– Valuation of time-charter rates for Capesize vessels based on vessel and contract specific factors and FFA curve

$$ldiff_{i,t} = \beta_0 + \beta_1 AGE_i + \beta_2 AGE_i^2 + \beta_3 DWT_i + \beta_4 SP_i + \beta_5 CON_i + \gamma_1 TCD_i + \gamma_2 LC_i + \gamma_3 OP_i + \gamma_4 PD_i + \gamma_5 ID_i + \lambda_1 SL_t + \lambda_2 MSI_t + \lambda_3 BP_t + \varepsilon_i$$

		Atlantic Delivery			Pacific Delivery		
FFA equivalent $/day		10,000	10,000	10,000	10,000	10,000	10,000
Constant	-1.4394						
AGE (years)	0.0143	5	5	5	5	5	5
AGE^2	-0.0012	25	25	25	25	25	25
DWT/1000	0.0048	**180000**	**172000**	**150000**	**180000**	**172000**	**150000**
Speed	0.0243	14	14	14	14	14	14
Consumption	-0.0004	50	50	50	50	50	50
TC Period	-0.0007	12	12	12	12	12	12
Forward Days	-0.0009	20	20	20	20	20	20
Ext Option Dummy	0.0098	1	1	1	1	1	1
Pacific Delivery Dummy	-0.1236	0	0	0	**1**	**1**	**1**
Indian Ocean Delivery Dummy	-0.1281	0	0	0	0	0	0
Slope of Forward curve	-0.0291	0.1	0.1	0.1	0.1	0.1	0.1
Default Premium	0.0093	1	1	1	1	1	1
Log(Fuel Price)	0.0729	350	350	350	350	350	350
Estimated Time Charter $/day		11,690	11,268	10,183	10,263	9,892	8,940
TC Premium over FFA		16.9%	12.7%	1.8%	2.6%	-1.1%	-10.6%

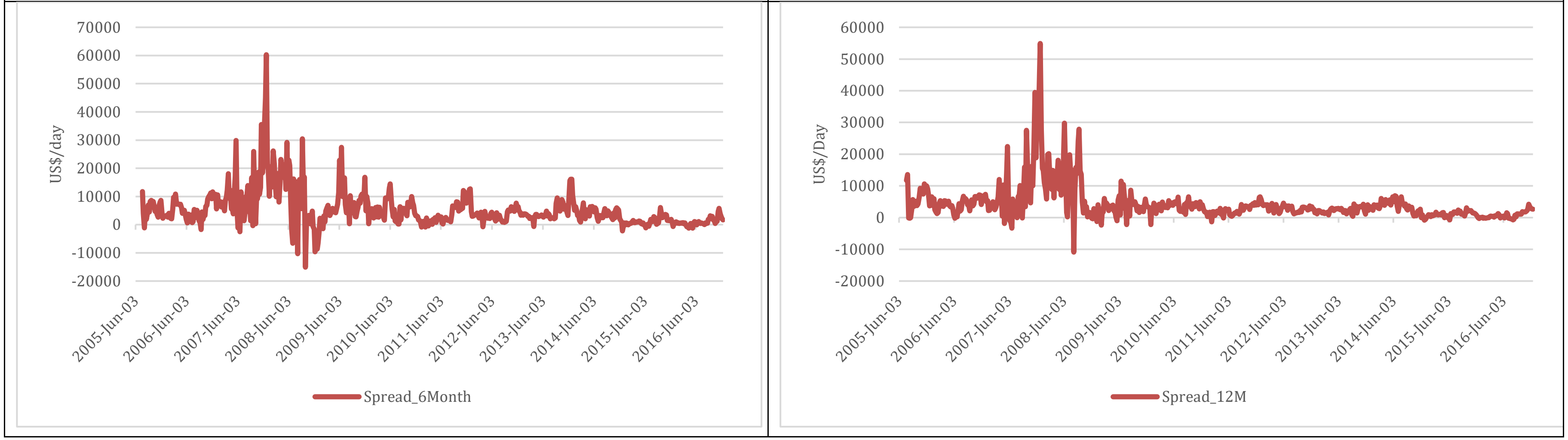
- The table uses the estimation results of equation (4), presented in Table 6, to illustrate the valuation of time-charter contracts using forward curve, vessel specific factors, contracts terms, and market conditions.

Figure 1: Capesize Time-Charter rate and FFA Equivalents



6-month TC and FFA equivalent

12-month TC and FFA equivalent



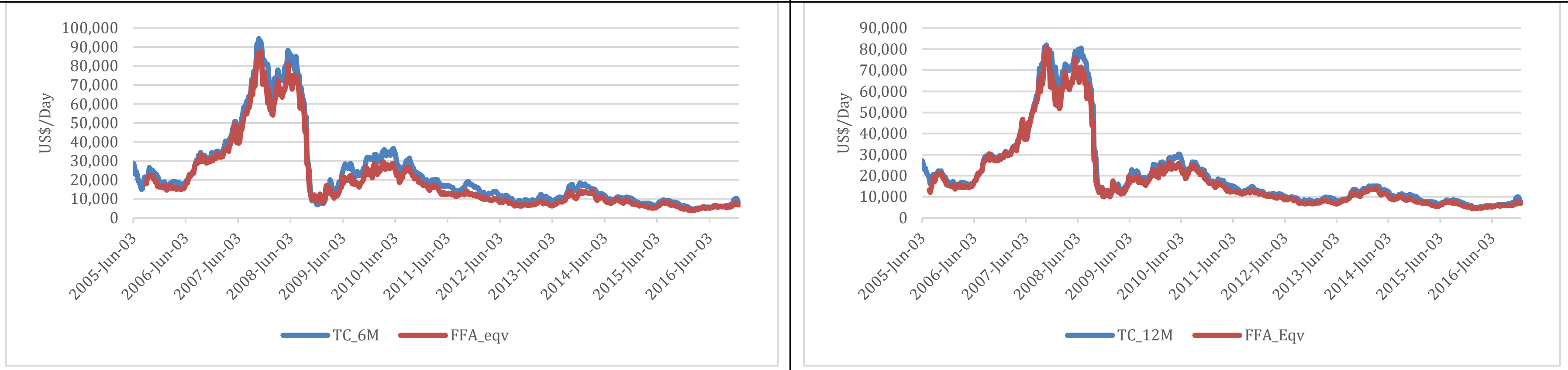
Spread between 6-month TC and FFA

Spread between 12-month TC and FFA

Figure 2: Panamax Time-Charter rate and FFA Equivalents

6-month TC and FFA equivalent

12-month TC and FFA equivalent



Spread between 6-month TC and FFA

Spread between 12-month TC and FFA

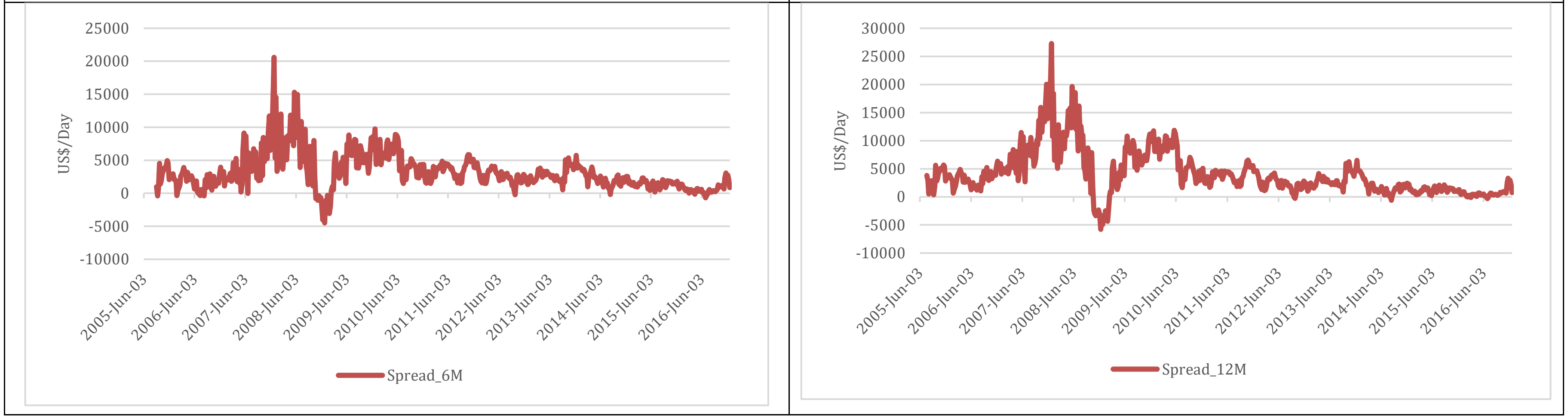
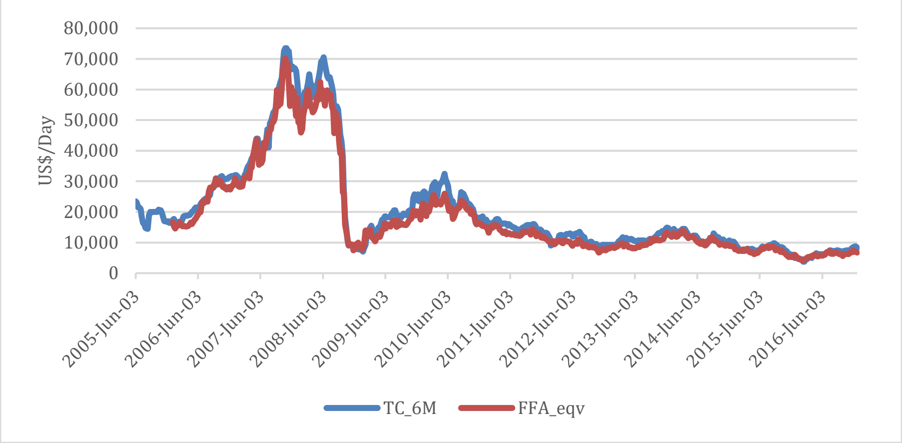
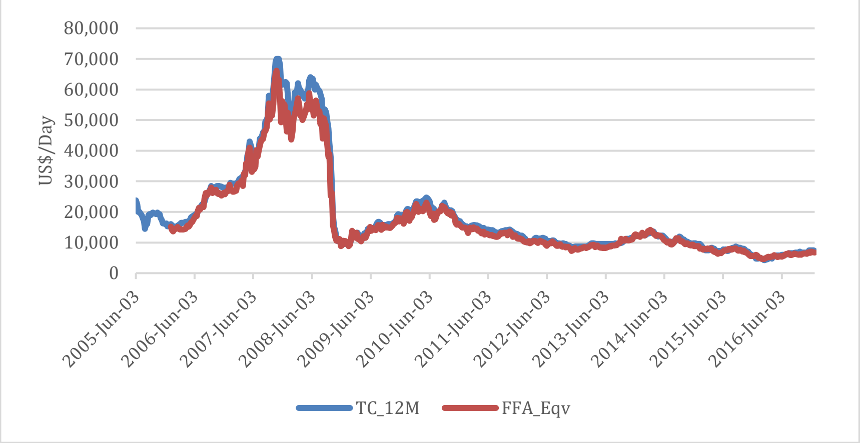


Figure 3: Supramax Time-Charter rate and FFA Equivalents

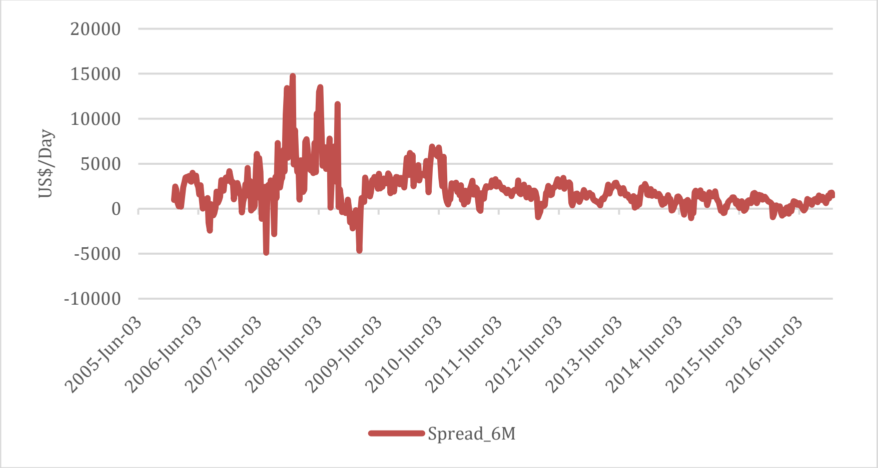
6-month TC and FFA equivalent



12-month TC and FFA equivalent



Spread between 6-month TC and FFA



Spread between 12-month TC and FFA

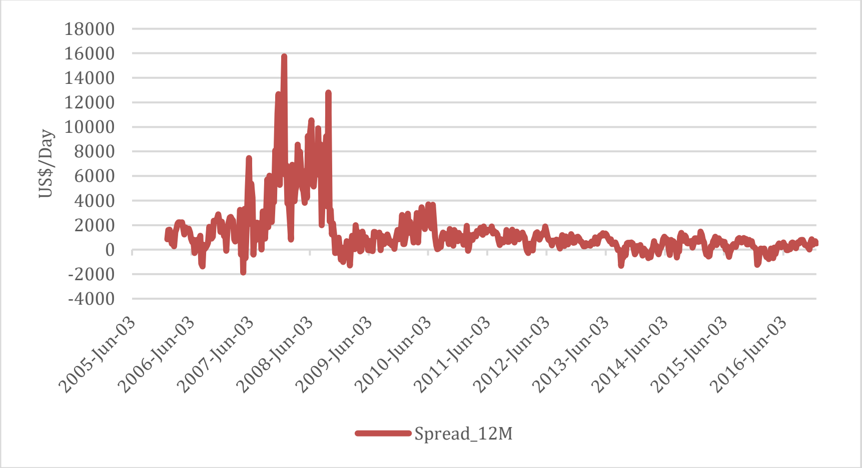


Figure 4: Cumulative profit from simple trading strategy