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Spatial efficiency in the dry bulk supramax market

An investigation through cointegration and profitable trading strategies

by

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Abstract

The freight rates across geographical regions in the drybulk segment may experience substantial differences on a short-term basis, but generally move in tandem in the long-term. If these temporary differences cannot be exploited financially by applying trading rules based on publicly available information, then the market can be viewed as spatially efficient. This paper uses cointegration analysis to establish the long-term relationship between supramax tripcharter rates, and moves on to evaluate the financial profitability of trigger based trading rules. These rules are based on spreads between certain tripcharter rates. The trading rules are applied in order to investigate whether the short-term differences allowed under cointegration are transient enough to coincide with a spatially efficient market. The results provide evidence of a profitable trading strategy, but when accounting for potential off-hire ballasting activity these profits are zeroed out. Thus, the conclusion points towards a spatially efficient dry bulk supramax market.

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1. Introduction

Reviewing historical tripcharter rates it becomes evident that carrying cargo in certain directions across geographical areas is more profitable than others. In a perfectly competitive market where trade frictions are eliminated, shipowners would instantaneously relocate their vessels in order to compete for the most profitable rates (Adland et al., 2013). This is in line with a spatially efficient freight market, where excess profits are eliminated due to fleet mobility across geographical regions.

To investigate whether the fleet mobility is sufficient enough to coincide with a spatially efficient market, we analyse the relationship between tripcharter rates by using cointegration analysis and trading rules. The analysis is applied on the dry bulk supramax segment, using the *fronthaul, backhaul, transatlantic* and *transpacific* tripcharter rates, as a spatial[1] movement lies embedded in their definition. In the short-run, these rates can experience substantial differences caused by the requirement of physical presence of the vessel, previous fixtures, asymmetrical trade volumes, cumulative decisions and previous experience of shipowners (Adland et al, 2013). However, such differences are not necessarily in conflict with an efficient market, if they cannot be exploited financially.

By establishing cointegration, we can assume that the fleet relocates to exploit short-term deviations from a certain long-term relationship between the tripcharter rates. When the fleet relocates between the areas subject to deviations, supply increases in the most profitable area, causing the rates to drop. This realignment of supply and demand moves the rates back to the long-term relationship, indicating a market that works efficiently in a spatial context.

However, if the short-term deviations allowed under cointegration are persistent enough, market participants may apply trading strategies[2] to exploit them. When such trading strategies yield excess profits, the notion of the efficient market hypothesis is breached (Adland & Strandenes, 2006). This implies that cointegration is a necessary, but not sufficient condition for market efficiency (Adland et al., 2013). In this manner, trading rules[3]

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[1] In this context, spatial is used to describe a movement across geographical areas.
[2] Trading strategies based on publicly available information that optimizes the sequence of tripcharter rates to maximize profits.
[3] Trading strategies and trading rules will be used synonymously.

represents a way of testing whether the short-term deviations allowed under cointegration, are transient enough to coincide with an efficient market.

Addressing the underlying mechanisms of geographical movements in the dry bulk supramax market, this paper seeks to answer the following research question: *Is the dry bulk supramax market spatially efficient?* Thus, the results and conclusions drawn here will be relevant for market participants, such as shipowners, pure operators, shipping pools and alike, in the development of their cross regional trading strategy. The remainder of this paper is structured as follows. First, an overview of empirical literature relevant to our research is given in section two. Subsequently, tripcharter rates and spreads used in the analysis are described in section three. In order to analyse cointegration among tripcharter rates, we assess stationarity using the Augmented Dickey Fuller test, followed by Johansen's test for cointegration, both methods explained in section four. Furthermore, as a part of the methodology, we develop seven trading rules that will be simulated for a vessel trading through historical tripcharter rates. The empirical results from the cointegration analysis and simulation of trading rules are presented in section five. Section six contains some concluding remarks.

2. Literature review

The most common approach to investigate market integration and efficiency in the shipping industry has been through analysis, either between freight rates within one sector, or through vessel prices across sectors.

Glen and Rogers (1997) analyze mulitiple freight rates that are used to establish the market conditions in the shipping sector. Their findings reveal that the series are highly correlated and non-stationary, which makes them able to conclude that they are cointegrated. Cointegration among frieght rates are also investigated by Berg-Andreassen (1996; 1997). In another paper, Glen (1997) provides evidence of cointegration in both the dry bulk, and tanker market, through an examination of the behavior of the secondhand vessel prices. Similar for most of these abovementioned papers are their alignment of the establishment of cointegration and market efficiency. In addition to cointegration analysis, an application of directed acyclical graphs finds that some routes are dominant, thus representing a "price leadership" (Haigh, Nomikos, & Bessler, 2004).

Cointegration techniques have also been applied as a way of testing the unbiasedness hypothesis in the freight forward market. Kavussanos et al. (2004) find that the one and two month FFA prices serve as unbiased predictors for the realised spot prices. This conclusion also hold for certain three months FFA routes, where 2 and 2A are found to be an unbiased predictor, while 1 and 1A are proven to be a biased predictor of the future spot price. Kavussanos and Alizadeh (2002) test the expectations hypothesis of the term structure between 1980 and 1997, but find no evidence to support the hypothesis. This failure is explained by the perception of risk that the shipowners evaluate in the choice between spot and time charter rates.

As cointegration requires the incorporated processes to be non-stationary the above mentioned literature need to provide evidence of such. The perception of freight rates being a non-stationary process is questioned by Koekebakker et al. (2006) who argue that the weak power of the tests used to analyze freight rates results in a failure to reject non-stationarity.

Testing the existence of profitable trading strategies, as proof of market inefficiency in the shipping industry, was introduced by Adland and Strandenes (2006). They evaluate a strategy

that identifies the peaks and troughs in the tanker market cycles by applying kernel smoothing on the spot freight rate. Their results suggest that a tanker operator could have achieved profits, and accordingly that the market is inefficient. This way of analysing market efficiency is in contrast to the historically more common approach of analysing the existence of a cointegrated relationship between either freight rates or vessel prices.

Technical trading rules have also been applied to decisions regarding sale and purchase of second-hand vessels. Alizadeh and Nomikos (2007) analyse the relationship between the vessel prices and earnings, and apply trading rules based on an earnings-price ratio that significantly out performs a buy and hold strategy. Adland and Koekebakker (2004) evaluate the market for second-hand vessels applying filter rules, moving averages and support and resistance levels in the pursuit of excess returns. The results suggest that none of the rules are capable of providing excess return to the buy and hold strategy, when accounting for transaction costs along with the possible price slippage that may exist in an illiquid market. Thus, their results points at an efficient market.

Tsioumas and Papadimitriou (2014) investigate whether a momentum based trading rule can provide excess returns, through technical analysis of the tripcharter rate and the underlying voyage charters, expressed as time charter equivalents. The results show that the trading rule outperforms the benchmark strategy of chartering in a vessel on tripcharter and then perform the underlying voyage charter.

Spatial market efficiency has been analysed by investigating differences in rates across regions. Adland et al. (2013) apply an optimal switching model on the spread between the tripcharter rates for an Atlantic and Pacific round voyage in the capesize market. The approach assumes an instantaneous switch between the two basins. Their findings conclude that the markets appear to be spatially efficient, but that a small added value through an active switching strategy can be found between mid-2003 and 2008. The small added value is further explained due to the premium from the fronthaul voyage created by the economic growth of the Far East.

They also argue that the existence of cointegration is not only a sufficient, but necessary condition for market efficiency. As cointegration allows for short-term deviations that may be

persistent enough for profitable trading strategies to exist, thus violating the notion of an efficient market (Adland et al., 2013). To my knowledge this is the only previous study that evaluates trading rules in a cross regional context. The study does not investigate cointegration among tripcharter rates, but draws the conclusion of a cointegrated relationship by showing that the spread is a stationary process.

In the geographical shipping literature, where spatial market inefficiency and lack of market integration is generally assumed to be present, Laulajainen (2006, 2007, and 2010) makes several attempts to explain the geographical differences that can be observed.

Laulajainen (2007) studies the systematic geographical differences in freight rates in the drybulk shipping market from a shipowners' perspective. He proposes that the difference between regions can be explained through a *Revenue Gradient*, entailing the ratio of demanded and available tonnage, that are both weighted by sailing distance to a discharge or loading region. Further, Laulajainen (2006) estimates route-specific freight rates through a static-gravity type model, which findings indicate that the route distance is the most important variable. Laulajainen (2010) argues that operational and tactical decisions are governing at a regional level, while dynamic inter-regional allocation of the fleet represents a strategic decision with an inherent risk.

Reviewing the abovementioned papers, it becomes evident that the literature mainly approaches market efficiency from two angles: either through a cointegration analysis or by providing evidence of profitable trading strategies. Much of the data applied in these studies are focused on the larger vessels segments, such as the panamax and capesize segment. These larger vessels are known to have more standardized trading patterns than the smaller supramax vessels, which will be investigated here.

Furthermore, this paper contributes by overcoming the issues regarding instantaneous switching between the two basins mentioned by Adland et al. (2013). Along the lines of their study, this papers contributes in the development of a more sophisticated approach to optimize chartering decisions in a cross regional context. In addition a cointegration analysis followed by an evaluation of trading rules, have to my knowledge not been performed on supramax tripcharter rates previously.

3. Data description

The dry bulk market is a fundamental part of the shipping industry, with sizes ranging from the smallest handysize vessels at around 10 000 DWT, to the capesize vessels at 100 000 DWT and above. These various segments have historically experienced similar market conditions, albeit with some differences during certain periods. The supramax segment consists of vessels at around 52 000 DWT, and is part of the segment that is more commonly referred to as the handymax segment, that ranges between 40 000 and 60 000 DWT. Thus, it is in the lower range of the dry bulk sector with respect to size. This implies fewer port restrictions, leading to a larger diversity in types of cargo carried, compared to the larger vessels. In addition supramax vessels are often fitted with cranes, which further increase the number of ports available for loading and discharge (Stopford, 2009).

3.1 Tripcharter freight rates

A shipping freight contract is one in which the charterer agrees to pay a certain amount of money per day for the hire of a vessel, or per ton of cargo carried. Depending on the service requested by the charterer, several different contracts are available. These can be divided into five main categories: voyage charter contracts, contracts of affreightment, tripcharter contracts, timecharter contracts and bareboat contracts (Alizadeh & Nomikos, 2009). The various contracts represent a different risk and cost allocation between the charterer and the shipowner. In this paper, only tripcharter contracts will be evaluated, as these are the ones best to incorporate the spatial movement of the vessel.

In a tripcharter contract, the charterer agrees to hire the vessel from the shipowner for the duration of a trip on a dollar per day basis. The shipowner will normally maintain the operational control over the vessel, while the charterer will bear the voyage costs. The loading port is normally set as the delivery point, while redelivery takes place at the discharge port, but vessels can also be hired for a round-trip (Alizadeh & Nomikos, 2009). However, redelivery and discharge port may not always be the same.

From a shipowner's perspective, a tripcharter contract has an advantage in that it compensates the shipowner for any delay that may occur, as hire is paid until the vessel is redelivered. The charterer on the other hand is responsible for the voyage costs, leaving him free to arrange for cheaper bunker prices and lower port costs (Alizadeh & Nomikos, 2009).

The tripcharter rates in the dry bulk shipping market can be divided into four major routes (Alizadeh & Nomikos, 2009). A *fronthaul* (FH) trip represents a voyage from the European continent to the Far East, while a *backhaul* (BH) trip represents the same voyage in the opposite direction. The *transatlantic* (TA) and *transpacific* (TP) voyages represent a round-trip between the European continent and the U.S. East Coast, and the Far East and U.S. West Coast, respectively (see Figure 1). The duration of these voyages are assumed to be nine weeks for the fronthaul, backhaul and transatlantic voyages, while the transpacific voyage is assumed to be six weeks.
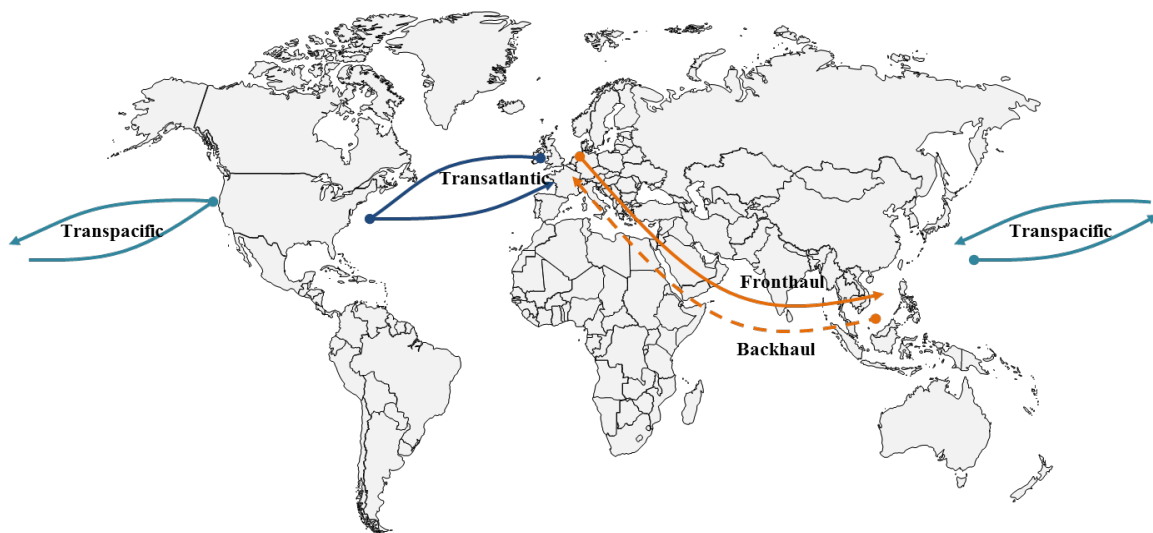
Figure 1 - Illustration of tripcharter rates (Source: Author's own)

This paper uses the weekly tripcharter rates from 2002 to October 23, 2015 provided by Clarksons Research. Reviewing these rates, it becomes evident that variations between the routes are present, but seems to be moving in similar patterns. By graphical inspection of Figure 2 it appears that the fronthaul voyage has been trading at a premium almost continuously since the bottom of the financial crisis. This is in contrast to the pattern that can be seen prior to the collapse in freight rates in late 2008.

Supramax Tripcharter Rates
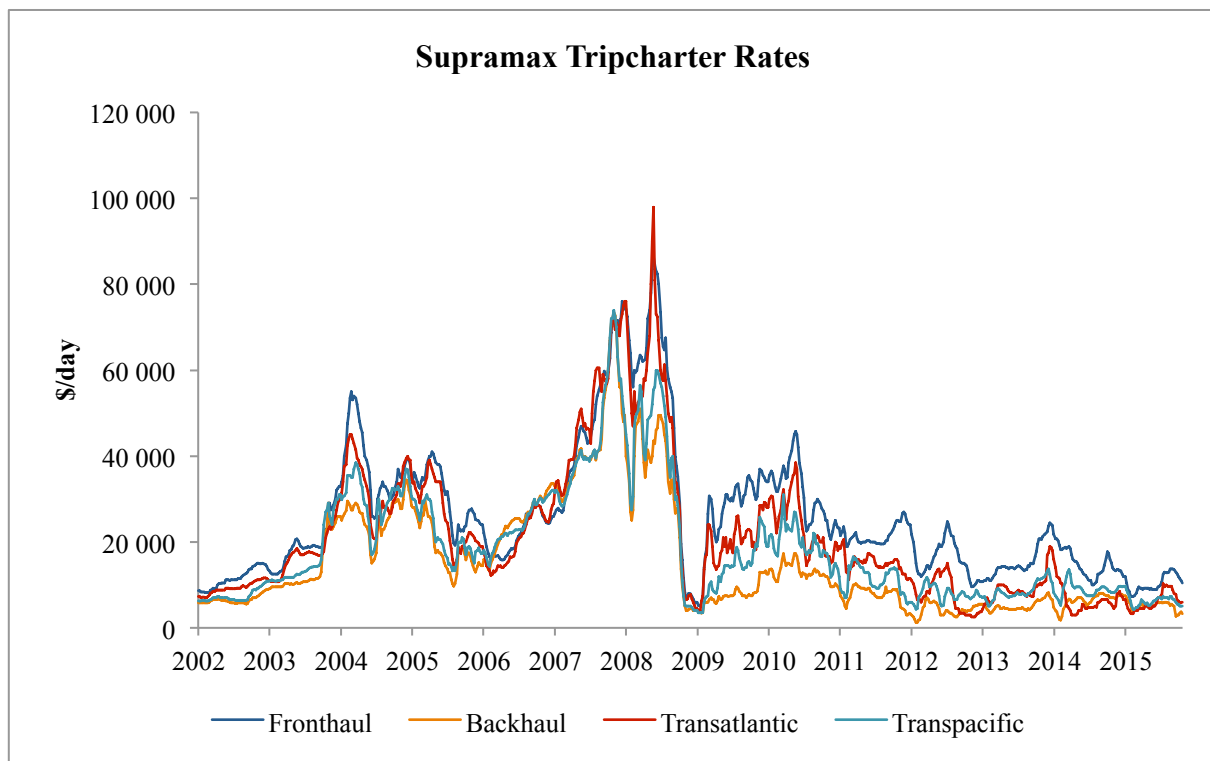
Figure 2 - Historical supramax tripcharter rates (Source: Clarksons SIN)

A more detailed inspection reveals that a fronthaul voyage had the highest tripcharter rates, on a $/day basis in 71.4% of the observations from 2002-2008, while this ratio has changed to 99.4% in the period from 2009 and onwards. The share in which the backhaul voyage has been recorded as the lowest tripcharter, has remained fairly constant. From 2002-2008 it was the lowest in 76.0% of the observations and this ratio only change to 78.1% through the latter period. On an overall basis the fronthaul voyage has been highest in 85.2% of the observations, while the backhaul voyage has been the lowest in 77.0%.

Selected descriptive statistics (see Table 1) of the time series speak of volatile tripcharter rates with a range of up to 95 500 $/day, in the case of transatlantic rates. Furthermore, the arithmetic mean over the timespan underpins the notion that the fronthaul voyage has the highest rates, while the backhaul voyage has the lowest. The rates have a kurtosis less than three and a positive skewness. In terms of the shape of the distribution curve, this means that the tails are flatter, or fatter, compared to the normal distribution (Wooldridge, 2013). The shape of the curve is also tilted to the left, due to the positive skewness, implying that we have a higher frequency of observations that are above the mode, than below.

Table 1 - Descriptive statistics of tripcharter rates.

	Fronthaul	*Backhaul*	*Transatlantic*	*Transpacific*
Mean	25 797	15 443	21 051	18 437
Median	21 500	9 500	16 500	13 850
Mode	12 500	7 500	4 500	7 000
Standard Deviation	15 738	13 379	16 438	13 481
Kurtosis	2,06	2,30	2,35	2,02
Skewness	1,47	1,54	1,53	1,45
Range	81 500	72 250	95 500	70 500
Minimum	5 000	1 250	2 500	3 500
Maximum	86 500	73 500	98 000	74 000

In sum it appears that substantial differences among the tripcharter rates may exist. Excluding trade frictions, i.e. relocation of vessels, and assuming symmetrical trade volumes across the globe, there should be no difference in the earnings per day on the different voyages. If such differences appear, shipowners would relocate their tonnage to more profitable areas. This would in turn lower the rates as supply increases (Adland et al., 2013). Thus, a deeper understanding of the difference among the tripcharter rates is needed.

3.2 Tripcharter spreads

Spreads provide important information to a shipowner as they indicate whether a certain voyage may be over or under-priced relative to the other[4]. From the four tripcharter rates it is possible to create six different spreads. These spreads have shown large variations entailing changing market dynamics between routes, although it appears that the sign on most of the spreads have maintained fairly constant (see Figure 3).

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[4] A spreads in our context is defined as the difference between two tripcharter rates, where as an example FH-BH would be the fronthaul rate less the backhaul rate.
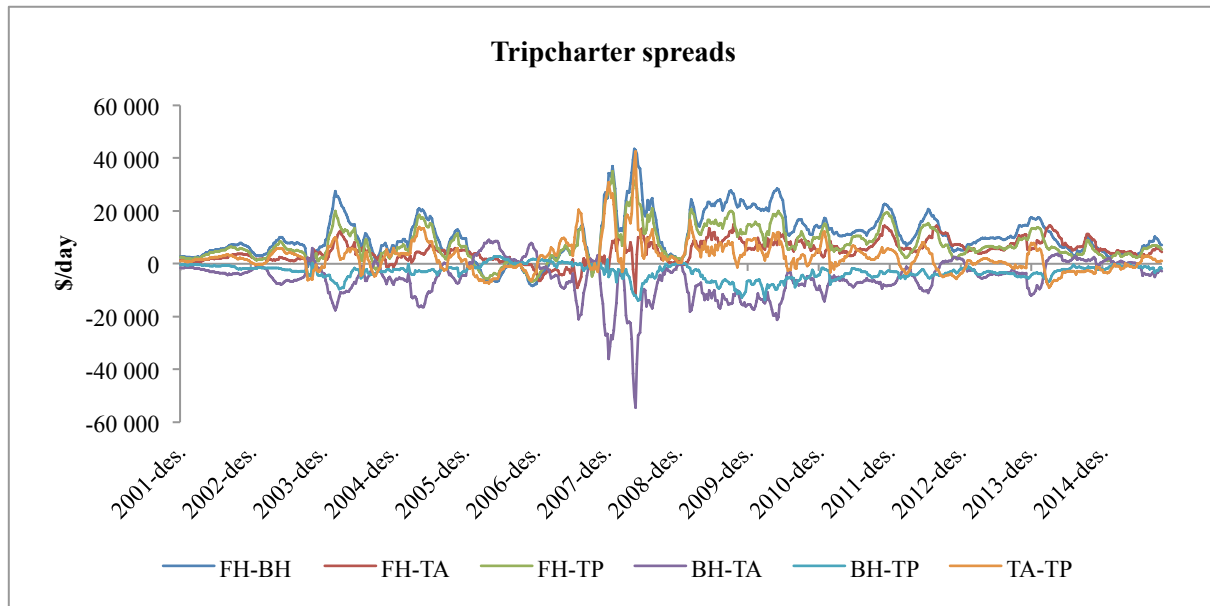
Figure 3 - Historical review of spreads between tripcharter rates (Source: Clarksons SIN)

Descriptive statistics (see Table 2) of the spreads reveals that the range at which the rates deviate from each other can be substantial. At the most the difference between the backhaul and transatlantic rates reached 63 600 $/day, while the maximum range between the backhaul and the transpacific rates only reached 16 750 $/day.

Table 2 - Descriptive statistics of tripcharter spreads.

	FH-BH	*FH-TA*	*FH-TP*	*BH-TA*	*BH-TP*	*TA-TP*
Mean	10 354	4 745	7 360	-5 608	-2 994	2 615
Median	9 000	5 000	6 000	-4 500	-2 500	2 000
Mode	7 000	5 500	5 500	1 000	-3 000	2 000
Standard Deviation	8 476	4 003	6 492	7 130	2 773	5 834
Kurtosis	0,78	0,56	1,31	6,66	1,40	7,59
Skewness	0,63	-0,12	0,81	-1,64	-0,95	1,89
Range	52 000	26 500	41 750	63 600	16 750	51 500
Minimum	-8 500	-11 500	-6 750	-54 500	-14 000	-9 000
Maximum	43 500	15 000	35 000	9 100	2 750	42 500

The explanations to these differences can be divided into five elements (Adland et al., 2013):

1) Being able to compete for a shipment requires the physical presence of the vessel. Since the global fleet is spread across the globe the actual number of vessels applicable for the shipment varies. This creates different dynamics between supply and demand for each fixture negotiation.

2) Only a portion of the fleet will be able to compete for a new shipment in the spot market due to previous fixtures.

3) In the regional markets, the fixtures will be influenced by the cumulative decisions of the shipowners, whose contemporaneous actions are only partly observable.

4) The direction of dry bulk commodities between regions seems asymmetrical due to China's need for major dry bulk commodities such as iron ore and coal.

5) Previous experience, or lack thereof, may result in a shipowner that is not indifferent to geographical trading region.

As pointed out by Adland et al. (2013), the premium paid for a fronthaul voyage can partly be explained by the asymmetric global demand patterns in the dry bulk sector, which is created by China. In recent years, the emergence of the Chinese economy has contributed to a premium in freight rates for cargo headed in this direction. The view of China as the world's manufacturer effectively corresponds to being the world's consumer of input factors, many of which are transported by dry bulk vessels. The importance of Chinese steel production is emphasised by the establishment of a lead lag relationship between the dry bulk freight rates and steel prices (Tsioumas & Papadimitriou, 2015). This is found to be unidirectional in the panamax segment and handysize spot market, while the remaining segments are bidirectional.

The other elements mentioned above are different from the effect of China, in that it is a caused by how the shipping industry is organized in itself. This could imply that the effects are more persistent and not as easily affected by changing market conditions.

On a regional basis, the tripcharter rates will be affected by the cumulative decisions of the shipowners or operators who cannot fully observe each other's actions. This causes the fleet movements between regions to "overshoot". Thus, the result is that areas which experiences a lack of supply in one week may endeavour over supply the next week, due to speculative ballasting activity in the pursuit of the highest rates (Adland et al., 2013).

3.3 Spreads in a spatial context

In the investigation of spatial efficiency, an elaboration of the different spreads and their relevance in our context is needed. Thus, we review a case where a shipowner or operator has a single vessel open for cargo and is considering the different spreads.

FH-TA and the BH-TP have a property that is not present among the other spreads. For a vessel located in the Atlantic basin the owner would have the choice between either taking a transatlantic voyage via the U.S. East Coast or taking a fronthaul voyage to the Far East. Should the vessel be located in the Pacific basin, the choice will be between a backhaul voyage and a transpacific voyage. In these two cases an owner with a single vessel can evaluate the spread, and then immediately commence upon either of the tripcharter rates. Thus, there is no "spatial" component involved, meaning that no relocation of the vessel is needed, regardless of which tripcharter rate is chosen. This interpretation of the two spreads, FH-TA and the BH-TP, implies that they are not adequate to determine spatial efficiency in our context, where we wish to evaluate if vessels efficiently are relocated between geographical areas seeking the most profitable rates.

This does not mean that the two abovementioned spreads are uninteresting. Considering the potentially large premium that the fronthaul voyage represents, an owner might speculate on this rate by either undertaking a transatlantic voyage or simply wait, as a way of taking a long position in the fronthaul voyage. This implies that the owner may not always enter into the most profitable voyage available at a given moment, which would be a breach of economic theory regarding rational and profit maximising market participants. However, this interpretation changes when viewed in a multi-period context where the owner would discount the potentially weaker backhaul rates that most likely will be performed in the future. A similar interpretation can be made of the BH-TP spread, which is generally of negative value. This spread might be viewed as the alternative cost of being relocated to the Atlantic basin, which is generally more profitable.

For all of the other spreads, one of the tripcharter rates would involve a relocation of the vessel from one basin to another. Consider the spread between the transatlantic and the transpacific tripcharter rates (TA-TP). Located in the Pacific, and faced with high transatlantic rates, we would have to relocate our vessel to the Atlantic basin via a backhaul

voyage to take advantage of the high rates. By analysing this spread, along with the others that incorporate a spatial component, we will be equipped to determine whether the supramax fleet moves efficiently in a geographical context.

In another attempt to interpret the spreads and distinguish them from each other, one can assume that an owner or operator has two identical vessels, each available to commence on either of the two-tripcharter rates immediately. In the case of FH-BH, an owner would have one vessel available for a fronthaul voyage and one available for a backhaul voyage. After the completion of these voyages, the owner would have the same geographical allocation of his fleet. Approaching the spreads in this context, it becomes evident that they represent different outcomes in terms of fleet allocation.

Reviewing FH-TA and BH-TP along these lines, a commencement on either tripcharter rate would imply a dispersion of the fleet. In this case, we move from an allocation with both vessels in the same basin, to an allocation with one vessel in each basin. On the other hand, the FH-TP and BH-TA represent a pooling of the vessels in the Pacific or Atlantic basin respectively. Lastly, FH-BH and TA-TP represent a constant allocation of the vessels between the two basins.

4. Methodology

4.1 The efficient market notion

The notion that asset prices reflect all available information is referred to as the efficient market hypothesis (Bodie, Kane, & Marcus, 2011). This approach to market efficiency was introduced by Fama (1970) and Samuelson (1965), and is still very much alive today. The efficient market hypothesis (EMH) takes on three forms, depending on the amount of information that is assumed to incorporate "all available information" (Fama, 1970). In its *weak* form, it is assumed that asset prices only reflect the information that can be derived from the history of past prices. The *semi-strong* form assumes that the prices incorporate all publicly available information, while the *strong* form assumes that all information is included in the price, even information exempted from the public.

Although the traditional form of the EMH does not directly apply to the freight rates when we assume that the rates cannot be traded in a secondary market, or stored for consumption or investment, the notion of market efficiency is still adequate (Adland & Strandenes, 2006). Under the assumption that the market is semi-strong form efficient, it should not be possible to generate excess profit[5] by taking chartering positions based on publicly available information. Consequently, this paper will assess the ability of trading strategies that are based on publicly available information, to generate excess profit. If profitable trading strategies are found, we will have provided evidence pointing at a breach of the EMH as interpreted here, which in turn points at an inefficient market.

4.2 Cointegration

Cointegration addresses a situation in which non-stationary time series share a common linear trend that is stationary (Verbeek, 2004). Thus, for the cointegration analysis we first need to establish that the time series are non-stationary, and secondly proceed to analyse whether they share a common stationary trend. The natural logarithms (ln) of the tripcharter rates are used throughout the cointegration analysis. In this way we eliminate the effect of extreme and rare observations, and allow for econometric methods that are based on ln

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[5] Here excess profit is not profits that stems from economic rent.

figures. The entire cointegration analysis has been performed using the statistical software EViews.

Wooldridge (2013) defines a *stationary* time series as a stochastic process in which the probability distribution is stable over time. Within this definition lies two more comprehensible conditions; being that the mean and standard deviation is stable over time. When a process has a stable mean, but variance around its mean, it consequently is a mean reverting process. The time series is then said to be memoryless, implying that a shock in one period will die out and have no effect in later periods. A *non-stationary* process will have the opposite properties to that of the stationary. It will be one in which the probability distribution varies over time, the mean is not constant and a shock in one period can persist over time.

Converting a non-stationary time series to a stationary can be conducted by differencing. Accordingly, if the process becomes stationary after being differenced once, it is said to be a process integrated of order one, labelled an *I(1)* process (Verbeek, 2004). As the time series are made stationary through differencing, they will only contain information about the change in level and not on the level itself.

An example of a non-stationary process is the unit root process. To evaluate the presence of a unit root the Augmented Dickey-Fuller (ADF) test has been performed. The ADF tests for the presence of a unit root in an autoregressive *(AR)* model with p lags that are included in order to assure that autocorrelation is absent in the error terms. The *AR(p)* model can be written as (Verbeek, 2004):

$$\Delta Y_t = \delta + \pi Y_{t-1} + c_1 \Delta Y_{t-1} + \cdots + c_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \qquad (1)$$

Where π represents:

$$\pi = \theta_1 + \theta_2 + \cdots + \theta_p - 1$$

The ADF test will then evaluate the following combined hypothesis:

$$H_0: \pi = 0$$
$$H_1: \pi < 0$$

If H_0 cannot be rejected, then a unit root is present and the process is non-stationary. To find out whether the series are *I(1)*, an identical test on the series in levels and in first difference will be performed. In order to be able to proceed to the cointegration analysis, H_0 should not be rejected for the series in levels, but rejected for the series in first difference.

In the evaluation of whether to reject the zero hypotheses, three selection criteria have been reviewed in order to assure an accurate conclusion. These are the Akaike Information Criterion (AIC), Schwartz Bayesian Information Criterion (SIC) and Hannan-Quinn Information Criterion (HQ). If the conclusions from these tests are different, the one provided by SIC should be preferred (Verbeek, 2004).

If two independent non-stationary variables are used in a standard regression, the results might indicate a solid relationship. Although, this will only be due to the fact that they are both trended, and not because they are related (Verbeek, 2004). This phenomenon is called *spurious regressions* (Granger & Newbold, 1974). However, two or more *I(1)* processes can have linear combinations that are stationary. If this combination is found, then the variables are cointegrated, implying that a long-run relationship between them exists (Verbeek, 2004).

Considering two non-stationary time series Y_t and X_t that are both *I(1)*. If there exists a value β, which will result in $Y_t - \beta X_t$ being a stationary process then Y_t and X_t are cointegrated (Verbeek, 2004). The relationship between the two variables can be described as:

$$Y_t - \beta X_t = \varepsilon_t \qquad\qquad (2)$$

This is called the cointegration equation (CE) where ε_t is the stationary process. This equation will be in its long-term equilibrium when $\varepsilon_t = 0$. As ε_t is allowed to deviate from zero in the short run, there must be an error correcting mechanism to ensure that its value on average will equal zero (Verbeek, 2004). An Error Correction Model (ECM) makes it

possible to study the long-term relationships and the short-term dynamics between two time series (Engle & Granger, 1987).

The ECM can be represented in a simplified form as (Verbeek, 2004):

$$\Delta Y_t = \delta + \phi_1 \Delta X_{t-1} - \gamma(Y_{t-1} - \beta X_{t-1}) + \varepsilon_t \qquad (3)$$

Examining the equation reveals that the change in the dependent variable can be explained by a constant, along with the short-term effects stemming from the independent variable and the cointegration equation. The actual effect from the latter two is affected by their corresponding constants, ϕ_1 and γ respectively. Note that the cointegration equation only will have an effect if it was in disequilibrium in the previous period.

A Vector Error Correction Model (VECM) is an extension of the ECM that makes us able to analyse cointegration in a multivariate system. Extending (3) into a multivariate system yield the following expression (Verbeek, 2004):

$$\Delta \vec{Y_t} = \vec{\delta} + \Gamma_1 \Delta \vec{Y}_{t-1} + \cdots + \Gamma_{p-1} \Delta \vec{Y}_{t-p+1} + \Pi \vec{Y}_{t-1} + \vec{\varepsilon_t} \qquad (4)$$

Where the long-run matrix is given by:

$$\Pi = \gamma \beta^{'} \qquad (5)$$

Here $\vec{Y_t}$ is a vector containing k variables that together can have $r \leq k - 1$ cointegration vectors. The matrixes comprising Π will have the dimension $k \times r$, where β contains the cointegration vectors and γ contains the weight by which they will affect the dependent variable (Verbeek, 2004). Lastly, Γ is a $k \times k$ matrix consisting of the constants for the lagged variables, while $\vec{\delta}$ is a vector consisting of k constants.

To test whether the tripcharter rates are cointegrated the approach introduced by S. Johansen (1988) has been applied, later referred to as Johansen's test for cointegration. This test is built on the VECM presented in (4), and allows us to determine the number of existing

cointegration relationships, *r*, between *k* variables, although only a bivariate version of the test will be applied here.

First, the number of lags that should be used in the test needs to be estimated. An unrestricted VAR model for each of the paired time series is created, and followed by a VAR Lag Order Selection Criteria test. This is to ensure that the necessary number of lags is included, in order to avoid autocorrelation in the residuals. The lag order selection will be based on the Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwatz Information Criterion (SIC) and Hannan Quinn Information Criterion (HQ). For Johansen's cointegration test, the lag order will be one less than what is estimated here, as it is performed in first difference. Secondly, we need to find the correct assumptions regarding trend and intercept to be used. The adequate assumptions are selected by performing a *Johansen Cointegration Test Summary*, which will reveal the best assumptions to apply.

After estimating the number of lags to include, and finding the correct assumptions regarding trend and intercept, one can proceed to the analysis of whether cointegration exists. This implies estimating the long-term matrix Π that defines the number of cointegration relationships. Estimations in Johansen's test for cointegration are based on a *trace test* and a *maximum eigenvalue test* (Verbeek, 2004). These two will have the same zero hypothesis, $H_0: r = 0$, meaning that no cointegration relationship exists. The alternative hypothesis for the two tests will differ. The trace test will have $H_1: r \leq 1$, while the maximum eigenvalue test will have a more strict alternative, $H_1: r = 1$. Thus, for both tests, a rejection of the zero hypotheses would imply that cointegration exists between the tested variables.

4.3 Trading rules

The cointegration analysis will provide indications of whether the supramax fleet relocates efficiently across geographical regions. Its existence would imply that any deviation from a long-term relationship between two rates only holds in the short-term. Under the notion of the efficient market hypothesis[6], trading rules based on publicly available information that seek to exploit these short-term deviations financially, cannot exist. Thus, if the deviations are not transient enough, then a trading rule pursuing them could yield excess return. The

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[6] As interpreted under Section 4.1.

investigation through trading rules is then a test of whether the persistence of the deviations allowed under cointegration coincides with an efficient market.

When using a trading rule to test for market efficiency its performance needs to be evaluated against a benchmark that implies an efficient market. If the market is efficient the best would be to hold the average, or "indexed", vessel. In our case the trading rules are evaluated in their ability to create return relative to chartering out the vessel on an "index-linked" contract. This contract will yield daily return equal to the average of the four supramax tripcharter rates. Accordingly, all the results presented in this paper regarding trading rules will be net of the return from the index-linked contract.

For our trading rules, it is assumed that the shipowner or operator owns a supramax vessel, which is redelivered in the Pacific basin, where it starts trading according to the chosen trading rule. This is instead of being chartered out on the index-linked contract. A trading rule is here defined as the rule or strategy that determines the sequence of tripcharter rates that the vessel will commence upon. A total of seven different trading rules, that an owner can apply, have been developed. Three of which will be referred to as the passive trading strategies, as they involve continuous trading in one basin, or a continuous switching of basin[7]. The remaining four will be classified as active trading strategies, as they involve switching between the basins, but where in addition repeated trading within each basin is allowed. Thus, the active trading strategies involve using combinations, or switching between, the three passive strategies. This switching will be decided according to the trading rules, all of which are based on the TA-TP spread and the FH-BH spread. In this paper, the wording trading rule and trading strategy will be used synonymously.

The assessments of the trading rules here are based on the accumulated return above the index. Accordingly, no risk parameter is embedded in the evaluation. Sharpe (1965) speaks of the notion that an assets return should be evaluated against the risk taken to achieve it. Formally, the Sharpe-ratio reviews the assets return net of the risk-free return, relative to the volatility in the return. Using the same analogy, one could review the accumulated return from the different trading rules, relative to the variation in the return. This would align the approach of evaluating passive and active trading strategies here, with the approach

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[7] This implies that only fronthaul and backhaul voyages are performed.

commonly used in the financial industry when considering a trading strategy's performance relative to its inherent risk. Albeit an investigation through this approach is left for future research.

The crux of trading is to know when to take certain actions. In general, the concept is based on the interception between different time series, or whether the time series are above or below a certain limit. The trading rules used here can be described as trigger-based trading rules, meaning that they are based on the underlying time series reaching as certain level, i.e. trigger-value.

A trigger-line (k) rule implies taking a short or long position in the underlying assets comprising the spread, according to which side of the line one is situated. Thus, a certain understanding of the relationship between them is needed. In a spread between A and B, any value above k would imply a long position in A and a short position in B. Should the spread move below k the opposite position in the two assets are taken. With a spread $S_t^{A\&B}$ between A and B, we would go long asset A and short asset B if $S_t^{A\&B} > k$, and take the reverse position if $S_t^{A\&B} < k$. Thus, the rule assumes that when the trigger value is crossed from below, the value of A will continue to increase, and if crossed from above, it will continue to decrease.

The trading rules have been evaluated in an in sample optimization and out of sample testing procedure. This procedure separates the historical data in two, one for optimization of the trading rule, and one for testing, in that chronological order. In this way we test the optimized trading rule on unknown future data that have not also been used in the optimization process.

According to this procedure the optimal trigger values to be used in the different trading rules should be found in the first subset of the historical data, later referred to as the in sample period. The optimal values are found by setting an adequate range for the rigger values, that is tested on the in sample subset of the data. In our case, the trigger values that yield the highest accumulated return, net of the index, will be set as the optimal value, and used in the out of sample testing. Having found the optimal parameters, we apply these to a subsequent period of the historical data, the out of sample period. If the trading rules, with the optimized trigger values, are able to generate profit above the index, we will have provided evidence of

market inefficiency. In this case we have have shown that it is possible to gain excess profit on future unknown rates through trading rules, based on historical publicly available information.

In this paper, the period from 2002 to 2010 is used as the in sample period. This timeframe incorporates both the build-up and collapse related to the financial crises, as well as the more normalized periods surrounding it. By optimizing the trading rules on this subset of data, the hope is that it will become more robust to changing market conditions. The remaining period, 2011 to October 23, 2015, is used as the out of sample testing period.

4.3.1 Passive strategies

The three passive strategies will make use of the same tripcharter rates, regardless of market conditions. They have been formalized as: 1) the pure Atlantic strategy (*Pure TA*), implying only taking transatlantic voyages[8]; 2) the pure Pacific strategy (*Pure TP*), meaning only taking transpacific voyages; and 3) the crosstrade strategy (*Crosstrade*), implying only taking fronthaul and backhaul voyages.
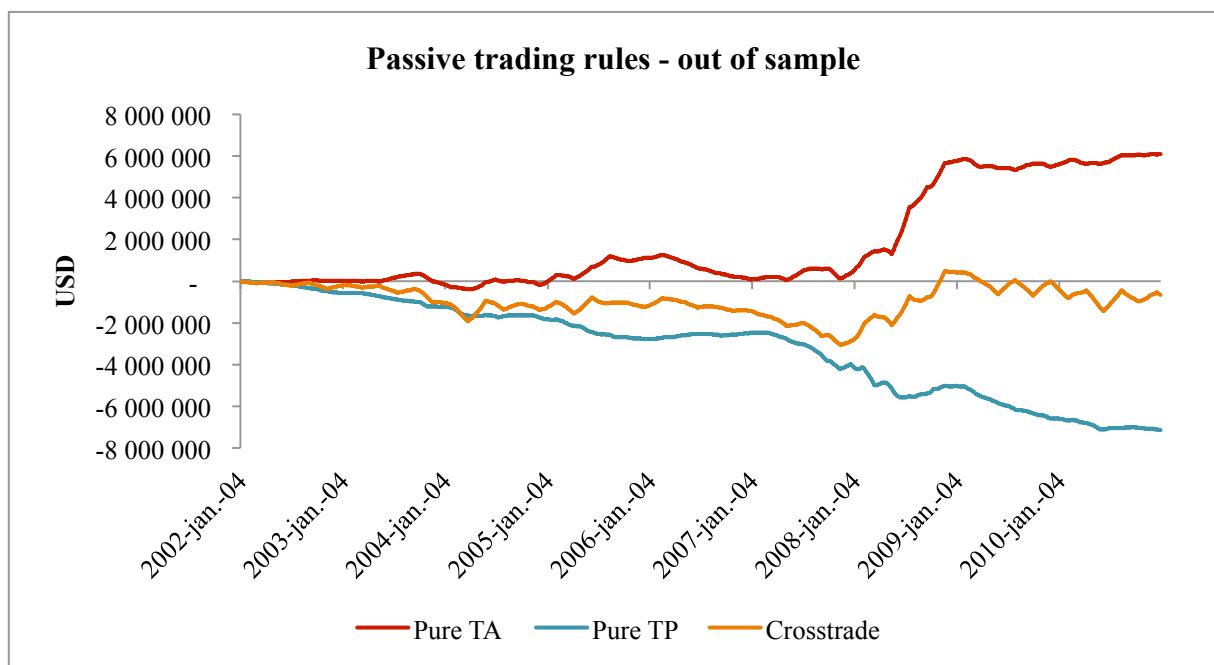

Figure 4 - Performance of passive trading rules through in sample period.

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[8] As it is assumed that the vessel starts trading in the Pacific basin a backhaul voyage is the first voyage in the Pure TA strategy.

When reviewed through the in sample period, these three passive strategies yield substantially different results (see Figure 4). The Pure TA strategy has proven to be the most profitable, while the Pure TP strategy has produced highly negative returns. For the Crosstrade strategy it has been assumed that 10% of the fuel cost[9] is covered by the owner, as a way to incorporate the risk of off-hire ballasting, caused by the potential lack of backhaul cargo. The two other strategies assume that no such ballasting activity, i.e. idle time, occurs. In the development of the active trading strategies, the results from the three passive strategies have been considered. The general idea has been to take advantage of the strong Atlantic market, but at the same time take advantage of particularly strong fronthaul rates.

4.3.2 Active strategies

The active trading strategies involve using combinations, i.e. switching between, the passive strategies. These active strategies are based on the TA-TP or FH-BH spread reaching a certain level, i.e. trigger value. It is assumed that no idle time occurs in neither of these strategies, thus the vessel immediately starts trading at a new rate after the last voyage has been completed. The spread quoted simultaneously with the completion of the last trip, is the one evaluated against the trigger value. In this way, the agent evaluates the current market conditions when he makes his decision. It is then assumed that the owner earns the tripcharter rate, according to his choice, stemming from the next observation. This assumption is based on the notion that little idle time occurs for the smaller vessel segments, such as the supramax vessel.

Furthermore, one can see that all of the rules are "tilted" towards the Atlantic basin, as a backhaul trip will be commenced upon if the spread is equal to the trigger value. The strategies have been simulated using the event-driven Microsoft programing language *Visual Basic for Applications* (VBA) in conjunction with Microsoft Excel. The codes created can be found in Appendix A.

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[9] The consumption per day is based on the theoretical supramax vessel specified by Clarksons Research (Clarksons Research, 2015)

Rule 1 - Switch triggered by TA-TP with one trigger value

This trading rule seeks to investigate whether an identification of a change in the relative profitability between trading in the Atlantic and Pacific basin can be used as a way to switch between the two.

We create the following trading rule based on the TA-TP spread:

If located in Atlantic and $S_t^{TA-TP} < k_{TA-TP}$ then go FH else go TA, and if located in Pacific and $S_t^{TA-TP} \geq k_{TA-TP}$ then go BH else go TP.

Based on this trading rule we will observe a higher frequency of TA trading the lower the value of k, and if $k \rightarrow -\infty$ then the simulation will yield the same result as the Pure TA strategy, and if $k \rightarrow \infty$ we would observe the Pure TP strategy. Thus, the closer we get to the mean, the more crosstrade will be observed. Depending on the value of k_{TA-TP}, the resulting strategy will comprise all of the three passive strategies, thus all of the four tripcharter rates.

The spread between TA and TP does in reality speak of the value of being able to instantaneously switch between the two basins. Due to the lag effect that exists in reality, a presence in the most profitable basin is difficult as the spread changes during the repositioning. In the real world, the owner should consider a certain limit (k) for the spread that triggers a switch of basin.

As an example, let us consider an owner located in the Atlantic facing a negative spread of -1000 \$/day. If he instantaneously could move to the Pacific, then he should. However, as it will take him weeks to get there, the spread might have changed to his disadvantage at the time of his arrival. Thus, it is natural to assume that the owner would demand a spread that has a more negative value, as the spread is a mean reverting process that is expected to move back to its positive mean (2 615 \$/day), where the Atlantic basin is more profitable than the Pacific.

Rule 2 – Switch triggered by TA-TP with two trigger values

The second rule is merely an extension of the first rule. Instead of having only one trigger value, we expand by having two trigger values.

The trading rule is formalized as:

If located in Atlantic and $S_t^{TA-TP} < k_{FH}$ then go FH else go TA, and if located in Pacific and $S_t^{TA-TP} \geq k_{BH}$ then go BH else go TP.

For this rule we would not observe any transatlantic trade as $k_{FH} \rightarrow \infty$, and no transpacific trade as $k_{BH} \rightarrow -\infty$. Thus, a simultaneous movement towards these limits would result in the Crosstrade strategy.

In essence this allows us to set different probabilities for a switch of basin, whether one is located in the Atlantic or Pacific basin. These probabilities are indicated by the trigger value's distance from the mean of the spread. This rule then gives us the opportunity to set a low probability for a switch from the Atlantic to the Pacific, combined with a high probability for a switch from the Pacific to Atlantic. Thus, being tilted towards the profitable Atlantic basin.

Rule 3 - Switch triggered by FH-BH

Compared to the trading rules based on the TA-TP spread, the third rule determines a switch between the two basins based on the spread between the fronthaul and the backhaul voyage. A limitation with the strategy based on the TA-TP spread is its inability to directly recognise highly profitable fronthaul rates, which we know can obtain particularly high levels. This strategy then investigates whether recognition of peaks in the fronthaul rates can be profitable.

The trading rule can be described as:

If located in Atlantic and $S_t^{FH-BH} > k_{FH}$ then go FH else go TA, and if located in Pacific and $S_t^{FH-BH} \leq k_{BH}$ go BH else go TP.

Interpreting this rule we see that as $k_{FH} \rightarrow \infty$ less fronthaul voyages will occur implying an increased frequency of transatlantic trade, and as $k_{FH} \rightarrow -\infty$ we will not observe any transatlantic trade. If $k_{BH} \rightarrow \infty$, then no transpacific trade will be made, while if $k_{BH} \rightarrow -\infty$, we would have the Pure TP strategy. Should trigger values move jointly in a direction where

$k_{FH} \to -\infty$ and $k_{BH} \to \infty$, then we will observe an increased frequency of the Crosstrade strategy.

Rule 4 - Switch triggered by two spreads: TA-TP and FH-BH

The three strategies mentioned above each have their limitations. While the first and second fail to recognise high fronthaul rates, the third fails to acknowledge the potential of while being located in the Pacific, it could be profitable to postpone the backhaul voyage and take a transpacific voyage while waiting for the backhaul rates to strengthen.

The reasoning behind this strategy is as follows. In the same manner as for the second strategy we rely on recognising the strong fronthaul rates, through the FH-BH spread, when located in the Atlantic. Thus, the approach under the second strategy will be brought forth here, while the strategy for returning to the Atlantic basin will change. When located in the Pacific we will decide when to return based on a trigger value for the TA-TP spread.

The trading rule can then be described as:

> *If located in Atlantic and $S_t^{FH-BH} > k_{FH}$ then go FH else go TA, and if located in Pacific and $S_t^{TA-TP} \le k_{BH}$ then go BH else go TP.*

For this rule we will observe increased transatlantic trade as $k_{FH} \to \infty$, and increased crosstrade as $k_{FH} \to -\infty$. If we are located in the Pacific the same movements of the trigger values will point towards increased crosstrade and increased transpacific trade, respectively. We see that when located in the Atlantic the rule is identical to the third trading rule. When located in the Pacific the rule is the same as the second, but the inequality sign has been set in the opposite direction. The idea behind this is that when the transpacific market is strong relative to the Atlantic, relocation through a backhaul voyage becomes less attractive to other vessels. This will in turn reduce tonnage supply on the backhaul voyages implying increasing rates. Thus, the latter part of the strategy has the property of being a contrarian market strategy.

5. Empirical Results

5.1 Cointegration

We start by testing for the presence of a unit root, and the results can be seen in the Table 3[10]. As stated we wish to not reject H_0 when the time series are in levels and reject H_0 when it is differenced once, as this allows us to assume that the tripcharter rates are *I(1)*.

Table 3 - Results from ADF test on tripcharter rates.

Unit root test in levels

	Fronthaul		Backhaul	
P-values	*Intercept*	*Intercept & Trend*	*Intercept*	*Intercept & Trend*
AIC	0.0209	0.0301	0.1479	0.0709
SIC	0.0349	0.0560	0.1479	0.0709
HQ	0.0337	0.0496	0.1479	0.0709

	Transatlantic		Transpacific	
P-values	*Intercept*	*Intercept & Trend*	*Intercept*	*Intercept & Trend*
AIC	0.0941	0.0501	0.1635	0.0466
SIC	0.0631	0.0324	0.0642	0.0466
HQ	0.0631	0.0324	0.0642	0.0466

Unit root test in first difference

	Fronthaul		Backhaul	
P-values	*Intercept*	*Intercept & Trend*	*Intercept*	*Intercept & Trend*
AIC	0.0000**	0.0000**	0.0000**	0.0000**
SIC	0.0000**	0.0000**	0.0000**	0.0000**
HQ	0.0000**	0.0000**	0.0000**	0.0000**

	Transatlantic		Transpacific	
P-values	Intercept	Intercept & Trend	Intercept	Intercept & Trend
AIC	0.0000**	0.0000**	0.0000**	0.0000**
SIC	0.0000**	0.0000**	0.0000**	0.0000**
HQ	0.0000**	0.0000**	0.0000**	0.0000**

** Significant at 1%.

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[10] The output tables from EViews that lies behind this summary table is excluded from the Appendix due to length considerations.

For all of the tripcharter rates we are able to conclude that there is a unit root present in the time series when in levels, but when the series are differenced once they become stationary. Thus, the results here indicate that the tripcharter rates are an *I(1)* process. This is in line with previous findings related to freight rates.

The same tests, that have been performed on the tripcharter rates, have been performed on the spreads between them (see Table 4[11]). For the spreads, we are able to conclude that FH-TA and BH-TP, the ones previously mentioned to have no spatial component, are non-stationary. The remaining spreads are found to be stationary. The selection criteria AIC does not reject H_0 for FH-TP, but is disregarded as it includes too many lags, 19 in total, which is often the case with the AIC test.

Table 4 - Results from ADF test on spreads.

	Unit root test in levels		
P-values	*FH-BH*	*FH-TA*	*FH-TP*
AIC	0.0097**	0.0102	0.0649
SIC	0.0091**	0.0187	0.0000**
HQ	0.0041**	0.0187	0.0000**
P-values	*BH-TA*	*BH-TP*	*TA-TP*
AIC	0.0000**	0.0157	0.0000**
SIC	0.0000**	0.0157	0.0000**
HQ	0.0000**	0.0157	0.0000**

** Significant at 1%.

Based on the results from the unit roots tests of the spreads, we are able to provide expectations towards the cointegration analysis that is to follow. Remembering the requirement for cointegration to exist, being that the common trend is a stationary process, we should expect to find cointegration between the tripcharter rates where the spread, in levels, is a stationary process. The expectation for the cointegration analysis is then to find cointegration between all pairs of tripcharter rates, except for the pairs FH and TA and BH and TP, as their spreads are a non-stationary process. Thus, we do not expect to find

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[11] See Note 10.

cointegration for the two pairs of tripcharter rates where a shipowner can commence upon both rates "immediately", and where as mentioned no spatial component is involved.

We then move on to the tests used to determine the correct lag order and assumptions regarding trend and intercept. The lag order was assessed first, in order to be able to apply these when performing the tests regarding trend and intercept. The results from these tests (see Table 5[12]) reveals that cointegration should be tested assuming intercept and no trend for FH&BH, FH&TP and BH&TP, while for FH&TA, BH&TP and TA&TP neither intercept, nor trend should be used.

Table 5 - Assumptions used in test for cointegration.

	VAR lag order selection	Lag order in Johansen's test	Assumptions used in Johansen's test
FH&BH	6	5	Intercept, no trend
FH&TA	5	4	No intercept, no trend
FH&TP	6	5	Intercept, no trend
BH&TA	4	3	No intercept, no trend
BH&TP	6	5	Intercept, no trend
TA&TP	4	3	No intercept, no trend

Having found the right assumptions and lag order we proceed to test for cointegration. The results from the six cointegration tests that have been conducted can be found in Table 6[13] below. These show the presence of one cointegration equation in all pairs of tripcharter rates, except for two. For the relation between the backhaul and transpacific rates, and the fronthaul and transatlantic rates, we cannot reject H_0 for neither the Trace Statistic nor the Max-Eigen Statistic. Thus, there is not statistical foundation to assume that these two pairs of tripcharter rates are in fact cointegrated. These results concur with the expectations outlined, from the results regarding the presence of a unit route in their spreads.

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[12] See Note 10.
[13] See Note 10.

Table 6 - Results from Johansen's test for cointegration.

Trace statistic

	r = 0	Prob	r<=1	Prob
FH&BH	25.47727	0.0087**	3.769534	0.4475
FH&TA	11.16391	0.0775	0.018471	0.9115
FH&TP	37.07949	0.0001**	5.627129	0.2215
BH&TA	28.92529	0.0000**	0.105541	0.7893
BH&TP	18.21082	0.0935	3.410774	0.5069
TA&TP	38.56339	0.0000**	0.055302	0.8471

Max-Eigen Statistic

	r = 0	Prob	r=1	Prob
FH&BH	21.70773	0.0054**	3.769534	0.4475
FH&TA	11.14544	0.0516	0.018471	0.9115
FH&TP	31.45236	0.0001**	5.627129	0.2215
BH&TA	28.81975	0.0000**	0.105541	0.7893
BH&TP	14.80004	0.0736	3.410774	0.5069
TA&TP	38.50809	0.0000**	0.055302	0.8471

** Significant at 1%.

The result pointing at a missing cointegrated relationship between the fronthaul and the transatlantic rates are sensitive to the assumption regarding intercept, used in the test. However, when reviewed in conjunction with the ADF test, which shows that the spread between these tow rates are non-stationary in levels, we follow the conclusion provided in Table 6.

Keeping in mind the mentioned characteristics of the two pairs where cointegration is absent, FH&TA and BH&TP, we can suggest that these rates are evaluated against each other in another way than for the other pairs. However, we might wrongfully assume absence of cointegration between the two rates due to a difference in duration that these contracts may have in reality, especially in the case of BH&TP.

The results from the cointegration test is mostly in line with what can be found in previous literature where the general perception is that freight rates are cointegrated. In terms of market efficiency we have now provided an indication, that the drybulk supramax segment is spatially efficient, as the two spreads where cointegration is absent, does not incorporate the previously mentioned spatial component.

5.2 Trading rules

5.2.1 In sample optimization

The different trading rules have been evaluated in an in sample optimization procedure where in total 1375 parameterisations has been simulated (see Appendix B). The results from the different strategies, along with the optimal trigger values can be seen in Figure 5-8 and Table 7.

Table 7 - Net income with optimal trigger values from in sample optimization

	TRIGGER VALUES	NET INCOME
Passive strategies	USD/day	USD
Pure TA	n.a.	$6 109 338
Pure TP	n.a.	-$7 145 303
Crosstrade	n.a.	-$649 498
Active strategies		
Rule 1	$k_{TA-TP} = -6\,000$	$6 540 888
Rule 2	$k_{FH} = -3\,500$ & $k_{BH} = 500$	$7 093 398
Rule 3	$k_{FH} = 24\,000$ & $k_{BH} = 25\,500$	$5 384 838
Rule 4	$k_{FH} = 27\,000$ & $k_{BH} = 8\,000$	$6 293 088

For Rule 1 we see that it would only be optimal to switch from the Atlantic to the Pacific if the transpacific rates are substantially higher (6 000 $/day) than the transatlantic. Rule 2 lowers the limit for this same switch, while a switch in the opposite direction occurs almost immediately after the Atlantic basin becomes more profitable than the Pacific. Rule 3 demands particularly high fronthaul levels before a switch to the Pacific basin occur. For Rule 4 we see that trigger value for a fronthaul is higher than in Rule 3.
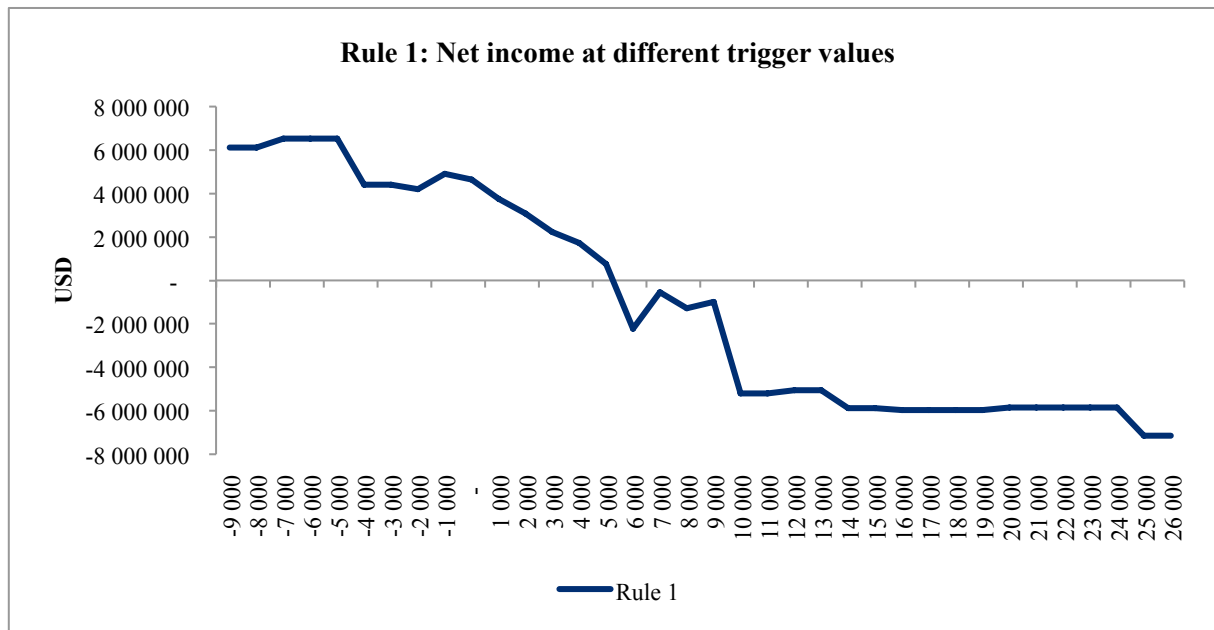
Figure 5 - Rule 1: Simulation results at different trigger values.
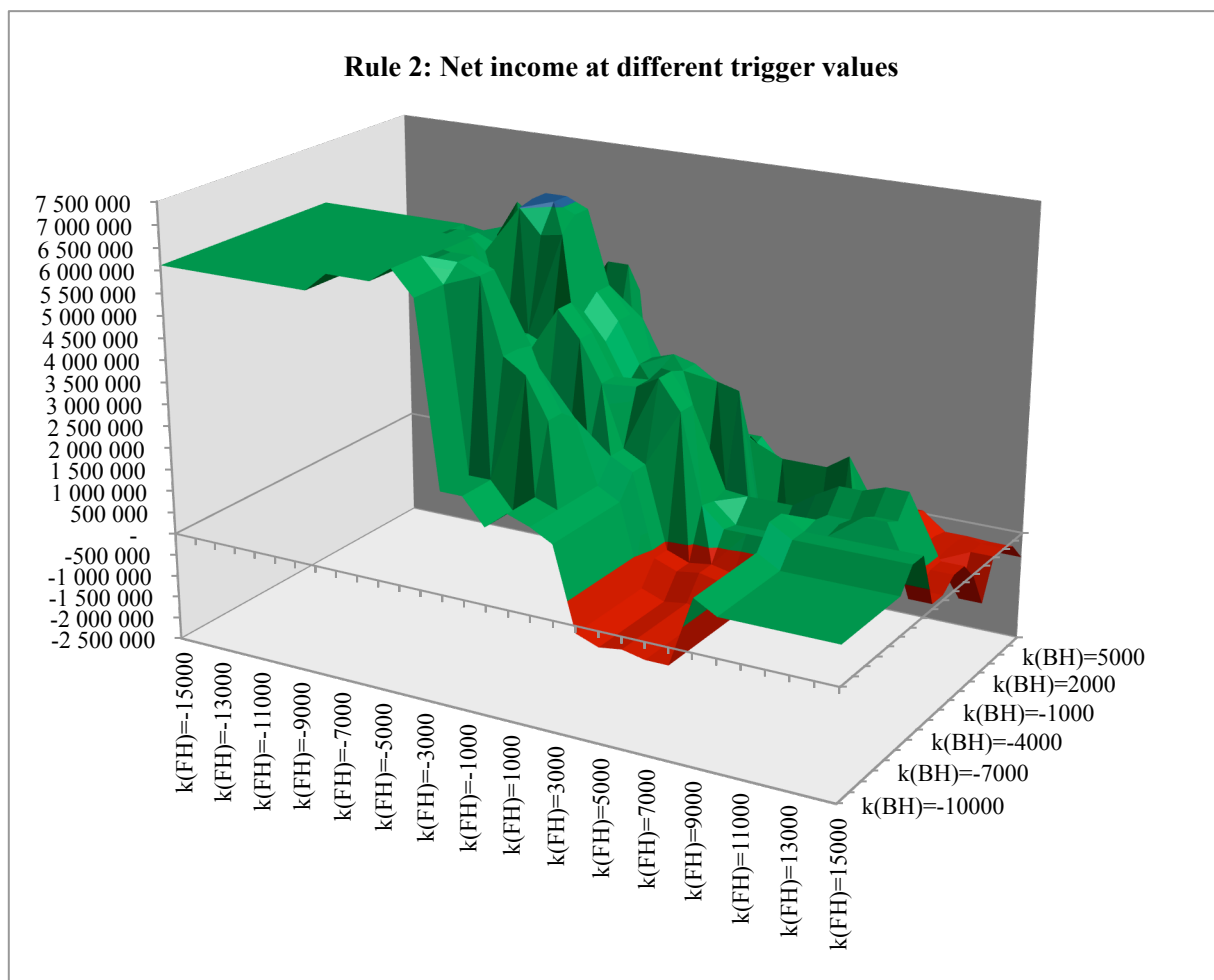
Figure 6 - Rule 2: Simulation results at different trigger values.
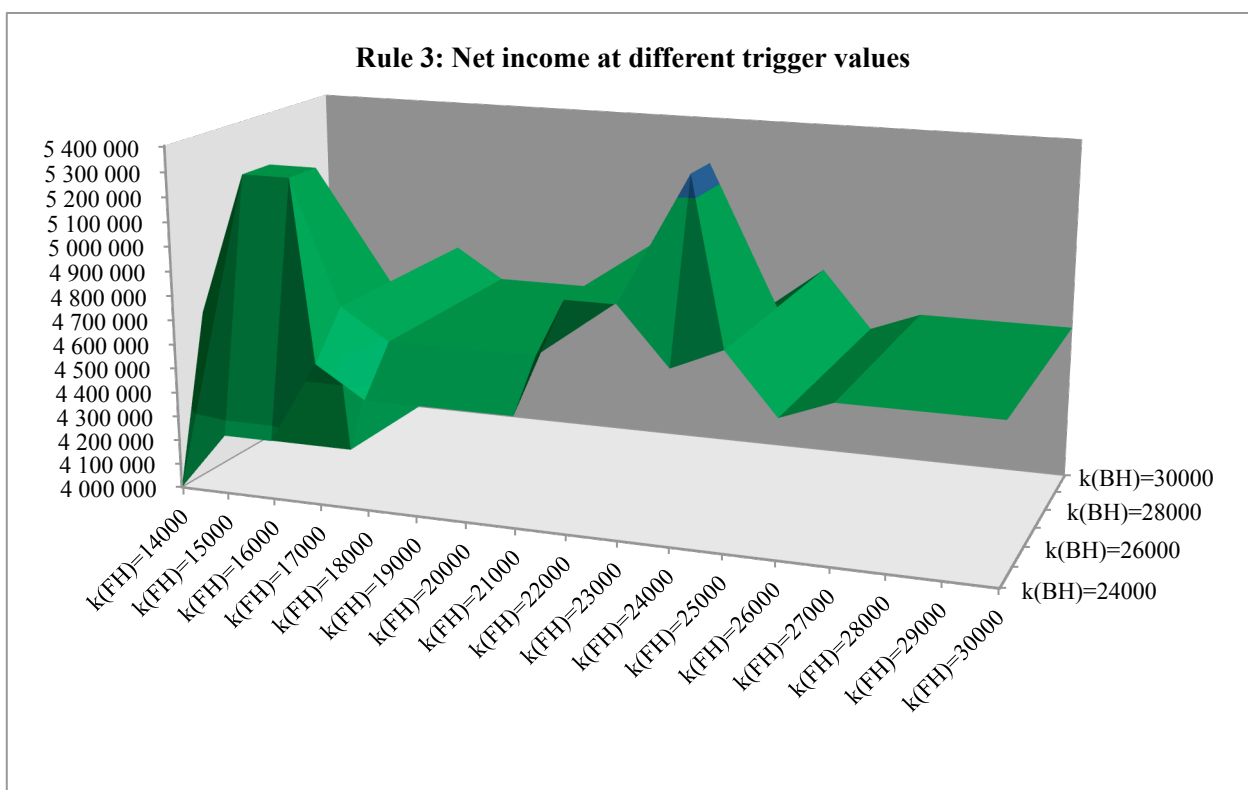
Figure 7 - Rule 3: Simulation results at different trigger values.
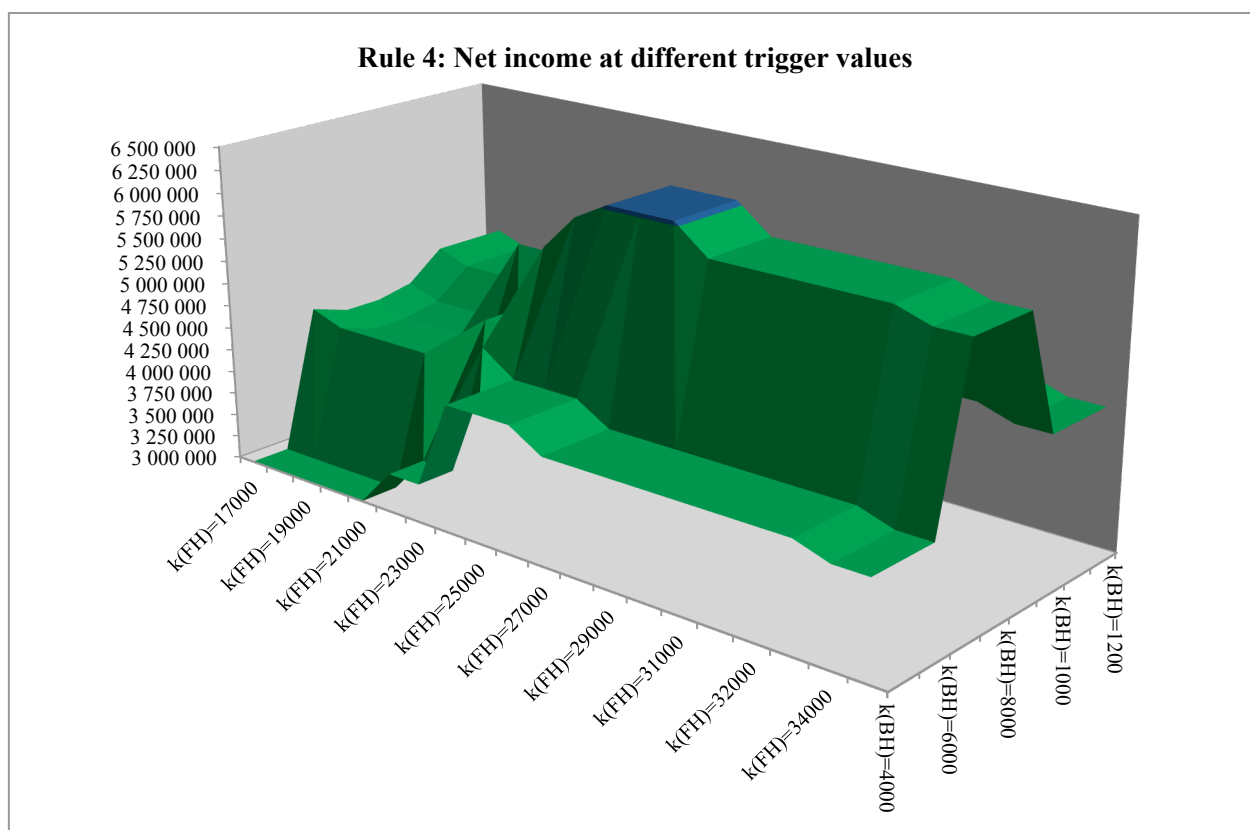
Figure 8 - Rule 4: Simulation results at different trigger values.

The blue shaded area in Figure 6-8, incorporates the maximum value obtained in the optimization process. In the cases where equal trigger values yield the same result, the midpoint between these are set as optimal. Rule 3 are not able to provide return above the Pure TA strategy, when the trigger values are held in the range in which it does not become equal to this strategy. Thus, the trigger values applied are suboptimal.

Looking at the development in accumulated return for the trading rules with optimal trigger values it appears that they have similar performance through time, except for the Pure TP- and Crosstrade strategy, which underperforms relative to the others (see Figure 9). An interesting observation is how the trading rules, except the Pure TP strategy, sees an upturn in their performance in the period after the financial crisis.
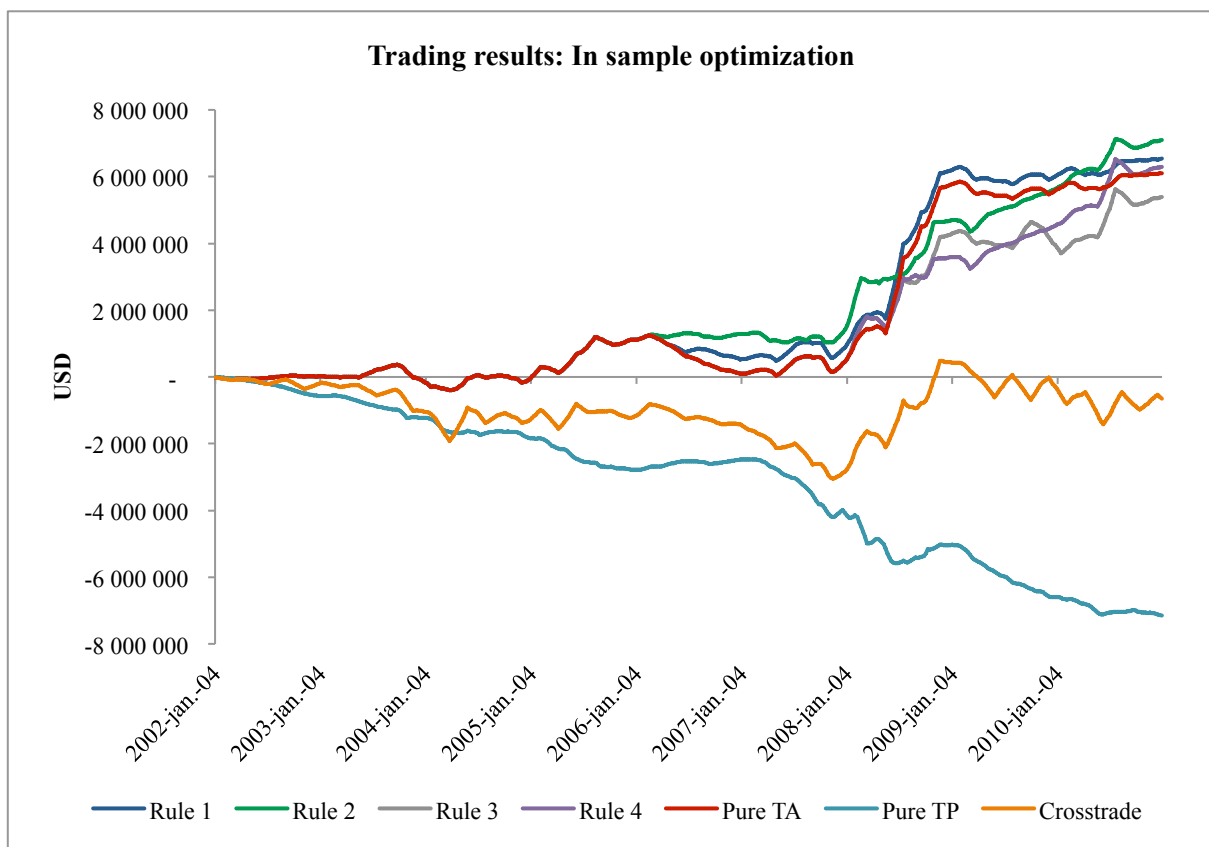
Figure 7 - Performance of trading rules with optimal trigger values through in sample period.

Reviewing the exposure each active strategy has to the different tripcharter rates, reveals a generally high frequency of transatlantic trade and a low frequency of transpacific trade. Keeping in mind the performance of the passive strategies on these rates, this allocation is hardly surprising. To the contrary, the best overall performing strategy, Rule 2, is the one with the highest exposure to the transpacific rates. This result implies that Rule 2 is the one best equipped to correctly "time" the return to the Atlantic basin.

Table 8 - Trips share of total number of trips completed

Route exposure	FH	BH	TA	TP
Rule 1	1.9 %	3.8 %	94.3 %	0.0 %
Rule 2	1.8 %	3.6 %	81.8 %	12.8 %
Rule 3	7.5 %	9.5 %	81.1 %	1.9 %
Rule 4	5.6 %	7.5 %	84.9 %	1.9 %

5.2.2 Out of sample testing

The trading rules with the optimal trigger values are then simulated through the out of sample subset of the data (2011- October 23, 2015). These tests show that six out of the seven rules are not able to provide excess profit, indicating a spatially efficient market (see Figure 10). On the other hand Rule 2 are able to provide an excess profit of $507 771 through the period. By graphical inspection of Figure 10 it appears that all strategies but Rule 2, have a downward sloping trend in their performance. We also observe that Rule 3 is equal to the Pure TA strategy throughout the period[14], indicating that the trigger value for the fronthaul voyage is too high for any crosstrade.

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[14] Thus, in Figure 10, the grey line representing Rule 3 lies behind the red representing the Pure TA strategy.
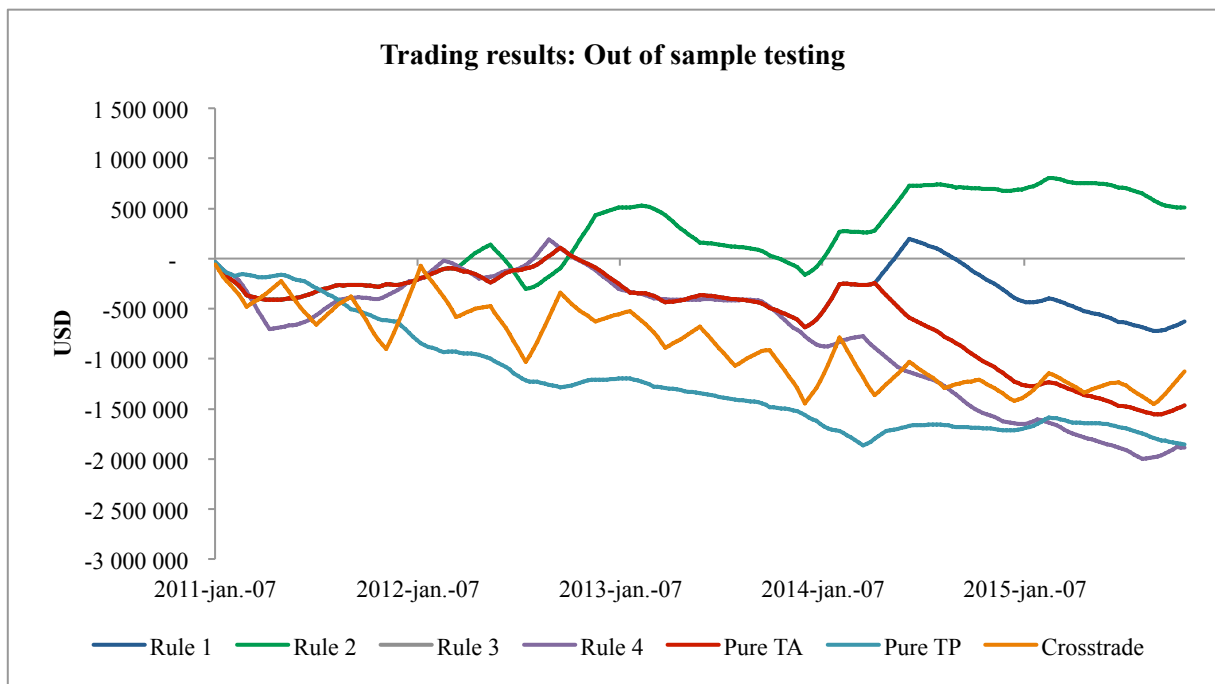
Figure 8 – Performance of trading rules with optimal trigger values through out of sample period.

Looking at the exposure the different trading rules have to the different routes (see Table 9) reveals that the transatlantic voyage is still the one most frequently performed, albeit the most profitable strategy now has a higher exposure to the transpacific rates than what it did in the in sample period. The backhaul leg performed in Rule 3 stems from the fact that vessel starts trading in the Pacific basin.

Table 9 - Trips share of the total number of trips completed.

Route exposure	FH	BH	TA	TP	Net income
Rule 1	3.6 %	7.1 %	89.3 %	0.0 %	$ -629 729
Rule 2	9.1 %	12.1 %	39.4 %	39.4 %	$ 507 771
Rule 3	0.0 %	3.6 %	96.4 %	0.0 %	$ -1 464 479
Rule 4	0.0 %	3.4 %	93.2 %	3.4 %	$ -1 886 229

The excess profit generated by Rule 2 is not far from zero compared to the amount of profits in circulation. As mentioned the simulation of the trading rule assumes that the vessel immediately are able to take on the next voyage, and consequently that no idle time occurs. Considering how close we are to the limit where spatial efficiency is acknowledged, a sensitivity analysis of the result from Rule 2 has been conducted (see Appendix C). This analysis tests the results robustness towards off-hire ballasting activity, where the two input variables are bunker price and days. The daily consumption is assumed to be 30 tons/day (Clarksons Research, 2015).

This analysis reveals that the excess return from the Rule 2 is robust for all likely bunker prices as long as the combined number of days with off-hire ballasting is equal to 20 days or less. If the average bunker price through the period is used, 577 $/ton[15], then we will have 29 days available for off-hire ballasting. As the out of sample time period consists of a total of 1 757 days, then only a small fraction (1.7%) can be used for ballasting. In sum, it then appears as if putting the second trading rule into practice and gain excess returns, might only be possible for the most skilled shipowners or operators, if even.

The abovementioned sensitivity to idle time points out an important aspect regarding the simulation of the trading rules. Generally, vessels will experience more idle time in weak markets, and lower in strong markets. This is a condition, which is not accounted for in the simulations. However, it is generally viewed that the smaller segments, such as the supramax vessels, are much less exposed to idle time. An aspect that makes the assumptions applied here, a valid proxy for the governing trading conditions in the supramax market.

To expand the trading rules used here to the larger vessel segment, a formal investigation regarding idle time should be performed. The results from these should then be used in the simulations to create a variable that identifies the market conditions and in turn sets an appropriate number of days, which the vessel is expected to be idle. In this way a more adequate estimation of the real-life trading conditions will be simulated.

[15] Arithmetic average of 380cst from Rotterdam, Singapore, Hong Kong and Japan (Clarksons SIN, 2015)

6. Concluding remarks

To analyse spatial efficiency in the dry bulk market, we examine the long-term relationship between tripcharter rates by using cointegration analysis and trading rules. Applying the analysis to the supramax segment, we use the fronthaul, backhaul, transatlantic and transpacific rates, as these rates represent a spatial movement of the vessel. Using Johansen's test for cointegration, the results suggest that four out of the six pairs of tripcharter rates are cointegrated; implying that at long-term relationship exists between them. We further argue that the two pairs where cointegration is absent are inadequate to evaluate spatial efficiency, as their spread has no spatial component. Accordingly, the results from the cointegration analysis, points at a market that is spatially efficient.

We further investigate whether the short-term deviations from the long-term relationship, allowed under cointegration, are persistent enough to exploit financially through a trading strategy. Where existence of such a trading strategy, based on publicly available information, would indicate an inefficient market. Using an in sample optimization and out of sample testing procedure, we simulate a vessel trading through historical tripcharter rates according to a certain trading rule. In total, we develop seven trading rules, categorized into passive and active trading strategies. The three trading strategies characterized as passive are pure transatlantic trade, pure transpacific trade and crosstrade. The remaining four strategies are based on trigger-values and are categorized as active trading strategies. These involve switching between the passive strategies according to a certain rule. All strategies are evaluated in their ability to generate return above the average of the tripcharter rates, i.e. the index.

The results from the simulations of the trading rules show that only one rule is able to generate excess profit. This rule is based on the spread between the transatlantic and transpacific tripcharter rates and uses two separate trigger values: one indicating a switch from the Atlantic to the Pacific basin, and one indicating a switch in the opposite direction. However, when accounting for a small amount of ballasting time where the vessel is off-hire, the profits generated are diminished. Consequently, as cointegration is established and no profitable trading rule is expected to exist when accounting for likely idle time, the results suggest that the dry bulk supramax market is spatially efficient.

Further research could analogously apply the methods used to tripcharter rates in other vessel segments, with the exemption of the adjustments that should be made through an assessment of the potential idle time that is expected to increase for larger vessels.

Bibliography

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

Adland, R., & Strandenes, S. (2006). Market efficiency in the bulk freight market revisited. *Maritime Policy & Management , 33*, 107-117.

Adland, R., Bjerknes, F., & Herje, F. (2013). Spatial efficiency in the bulk freight market.

Alizadeh, A. H., & Nomikos, N. K. (2007). Investment timing and trading strategies in the sale and purchase market for ships. *Transportation Research* , 126-143.

Alizadeh, A. H., & Nomikos, N. K. (2009). *Shipping Derivatives and Risk Management.* London: Palegrave.

Berg-Andreassen, J. (1997). Efficiency and interconnectivity in international shipping markets. *International Journal of Transport Economics* , 241-257.

Berg-Andreassen, J. (1996). Some properties of international maritime statistics. *Maritime Policy and Management* , 381-395.

Bodie, Z., Kane, A., & Marcus, A. J. (2011). *Investments 9th edition.* New York: McGraw-Hill/Irvin.

Clarksons Research. (2015). *Sources & Metods for the Shipping Intelligence Weekly.* Clarksons Research.

Engle, R. F., & Granger, C. (1987). Co-Integration and Error Correction: Representation, Estimation and Testing. *Econometrica* , 251-276.

Fama, E. (1970). Efficient capital markets: a review of theory and empirical work. *Journal of Finance* , 383-417.

Glen, D. R. (1997). The market for second-hand ships: some results on efficiency using cointegration. *Maritime Policy and Management , 24* (3), 245-260.

Granger, C., & Newbold, P. (1974). Spurious Regressions in Econometrics. *Journal of Econometrics* , 111-120.

Haigh, M. S., Nomikos, N. K., & Bessler, D. A. (2004). Integration and Causality in International Freight Markets: Modelling with Error Correction and Directed Acyclical Graphs. *Southern Economic Journal* , 145-162.

Johansen, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control* , 231-254.

Kavussanos, M. G., & Alizadeh, A. H. (2002). The Expectation of the Terms Structure and Risk Premiums in Dry Bulk Shipping Freight Markets. *Journal of Transport Economics and Policy* , 267-304.

Kavussanos, M. G., Menachof, D., & Visvikis, I. (2004). The unbiasedness hypothesis in the freight forward market: Evidence from cointegration tests. *Review of Derivative Research* , 241-266.

Koekebakker, S., Adland, R., & Sødal, S. (2006). Are Spot Freight Rates Stationary? *Journal of Transport Economics and Policy , 40*, 449-472.

Laulajainen, R. (2006). A static theory of dry bulk freight rates by route. *Maritime Policy and Management* , 447-461.

Laulajainen, R. (2007). Dry bulk shipping market inefficiency, the wide perspective. *Journal of Transport Geography* , 217-224.

Laulajainen, R. (2010). Geography sets the tone to tramp routing. *International Journal of Shipping and Transportation Logistics* , 364-382.

Rogers, P., & Glen, D. (1997). Does weight matter? A statistical analysis of the SSY Capesize index. *Maritime Policy and Management , 24* (4), 351-364.

Samuelson, P. A. (1965). Proof that properly anticipated prices fluctuate randomly. *Industrial Management Review* , 41-49.

Stopford, M. (2009). *Maritime Economics 3rd edition.* London: Routledge.

Tsioumas, V., & Papadimitriou, S. (2015). Chinese steel production and shipping freight markets: A causality analysis. *International Journal of Business and Economic Development* , 116-124.

Tsioumas, V., & Papadimitriou, S. (2014). Excess return in the spot market for bulk carriers. *Maritime Economics and Logistics* , 399-415.

Verbeek, M. (2004). *A Guide to Modern Econometrics 2nd edition* (Vol. 2). West Sussex: John Wiley & Sons, Ltd.

Wooldridge, J. M. (2013). *Introduction to Econometrics: A Modern Approach 5th edition* (Vol. 5). South-Western: South-Western Cengage Learning.

Data Sources

Clarksons Research, Shipping Intelligence Network (SIN), (2015)

"Supramax 52,000 dwt Tripcharter Rate, Cont - Far East"

[Accessed October 26, 2015]

"Supramax 52,000 dwt Tripcharter Rate, Far East - Cont"

[Accessed October 26, 2015]

"Supramax 52,000 dwt Tripcharter Rate, Transatlantic R/V"

[Accessed October 26, 2015]

"Supramax 52,000 dwt Tripcharter Rate, Transpacific R/V (via NOPAC)"

[Accessed October 26, 2015]

"Supramax 52,000 dwt, Average Trip Rates"

[Accessed October 26, 2015]

"380cst bunker prices, Rotterdam"

[Accessed November 30, 2015]

"380cst bunker prices, Singapore"

[Accessed November 30, 2015]

"380cst bunker prices, Hong Kong"

[Accessed November 30, 2015]

"380cst bunker prices, Japan"

[Accessed November 30, 2015]

Appendix A

The trading rules created are built on a similar approach using the following procedure:

1. The variables needed to obtain values and navigate in the spreadsheet are declared.

2. Certain variables are then given their appropriate value, which is taken from the spreadsheet itself.

3. Then the first voyage is simulated, here the spread and the first tripcharter rates occurs at the same point in time. The spread is evaluated against the given trigger value.

4. When the first voyage has been performed, we start the *Do While* iteration that will run as long as the next observation is not empty.

   a. First the spread variable is given the value from the spreadsheet.

   b. Then the value of this spread is tested, using and *If* statement, against the trigger value along with a condition that identifies which basin the vessel is located in.

   c. When both conditions are met, the tripcharter rate determined by the trading rule are printed out in numbers corresponding to the duration of the trip, using a *For* iteration.

   d. When the condition for the *Do While* is no longer met, the simulation is completed, and the statistics obtained regarding the number of each trip performed is sent to the spreadsheet.

A1 – VBA code Rule 1

```
Sub Rule1insample()
Range("h12:h1000").Value = ClearContents
Dim tatradelth, tptradelth, transitlth, limit, starting, cfcolumn, cfrow, cash
Dim rowcount, spread, check, location, iterations
Dim fhcount, bhcount, tacount, tpcount
tatradelth = Range("tatradelth").Value
tptradelth = Range("tptradelth").Value
transitlth = Range("transitlth").Value
limit = Range("limit").Value
starting = Range("starting").Value
cfcolumn = Range("first").Column
cfrow = Range("first").Row
location = starting
    spread = Cells(cfrow, cfcolumn – 1).Value
If spread >= limit Then
    location = "TA"
    cash = Cells(cfrow, cfcolumn – 4).Value
    bhcount = bhcount + 1
    For rowcount = 1 To transitlth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
    Else
    location = "TP"
    cash = Cells(cfrow, cfcolumn – 2).Value
    tpcount = tpcount + 1
    For rowcount = 1 To tptradelth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
End If
    iterations = Cells(cfrow – 1, cfcolumn – 6).Value
Do While iterations > 0
    spread = Cells(cfrow – 1, cfcolumn – 1).Value
If spread >= limit And location = "TA" Then
    location = "TA"
    cash = Cells(cfrow, cfcolumn – 3).Value
    tacount = tacount + 1
    For rowcount = 1 To tatradelth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
    ElseIf spread >= limit And location = "TP" Then
    location = "TA"
    cash = Cells(cfrow, cfcolumn – 4).Value
    bhcount = bhcount + 1
    For rowcount = 1 To transitlth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
    ElseIf spread < limit And location = "TA" Then
    location = "TP"
    cash = Cells(cfrow, cfcolumn – 5).Value
    fhcount = fhcount + 1
    For rowcount = 1 To transitlth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
    ElseIf spread < limit And location = "TP" Then
    location = "TP"
    cash = Cells(cfrow, cfcolumn – 2).Value
    tpcount = tpcount + 1
    For rowcount = 1 To tptradelth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
End If
    iterations = Cells(cfrow, cfcolumn – 6).Value
Loop
    Range("a482:z550").Value = ClearContents
    Range("v4").Value = fhcount
    Range("v5").Value = bhcount
    Range("v6").Value = tacount
    Range("v7").Value = tpcount
End Sub
```

A2 – VBA code Rule 2

```
Sub Rule2insample()
Range("i12:i1000").Value = ClearContents
Dim tatradelth, tptradelth, transitlth, starting, cfcolumn, cfrow, cash
Dim rowcount, spread, check, location, iterations
Dim fhcount, bhcount, tacount, tpcount
Dim fhlimit, bhlimit
tatradelth = Range("tatradelth").Value
tptradelth = Range("tptradelth").Value
transitlth = Range("transitlth").Value
fhlimit = Range("fhlimit").Value
bhlimit = Range("bhlimit").Value
starting = Range("starting").Value
cfcolumn = Range("first").Column
cfrow = Range("first").Row
location = starting
    spread = Cells(cfrow, cfcolumn – 2).Value
If spread >= bhlimit Then
    location = "TA"
    cash = Cells(cfrow, cfcolumn – 5).Value
    bhcount = bhcount + 1
    For rowcount = 1 To transitlth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
    Else
    location = "TP"
    cash = Cells(cfrow, cfcolumn – 3).Value
    tpcount = tpcount + 1
    For rowcount = 1 To tptradelth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
End If
    iterations = Cells(cfrow, cfcolumn – 7).Value
Do While iterations > 0
If location = "TA" Then
        spread = Cells(cfrow – 1, cfcolumn – 1).Value
        If spread >= fhlimit And location = "TA" Then
            location = "TA"
            cash = Cells(cfrow, cfcolumn – 4).Value
            tacount = tacount + 1
            For rowcount = 1 To tatradelth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
            ElseIf spread < fhlimit And location = "TA" Then
            location = "TP"
            cash = Cells(cfrow, cfcolumn – 6).Value
            fhcount = fhcount + 1
            For rowcount = 1 To transitlth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
        End If
    Else
        spread = Cells(cfrow – 1, cfcolumn – 2).Value
        If spread >= bhlimit And location = "TP" Then
        location = "TA"
        cash = Cells(cfrow, cfcolumn – 5).Value
        bhcount = bhcount + 1
        For rowcount = 1 To transitlth
            Cells(cfrow, cfcolumn).Value = cash
            cfrow = cfrow + 1
        Next rowcount
        ElseIf spread < bhlimit And location = "TP" Then
        location = "TP"
        cash = Cells(cfrow, cfcolumn – 3).Value
        tpcount = tpcount + 1
        For rowcount = 1 To tptradelth
            Cells(cfrow, cfcolumn).Value = cash
            cfrow = cfrow + 1
        Next rowcount
        End If
End If
    iterations = Cells(cfrow, cfcolumn – 7).Value
Loop
    Range("a482:z800").Value = ClearContents
    Range("w4").Value = fhcount
    Range("w5").Value = bhcount
    Range("w6").Value = tacount
    Range("w7").Value = tpcount
End Sub
```

A3 – VBA code Rule 3

```
Sub Rule3insample()
Range("h12:h1000").Value = ClearContents
Dim tatradelth, tptradelth, transitlth, starting, cfcolumn, cfrow, cash
Dim rowcount, spread, check, location, iterations
Dim fhcount, bhcount, tacount, tpcount
Dim fhlimit, bhlimit
tatradelth = Range("tatradelth").Value
tptradelth = Range("tptradelth").Value
transitlth = Range("transitlth").Value
fhlimit = Range("fhlimit").Value
bhlimit = Range("bhlimit").Value
starting = Range("starting").Value
cfcolumn = Range("first").Column
cfrow = Range("first").Row
location = starting
    spread = Cells(cfrow, cfcolumn - 1).Value
If spread <= bhlimit Then
        location = "TA"
        cash = Cells(cfrow, cfcolumn - 4).Value
        bhcount = bhcount + 1
        For rowcount = 1 To transitlth
            Cells(cfrow, cfcolumn).Value = cash
            cfrow = cfrow + 1
        Next rowcount
    Else
        location = "TP"
        cash = Cells(cfrow, cfcolumn - 2).Value
        tpcount = tpcount + 1
        For rowcount = 1 To tptradelth
            Cells(cfrow, cfcolumn).Value = cash
            cfrow = cfrow + 1
        Next rowcount
End If
    iterations = Cells(cfrow, cfcolumn - 6).Value
Do While iterations > 0
    spread = Cells(cfrow - 1, cfcolumn - 1).Value
If location = "TA" Then
        If spread > fhlimit And location = "TA" Then
            location = "TP"
            cash = Cells(cfrow, cfcolumn - 5).Value
            fhcount = fhcount + 1
            For rowcount = 1 To transitlth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
        ElseIf spread <= fhlimit And location = "TA" Then
            location = "TA"
            cash = Cells(cfrow, cfcolumn - 3).Value
            tacount = tacount + 1
            For rowcount = 1 To tatradelth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
        End If
    Else
        If spread <= bhlimit And location = "TP" Then
            location = "TA"
            cash = Cells(cfrow, cfcolumn - 4).Value
            bhcount = bhcount + 1
            For rowcount = 1 To transitlth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
        ElseIf spread > bhlimit And location = "TP" Then
            location = "TP"
            cash = Cells(cfrow, cfcolumn - 2).Value
            tpcount = tpcount + 1
            For rowcount = 1 To tptradelth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
        End If
End If
    iterations = Cells(cfrow, cfcolumn - 6).Value
Loop
    Range("a482:z800").Value = ClearContents
    Range("v4").Value = fhcount
    Range("v5").Value = bhcount
    Range("v6").Value = tacount
    Range("v7").Value = tpcount
End Sub
```

A4 – VBA code Rule 4

```
Sub Rule4insample()
Range("i12:i1000").Value = ClearContents
Dim tatradelth, tptradelth, transitlth, starting, cfcolumn, cfrow, cash
Dim rowcount, spread, check, location, iterations
Dim fhcount, bhcount, tacount, tpcount
Dim fhlimit, bhlimit
tatradelth = Range("tatradelth").Value
tptradelth = Range("tptradelth").Value
transitlth = Range("transitlth").Value
fhlimit = Range("fhlimit").Value
bhlimit = Range("bhlimit").Value
starting = Range("starting").Value
cfcolumn = Range("first").Column
cfrow = Range("first").Row
location = starting
    spread = Cells(cfrow, cfcolumn – 2).Value
If spread <= bhlimit Then
    location = "TA"
    cash = Cells(cfrow, cfcolumn – 5).Value
    bhcount = bhcount + 1
    For rowcount = 1 To transitlth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
    Else
    location = "TP"
    cash = Cells(cfrow, cfcolumn – 3).Value
    tpcount = tpcount + 1
    For rowcount = 1 To tptradelth
        Cells(cfrow, cfcolumn).Value = cash
        cfrow = cfrow + 1
    Next rowcount
End If
    iterations = Cells(cfrow, cfcolumn – 7).Value
Do While iterations > 0
If location = "TA" Then
        spread = Cells(cfrow – 1, cfcolumn – 1).Value
        If spread > fhlimit And location = "TA" Then
            location = "TP"
            cash = Cells(cfrow, cfcolumn – 6).Value
            fhcount = fhcount + 1
            For rowcount = 1 To transitlth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
            ElseIf spread <= fhlimit And location = "TA" Then
            location = "TA"
            cash = Cells(cfrow, cfcolumn – 4).Value
            tacount = tacount + 1
            For rowcount = 1 To tatradelth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
        End If
    Else
            spread = Cells(cfrow – 1, cfcolumn – 2).Value
            If spread <= bhlimit And location = "TP" Then
            location = "TA"
            cash = Cells(cfrow, cfcolumn – 5).Value
            bhcount = bhcount + 1
            For rowcount = 1 To transitlth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
            ElseIf spread > bhlimit And location = "TP" Then
            location = "TP"
            cash = Cells(cfrow, cfcolumn – 3).Value
            tpcount = tpcount + 1
            For rowcount = 1 To tptradelth
                Cells(cfrow, cfcolumn).Value = cash
                cfrow = cfrow + 1
            Next rowcount
        End If
End If
    iterations = Cells(cfrow, cfcolumn – 7).Value
Loop
    Range("a733:z800").Value = ClearContents
    Range("w4").Value = fhcount
    Range("w5").Value = bhcount
    Range("w6").Value = tacount
    Range("w7").Value = tpcount
End Sub
```

Appendix B

B1 – In sample optimization Rule 1

k(TA-TP)	Rule 1	FH	BH	TA	TP
- 10 000	6 109 338	0,0 %	1,9 %	98,1 %	0,0 %
- 9 000	6 109 338	0,0 %	1,9 %	98,1 %	0,0 %
- 8 000	6 109 338	0,0 %	1,9 %	98,1 %	0,0 %
- 7 000	6 540 888	1,9 %	3,8 %	94,3 %	0,0 %
- 6 000	6 540 888	1,9 %	3,8 %	94,3 %	0,0 %
- 5 000	6 540 888	1,9 %	3,8 %	94,3 %	0,0 %
- 4 000	4 410 438	3,8 %	5,7 %	86,8 %	3,8 %
- 3 000	4 410 438	3,8 %	5,7 %	86,8 %	3,8 %
- 2 000	4 189 938	5,7 %	7,5 %	83,0 %	3,8 %
- 1 000	4 918 638	9,3 %	11,1 %	72,2 %	7,4 %
-	4 652 148	10,9 %	12,7 %	63,6 %	12,7 %
1 000	3 754 398	12,7 %	14,5 %	60,0 %	12,7 %
2 000	3 067 348	13,6 %	15,3 %	40,7 %	30,5 %
3 000	2 224 548	16,7 %	18,3 %	28,3 %	36,7 %
4 000	1 723 348	14,1 %	15,6 %	18,8 %	51,6 %
5 000	759 448	15,6 %	17,2 %	15,6 %	51,6 %
6 000 -	2 217 653	16,7 %	16,7 %	4,5 %	62,1 %
7 000 -	542 903	11,8 %	11,8 %	8,8 %	67,6 %
8 000 -	1 272 653	11,8 %	11,8 %	7,4 %	69,1 %
9 000 -	978 653	10,1 %	10,1 %	7,2 %	72,5 %
10 000 -	5 192 303	6,8 %	6,8 %	0,0 %	86,5 %
11 000 -	5 192 303	6,8 %	6,8 %	0,0 %	86,5 %
12 000 -	5 040 053	5,3 %	5,3 %	0,0 %	89,3 %
13 000 -	5 040 053	5,3 %	5,3 %	0,0 %	89,3 %
14 000 -	5 864 303	3,9 %	3,9 %	0,0 %	92,1 %
15 000 -	5 864 303	3,9 %	3,9 %	0,0 %	92,1 %
16 000 -	5 969 303	2,6 %	2,6 %	0,0 %	94,8 %
17 000 -	5 969 303	2,6 %	2,6 %	0,0 %	94,8 %
18 000 -	5 969 303	2,6 %	2,6 %	0,0 %	94,8 %
19 000 -	5 969 303	2,6 %	2,6 %	0,0 %	94,8 %
20 000 -	5 853 803	1,3 %	1,3 %	0,0 %	97,4 %
21 000 -	5 853 803	1,3 %	1,3 %	0,0 %	97,4 %
22 000 -	5 853 803	1,3 %	1,3 %	0,0 %	97,4 %
23 000 -	5 853 803	1,3 %	1,3 %	0,0 %	97,4 %
24 000 -	5 853 803	1,3 %	1,3 %	0,0 %	97,4 %
25 000 -	7 145 303	0,0 %	0,0 %	0,0 %	100,0 %
26 000 -	7 145 303	0,0 %	0,0 %	0,0 %	100,0 %
27 000 -	7 145 303	0,0 %	0,0 %	0,0 %	100,0 %
28 000 -	7 145 303	0,0 %	0,0 %	0,0 %	100,0 %
29 000 -	7 145 303	0,0 %	0,0 %	0,0 %	100,0 %
30 000 -	7 145 303	0,0 %	0,0 %	0,0 %	100,0 %

B2 – In sample optimization Rule 2

k(FH)	k(BH)=-10000	k(BH)=-9000	k(BH)=-8000	k(BH)=-7000	k(BH)=-6000	k(BH)=-5000	k(BH)=-4000	k(BH)=-3000	k(BH)=-2000	k(BH)=-1000	k(BH)=0	k(BH)=1000	k(BH)=2000	k(BH)=3000	k(BH)=4000	k(BH)=5000	k(BH)=6000	k(BH)=7000
k(FH)=15000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=14000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=13000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=12000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=11000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=10000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=9000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=8000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=7000	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	6 109 338	5 801 688 -	5 510 838 -	4 893 438 -	4 893 438 -	4 470 288 -	4 130 088 -
k(FH)=6000	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 319 338	6 319 338	4 286 748	4 286 748	6 633 498 -	5 893 248 -	2 314 848 -	2 314 848 -	1 891 698 -	4 374 948 -
k(FH)=5000	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 540 888	6 319 338	6 105 138	4 286 748	4 286 748	3 742 848 -	5 893 248 -	2 314 848 -	2 314 848 -	1 891 698 -	4 374 948 -
k(FH)=4000	6 887 388	6 887 388	6 887 388	6 693 138	6 693 138	4 410 438	4 410 438	4 410 438	4 410 438	7 013 388	7 093 398	7 093 398	3 742 848 -	3 786 948 -	3 169 548 -	3 169 548 -	4 867 398 -	4 116 648 -
k(FH)=3000	6 348 738	6 348 738	6 348 738	6 472 638	6 472 638	4 410 438	4 410 438	4 410 438	4 410 438	6 474 738	7 093 398	7 093 398	3 742 848 -	3 786 948 -	2 598 348 -	3 169 548 -	4 867 398 -	4 116 648 -
k(FH)=2000	2 300 988	2 300 988	2 300 988	4 834 638	4 834 638	4 189 938	4 189 938	4 189 938	4 189 938	6 556 638	6 872 898	6 872 898	3 619 998 -	3 215 748 -	3 025 698 -	2 193 048 -	645 103 -	419 353 -
k(FH)=1000	2 300 988	2 300 988	2 300 988	4 513 338	4 513 338	4 760 088	2 640 348	5 270 598	5 270 598	4 918 638	5 234 898	5 234 898	4 410 648 -	2 068 098 -	1 702 698 -	870 048 -	645 103 -	419 353 -
k(FH)=0	1 718 238	1 718 238	1 718 238	3 615 588	3 615 588	3 339 088	2 458 348	4 687 848	4 687 848	4 335 888	4 652 148	4 652 148	3 486 648 -	2 151 048 -	1 730 698 -	898 048 -	184 853 -	40 898 -
k(FH)=1000	2 118 988	2 118 988	2 118 988	1 939 438	1 939 438	1 939 438	2 160 288	3 790 098	3 790 098	3 438 138	3 754 398	3 754 398	3 067 348 -	1 662 448 -	2 055 148 -	1 041 898 -	922 898 -	1 108 748 -
k(FH)=2000	1 939 438	1 939 438	1 939 438	1 670 988	1 670 988	1 670 988	134 838	2 428 738	3 650 238	3 650 238	3 753 348	3 917 848	3 331 248 -	1 662 448 -	1 733 848 -	720 598 -	943 898 -	1 108 748 -
k(FH)=3000	1 670 988	1 670 988	1 670 988	165 463	165 463	165 463	208 338	2 160 288	3 929 188	3 929 188	3 785 548	3 785 548	2 466 048 -	2 224 548 -	1 723 348 -	710 098 -	1 288 403 -	557 498 -
k(FH)=4000	165 463	165 463	165 463	354 463	354 463	354 463	98 088	134 838	1 260 648	3 261 388	909 948	3 470 548	2 088 048 -	926 748 -	958 948 -	759 448 -	1 288 403 -	557 498 -
k(FH)=5000	354 463	354 463	354 463	280 963	280 963	280 963	98 088	208 338	819 648	1 175 388	1 256 448	3 344 548	1 044 102 -	1 732 098 -	517 948 -	318 448 -	2 217 653 -	542 903 -
k(FH)=6000	280 963	280 963	280 963	391 213	391 213	391 213	1 669 588	98 088	819 648	734 388	1 203 948	647 553	739 603 -	1 548 348 -	517 948 -	318 448 -	2 065 403 -	542 903 -
k(FH)=7000	391 213	391 213	391 213	391 213	391 213	391 213	1 376 988	98 088	819 648	734 388	1 203 948	476 053	739 603 -	1 548 348 -	517 948 -	318 448 -	2 065 403 -	542 903 -
k(FH)=8000	391 213	391 213	391 213	1 180 288	1 180 288	1 180 288	1 376 988	1 669 588	1 166 148	1 080 888	1 203 948	476 053	739 603 -	1 894 848 -	440 948 -	440 948 -	297 098 -	149 153 -
k(FH)=9000	1 180 288	1 180 288	1 180 288	887 688	887 688	887 688	1 376 988	1 376 988	1 455 948	1 370 688	1 550 448	96 303	359 853 -	114 853 -	440 948 -	440 948 -	297 098 -	149 153 -
k(FH)=10000	887 688	887 688	887 688	887 688	887 688	887 688	1 376 988	1 376 988	1 455 948	1 370 688	1 840 248	96 303	359 853 -	114 853 -	440 948 -	440 948 -	297 098 -	149 153 -
k(FH)=11000	887 688	887 688	887 688	887 688	887 688	887 688	1 376 988	1 376 988	1 713 198	1 545 688	1 840 248	96 303	359 853 -	83 353 -	16 503 -	16 503 -	100 853 -	489 353 -
k(FH)=12000	887 688	887 688	887 688	887 688	887 688	887 688	1 376 988	1 376 988	1 713 198	1 545 688	2 015 248	96 303	359 853 -	83 353 -	16 503 -	16 503 -	100 853 -	489 353 -
k(FH)=13000	887 688	887 688	887 688	887 688	887 688	887 688	1 376 988	1 376 988	117 688	117 688	2 015 248	374 098	63 403 -	872 953 -	15 698 -	15 698 -	128 153 -	574 403 -
k(FH)=15000	887 688	887 688	887 688	887 688	887 688	887 688	1 376 988	1 376 988	117 688	117 688	374 098	374 098	63 403 -	872 953 -	15 698 -	15 698 -	128 153 -	574 403 -

B3 – In sample optimization Rule 3

	k(BH)=20000	k(BH)=21000	k(BH)=22000	k(BH)=23000	k(BH)=24000	k(BH)=25000	k(BH)=26000	k(BH)=27000	k(BH)=28000	k(BH)=29000	k(BH)=30000
k(FH)=14000	2 724 138	3 648 138	3 190 338	3 190 338	3 657 588	4 677 138	4 677 138	3 801 088	3 801 088	3 801 088	3 801 088
k(FH)=15000	3 306 888	4 230 888	3 773 088	3 773 088	4 240 338	5 259 888	5 259 888	3 983 088	3 983 088	3 983 088	3 983 088
k(FH)=16000	3 306 888	4 230 888	3 773 088	3 773 088	4 240 338	5 259 888	5 259 888	3 983 088	3 983 088	3 983 088	3 983 088
k(FH)=17000	4 250 838	4 602 588	4 602 588	4 576 338	4 576 338	4 754 838	4 754 838	4 754 838	4 754 838	4 754 838	4 754 838
k(FH)=18000	4 124 838	4 476 588	4 476 588	4 450 338	4 450 338	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838
k(FH)=19000	4 124 838	4 476 588	4 476 588	4 450 338	4 450 338	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838
k(FH)=20000	4 124 838	4 476 588	4 476 588	4 450 338	4 450 338	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838
k(FH)=21000	4 124 838	4 476 588	4 476 588	4 450 338	4 450 338	4 928 088	4 928 088	4 928 088	4 928 088	4 928 088	4 928 088
k(FH)=22000	4 124 838	4 476 588	4 476 588	4 922 838	4 922 838	4 928 088	4 928 088	4 928 088	4 928 088	4 928 088	4 928 088
k(FH)=23000	4 124 838	4 476 588	4 476 588	4 922 838	4 922 838	4 928 088	4 928 088	4 928 088	4 928 088	4 928 088	4 928 088
k(FH)=24000	3 453 888	4 377 888	4 697 088	4 697 088	4 697 088	5 384 838	5 384 838	4 628 838	4 628 838	4 628 838	4 628 838
k(FH)=25000	4 518 588	4 870 338	4 870 338	4 786 338	4 786 338	4 786 338	4 786 338	4 786 338	4 786 338	4 786 338	4 786 338
k(FH)=26000	4 282 338	4 870 338	4 870 338	4 550 088	4 550 088	4 550 088	4 550 088	4 550 088	4 550 088	4 550 088	4 550 088
k(FH)=27000	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838
k(FH)=28000	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838
k(FH)=29000	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838
k(FH)=30000	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838	4 628 838

B4 – In sample optimization Rule 4

	k(BH)=-6000	k(BH)=-5000	k(BH)=-4000	k(BH)=-3000	k(BH)=-2000	k(BH)=-1000	k(BH)=0	k(BH)=1000	k(BH)=2000	k(BH)=3000	k(BH)=4000	k(BH)=5000	k(BH)=6000	k(BH)=7000	k(BH)=8000	k(BH)=9000	k(BH)=10000	k(BH)=11000	k(BH)=12000
k(FH)=-6000	-7 006 913	-7 874 213	-7 874 213	-7 874 213	-4 943 663	-4 943 663	-4 235 963	-2 050 913	1 003 538	29 838	1 596 438	2 100 438	2 100 438	2 330 388	2 330 388	3 354 138	2 922 588	2 922 588	2 922 588
k(FH)=-7000	-5 714 363	-5 714 363	-5 714 363	-1 803 113	-1 329 563	-1 329 563	-3 464 213	-1 321 163	1 449 788	990 588	1 505 088	2 009 088	2 009 088	2 239 038	2 239 038	3 262 788	2 831 238	2 831 238	2 831 238
k(FH)=-8000	-4 496 363	-4 496 363	-4 496 363	-1 004 063	-1 004 063	-573 563	-1 767 413	-63 613	712 688	253 488	1 530 088	2 034 288	2 034 288	2 264 238	2 264 238	3 287 988	2 856 438	2 856 438	2 856 438
k(FH)=-9000	-4 496 363	-4 496 363	-4 496 363	-2 018 363	-1 544 813	-1 544 813	-2 487 713	-276 413	2 451 488	1 992 288	1 187 988	1 910 738	2 694 738	2 694 738	2 694 238	2 773 488	2 840 688	2 840 688	2 840 688
k(FH)=-10000	-4 496 363	-4 496 363	-4 496 363	-2 018 363	-1 544 813	-1 544 813	-3 103 013	-276 413	2 045 138	1 878 888	1 474 638	2 197 388	2 981 388	2 981 388	2 981 388	3 060 138	3 048 588	3 048 588	3 048 588
k(FH)=-11000	-4 496 363	-4 496 363	-4 496 363	-738 938	-738 938	-1 169 438	-639 713	-1 679 388	1 897 088	1 814 838	859 338	2 197 388	2 981 388	2 981 388	2 981 388	3 060 138	3 048 588	3 048 588	3 048 588
k(FH)=-12000	-4 496 363	-4 496 363	-4 496 363	-738 938	-738 938	-1 169 438	-639 713	-1 679 388	1 897 088	1 814 838	859 338	2 197 388	2 981 388	2 981 388	2 981 388	3 060 138	3 048 588	3 048 588	3 048 588
k(FH)=-13000	-4 496 363	-4 496 363	-4 496 363	-738 938	-738 938	-854 963	-938 963	-1 380 138	1 597 838	1 515 588	560 088	1 866 638	2 650 638	2 650 638	2 650 638	2 729 388	3 234 088	3 234 088	3 234 088
k(FH)=-14000	-4 496 363	-4 496 363	-4 496 363	-738 938	-738 938	-854 963	-335 213	-1 380 138	1 939 088	1 856 838	1 856 838	3 163 388	3 217 638	3 217 638	3 217 638	3 296 388	3 801 088	3 801 088	3 801 088
k(FH)=-15000	-4 167 713	-4 167 713	-4 167 713	-738 938	-738 938	-1 991 063	-1 471 313	-833 963	48 738	1 394 838	1 394 838	2 734 638	4 708 638	4 576 338	4 576 338	4 655 088	3 983 088	3 983 088	3 983 088
k(FH)=-16000	-4 167 713	-4 167 713	-4 167 713	-738 938	-738 938	-1 991 063	-1 471 313	-833 963	48 738	1 394 838	1 394 838	2 734 638	4 708 638	4 576 338	4 576 338	4 655 088	3 983 088	3 983 088	3 983 088
k(FH)=-17000	-4 167 713	-4 167 713	-4 167 713	-738 938	-738 938	-2 356 813	-1 837 063	-1 199 713	48 738	1 195 338	1 195 338	2 734 638	4 509 138	4 376 838	4 376 838	4 455 588	4 754 838	4 754 838	4 754 838
k(FH)=-18000	-4 167 713	-4 167 713	-4 167 713	-738 938	-738 938	-2 356 813	-1 837 063	-1 199 713	48 738	1 195 338	1 195 338	2 734 638	4 383 138	4 250 838	4 250 838	4 329 588	4 628 838	4 628 838	4 628 838
k(FH)=-19000	-4 167 713	-4 167 713	-4 167 713	-738 938	-738 938	-2 356 813	-1 837 063	-1 199 713	48 738	911 838	911 838	2 451 138	4 383 138	4 250 838	4 250 838	4 329 588	4 628 838	4 628 838	4 628 838
k(FH)=-20000	-4 167 713	-4 167 713	-4 167 713	-738 938	-738 938	-2 356 813	-1 837 063	-1 199 713	48 738	911 838	911 838	2 451 138	4 383 138	4 250 838	4 250 838	4 329 588	4 628 838	4 628 838	4 628 838
k(FH)=-21000	-4 167 713	-4 167 713	-4 167 713	-2 373 263	-2 523 763	-2 523 763	-2 004 013	-218 838	1 467 288	2 330 388	2 330 388	2 592 888	4 383 138	4 250 838	4 250 838	5 253 588	4 628 838	4 628 838	4 628 838
k(FH)=-22000	-4 167 713	-4 167 713	-4 167 713	-2 373 263	-2 523 763	-2 523 763	-2 004 013	-218 838	2 554 038	3 417 138	3 417 138	3 417 138	4 068 138	4 723 338	4 723 338	5 253 588	4 928 088	4 928 088	4 928 088
k(FH)=-23000	-4 167 713	-4 167 713	-4 167 713	-2 373 263	-2 523 763	-2 523 763	-2 004 013	-218 838	2 554 038	3 417 138	3 417 138	3 417 138	4 639 338	4 723 338	4 723 338	5 253 588	4 928 088	4 928 088	4 928 088
k(FH)=-24000	-4 167 713	-4 167 713	-4 167 713	-2 373 263	-2 523 763	-2 523 763	-657 038	-218 838	4 208 838	4 387 338	4 387 338	4 387 338	4 387 338	5 694 588	5 694 588	5 694 588	4 628 838	4 628 838	4 628 838
k(FH)=-25000	-4 167 713	-4 167 713	-4 167 713	-2 373 263	-2 523 763	-2 523 763	-657 038	-218 838	4 208 838	4 387 338	4 387 338	4 387 338	4 387 338	6 088 338	6 088 338	6 088 338	4 786 338	4 786 338	4 786 338
k(FH)=-26000	-2 410 013	-2 410 013	-2 410 013	-2 410 013	-2 560 513	-182 088	-657 038	-182 088	4 208 838	4 387 338	4 387 338	4 387 338	4 387 338	6 293 088	6 293 088	6 293 088	4 550 088	4 550 088	4 550 088
k(FH)=-27000	-525 263	-525 263	-525 263	-525 263	-675 763	-675 763	-657 038	-481 338	4 166 838	4 166 838	4 166 838	4 166 838	4 166 838	6 293 088	6 293 088	6 293 088	4 628 838	4 628 838	4 628 838
k(FH)=-28000	-525 263	-525 263	-525 263	-525 263	-675 763	-675 763	-657 038	-481 338	4 166 838	4 166 838	4 166 838	4 166 838	4 166 838	5 993 838	5 993 838	6 293 088	4 628 838	4 628 838	4 628 838
k(FH)=-29000	-525 263	-525 263	-525 263	-525 263	-675 763	-675 763	-657 038	-481 338	4 166 838	4 166 838	4 166 838	4 166 838	4 166 838	5 993 838	5 993 838	5 993 838	4 628 838	4 628 838	4 628 838
k(FH)=-30000	-525 263	-525 263	-525 263	-525 263	-675 763	-675 763	-657 038	-481 338	4 166 838	4 166 838	4 166 838	4 166 838	4 166 838	5 993 838	5 993 838	5 993 838	4 628 838	4 628 838	4 628 838
k(FH)=-31000	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-6 085 188	-657 038	-6 085 188	4 166 838	4 166 838	4 166 838	4 166 838	4 166 838	5 993 838	5 993 838	5 993 838	4 628 838	4 628 838	4 628 838
k(FH)=-32000	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-6 085 188	-657 038	-6 085 188	4 166 838	4 166 838	4 166 838	4 166 838	4 166 838	5 993 838	5 993 838	5 993 838	4 628 838	4 628 838	4 628 838
k(FH)=-33000	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-6 085 188	-657 038	-6 085 188	4 166 838	4 166 838	4 166 838	4 166 838	4 166 838	5 993 838	5 993 838	5 993 838	4 628 838	4 628 838	4 628 838
k(FH)=-34000	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-6 085 188	-531 038	-6 085 188	4 040 838	4 040 838	4 040 838	4 040 838	4 040 838	5 867 838	5 867 838	5 867 838	4 502 838	4 502 838	4 502 838
k(FH)=-35000	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-4 928 088	-6 085 188	-531 038	-6 085 188	4 040 838	4 040 838	4 040 838	4 040 838	4 040 838	5 867 838	5 867 838	5 867 838	4 502 838	4 502 838	4 502 838

Appendix C

C1 – Sensitivity analysis Rule 2

Bunker price - $/ton

Days on off-hire ballasting

$/ton	20	25	30	35	40	45	50	55	60	65	70	75	80
200	120 000	150 000	180 000	210 000	240 000	270 000	300 000	330 000	360 000	390 000	420 000	450 000	480 000
220	132 000	165 000	198 000	231 000	264 000	297 000	330 000	363 000	396 000	429 000	462 000	495 000	528 000
240	144 000	180 000	216 000	252 000	288 000	324 000	360 000	396 000	432 000	468 000	504 000	540 000	576 000
260	156 000	195 000	234 000	273 000	312 000	351 000	390 000	429 000	468 000	507 000	546 000	585 000	624 000
280	168 000	210 000	252 000	294 000	336 000	378 000	420 000	462 000	504 000	546 000	588 000	630 000	672 000
300	180 000	225 000	270 000	315 000	360 000	405 000	450 000	495 000	540 000	585 000	630 000	675 000	720 000
320	192 000	240 000	288 000	336 000	384 000	432 000	480 000	528 000	576 000	624 000	672 000	720 000	768 000
340	204 000	255 000	306 000	357 000	408 000	459 000	510 000	561 000	612 000	663 000	714 000	765 000	816 000
360	216 000	270 000	324 000	378 000	432 000	486 000	540 000	594 000	648 000	702 000	756 000	810 000	864 000
380	228 000	285 000	342 000	399 000	456 000	513 000	570 000	627 000	684 000	741 000	798 000	855 000	912 000
400	240 000	300 000	360 000	420 000	480 000	540 000	600 000	660 000	720 000	780 000	840 000	900 000	960 000
420	252 000	315 000	378 000	441 000	504 000	567 000	630 000	693 000	756 000	819 000	882 000	945 000	1 008 000
440	264 000	330 000	396 000	462 000	528 000	594 000	660 000	726 000	792 000	858 000	924 000	990 000	1 056 000
460	276 000	345 000	414 000	483 000	552 000	621 000	690 000	759 000	828 000	897 000	966 000	1 035 000	1 104 000
480	288 000	360 000	432 000	504 000	576 000	648 000	720 000	792 000	864 000	936 000	1 008 000	1 080 000	1 152 000
500	300 000	375 000	450 000	525 000	600 000	675 000	750 000	825 000	900 000	975 000	1 050 000	1 125 000	1 200 000
520	312 000	390 000	468 000	546 000	624 000	702 000	780 000	858 000	936 000	1 014 000	1 092 000	1 170 000	1 248 000
540	324 000	405 000	486 000	567 000	648 000	729 000	810 000	891 000	972 000	1 053 000	1 134 000	1 215 000	1 296 000
560	336 000	420 000	504 000	588 000	672 000	756 000	840 000	924 000	1 008 000	1 092 000	1 176 000	1 260 000	1 344 000
580	348 000	435 000	522 000	609 000	696 000	783 000	870 000	957 000	1 044 000	1 131 000	1 218 000	1 305 000	1 392 000
600	360 000	450 000	540 000	630 000	720 000	810 000	900 000	990 000	1 080 000	1 170 000	1 260 000	1 350 000	1 440 000
620	372 000	465 000	558 000	651 000	744 000	837 000	930 000	1 023 000	1 116 000	1 209 000	1 302 000	1 395 000	1 488 000
640	384 000	480 000	576 000	672 000	768 000	864 000	960 000	1 056 000	1 152 000	1 248 000	1 344 000	1 440 000	1 536 000
660	396 000	495 000	594 000	693 000	792 000	891 000	990 000	1 089 000	1 188 000	1 287 000	1 386 000	1 485 000	1 584 000
680	408 000	510 000	612 000	714 000	816 000	918 000	1 020 000	1 122 000	1 224 000	1 326 000	1 428 000	1 530 000	1 632 000
700	420 000	525 000	630 000	735 000	840 000	945 000	1 050 000	1 155 000	1 260 000	1 365 000	1 470 000	1 575 000	1 680 000