Norwegian University
of Life Sciences

Master's Thesis 2018 30 ECTS
School of Economics and Business
Ole Gjølberg

How can bunker oil price risk be reduced using fuel oil futures?

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An empirical study on how to reduce risk in shipping:
- Using fuel oil futures to hedge bunker oil price risk

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ACKNOWLEDGEMENTS

This master's thesis is the finalization of my two-year master's degree in finance at the Norwegian University of Life Sciences. Even as this is a work written unmitigated by myself, the task would not have been possible without the help and support received. Both in the progress of developing this work, and throughout my entire academic career.

I would first like to thank Ole Gjølberg and Marie Steen for their continuous guidance throughout this semester. Their insight in this process have been of tremendous help in making of this thesis. Further, I would like to thank Siri Josefine Mo for assistance with proofreading and language. I would also like to extend to my fellow students for making this process manageable and providing moral support. Special thanks to Eva Elverud Skålnes, Oscar Undhjem and Karen Elise Røsandnes.

My family also deserves gratitude. They have always supported me throughout my studies and helped in any way possible.

Lastly, I want to thank my partner and better half, Martine Hakelund Hansen. The unrelenting and never fading love, support and help cannot be underestimated. Thanks for always keeping me sane, on schedule, and focused on my goals. I could not have managed without you.

Ås, May 2018

Hans Kristian Skarbø Svinø

ABSTRACT

The primary objective of this thesis is to study fuel oil futures contacts to find possible ways to reduce bunker oil price risk. Specified, by examining the hedge performance of fuel oil futures to find out “how can bunker oil price risk be reduced using fuel oil futures?”. The thesis also has a second objective, to examine the relationship between freight rates and bunker oil to find if there is a natural hedge possibility. It begins by introducing the objectives, providing background and reviewing previous literature on the subject. Further, the data and methodology are presented, followed by analysis and discussion on the performance.

Monthly freight, bunker and fuel oil price data from 2008 to 2017 are used. Bunker and fuel oil prices are based on the Rotterdam and Singapore port. Futures contract prices are spliced and extracted 3, 6 and 12 months before settlement. The analysis of this data show variance reduction ranging from 0.635 to 0.835 for hedging bunker price changes. The results varied with increased results in the period from 2008-2012, and reduced results in the period from 2013-2016. This indicated that some periods are more applicable for hedging, which corresponds well with previous literature. In total, it seems to indicate that fuel oil futures could work well to hedge bunker oil price risk.

The study finds no support for the secondary objective of locating a potential natural hedge in the freight/bunker oil relationship. Analysis was also performed on the spread between freight rates and bunker oil prices to examine if fuel oil futures could be used to hedge it. Low correlation and poor results show that there is limited possibility of any link between bunker oil and freight rates – and that the changes in variance are unrelated.

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1 INTRODUCTION

Shipping is the process of transporting goods, and is a business associated with high levels of risk. There is one type of risk which is the most important to ship owners, the operational risk. This can be divided into two parts; the source of income and the costs of running ships. Freight rates represents the income for a ship owner, while fuel is the main driver of cost, representing 40-60% of the total costs, depending on the price (Gjølberg & Johnsen, 1986; Alizadeh et al., 2004; Wang &Teo, 2013). This means that unexpected changes in fuel prices will be representative for the operational cost risks for ship owners.

In modern shipping, bunker oil is the main source of fuel. Bunker is created by extracting the residual oil from crude oil refining, the thick, black oil which remains after lighter oils are distilled. The term "bunker" resides from the period when coal bunkers were used as storage, and is a general term for oil used as fuel for maritime vessels. In the period from 2008 to 2017, bunker oil prices have varied from $137 to $747 per ton. This means that incentives are present to increase price stability. The purpose is to achieve reduced overall operational risk in shipping.

The first objective of the thesis is to analyse how the operational risk in shipping can be reduced – by minimizing bunker oil price risk. Several studies on this subject have been done previously (Gjølberg & Johnsen, 1986; Menachof & Dicer, 2001; Alizadeh et al., 2004). These have studied the potential of cross-hedging in similar petroleum instruments. Another study investigated bunker futures listed on Imarex (Gilleshammer & Hansen, 2010) – but this exchange does no longer exist. The main contribution from this thesis is to analyse hedging performance in futures contracts on fuel oil, and discuss the findings in comparison to the previous studies on the subject. The price data for this thesis is based on prices in Rotterdam and Singapore – both for bunker oil prices and fuel oil futures prices. The futures are exchange traded derivatives listed on the New York Mercantile Exchange. By investigating the direct hedging performance of the futures contracts with different time to maturity, the main research question may be answered; "how can bunker oil price risk be reduced by using fuel oil futures"?

Another interesting possibility is to look at the spread in the operational risk. This is given by the difference in freight rates and bunker oil price changes. By performing the same analysis on the spread as on bunker oil prices directly, a potential hedge on the total risk may be found in the futures.

The second objective is to find if the relation between freight rates and bunker oil prices can be utilized to reduce risk. This is done by analysing the freight market using freight indexes from the Baltic Exchange. This raises a second research question; “is there a natural hedge in the relationship between freight rates and bunker oil”? Meaning; whether changes in one of them would be reflected in the other. If this is true, then changes in the income for ship owners, results in changes in costs as well. A natural hedge relationship would then reduce the operational risk without requiring any management.

To answer the research questions, the thesis is divided into several chapters. The first two describes the basics behind hedging and review of the relevant previous literature on hedging with futures. General theories and previous studies on how to hedge bunker oil price risk is presented. Studies on similar subjects will also be reviewed to some extent.

Further, chapter four goes into more detail on explaining the risks in shipping. Here the different parts of the operational risk are discussed. First the freight indexes are presented and explained. Here, descriptive data on the different indices back to 2008 are discussed. After that, the cost perspective of the operational risk, and why a ship owner would be incentivized to reduce this is presented. This builds into the fifth chapter which goes more into detail on bunker oil and presents the price data on the oil for the last ten years. The chapter explains the descriptive data, compares it to crude oil – both directly and in volatility. The last part investigates the freight and bunker oil data and compares them to examine if there is a natural hedge in bunker oil in freight rates.

Chapter six presents the methodology for hedging using futures and the futures data to be used in the thesis. The contracts characteristics are shown, and the viability of these futures are discussed using the Carlton framework (Carlton, 1984). The minimum variance approach is explained in chapter seven. This method estimates the optimal hedge ratio and efficiency (Ederington, 1979) in futures based on the standard regression model. In chapter eight, the data is analysed, and the results are shown. This chapter covers the standard hedging and periodic hedging performance of the fuel oil futures. It also includes a model for estimating hedge performance for a model using a several contracts to hedge an average of bunker prices. In addition, the chapter shows the results from attempting to hedge the spread between bunker and freight rates. The last chapters include the discussion and conclusion. Here the findings in the thesis are discussed and compared to earlier studies on the subject.

2 WHAT IS HEDGING?

To understand how futures markets function, we first need to understand the reasons why they exist. One of the main properties of futures are to reduce uncertainty by neutralizing risk. This means that a major share of involved participants are hedgers. Hedgers are entities that seek to use the futures market to reduce a certain risk that they pose. This could be hedging for price risk in commodities, delivery risk, currency risk or risk in other financial assets (Hull, 2015). Hedging is a term used for all investments that function to reduce the risk of the underlying asset. Much like insurance that you may purchase on belongings, futures can be purchased to secure the price of assets. It all started with commodities, when farmers wanted to secure prices for their produce. The uncertainty in agriculture meant that they had incentives for establishing a market where they could sell or buy produce before the delivery of goods was due. Giving birth to the futures market, this allowed actors to engage in long or short positions on commodities. This was done using legally binding contracts backed by a physically deliverable commodity.

The principle behind this was simple. A farmer could enter a contract to sell an amount of wheat in six months. The counterpart(s) would be interested parties which needed to secure their delivery of wheat; for instance, bakers. They agree on a price of 100. The farmer would then be *short* the futures contract, while the baker(s) would have a *long* position. Six months go by, and the farmer delivers his wheat. The price has gone down to 90, which means that he gets paid less for his produce directly. At the same time, the baker(s) pay less for the wheat. Meanwhile, the value of the futures contract has gone down to 90 as well, meaning that the baker(s) lost 10, while the farmer earned 10 from this decline due to his short position.

As explained in the example, there are two main ways of hedging, either *long* or *short*. A long hedger is one who require a certain asset in the future or need to hedge the purchasing price (ship owner). And a short hedger would be a party that requires to hedge the selling price of an asset (oil producer). The risk of hedging is the opposite of what is found in other financial assets like stocks. Hedging is a tool to ensure stability, and thus means that the downside to a long hedge is when the price drops. Likewise, for the short hedger, the risk you take is that the prices may increase instead. One of the downsides to hedging is that while you gain stability, any potential yield will be neutralized. This example is illustrated by Hull (2015) and can be transferred to our previous example as well;

The baker(s) lost 10 in the(ir) futures agreement. They could have bought the wheat for 90 when they needed it. And to enter a futures agreement, some form of transactional cost would also apply. But the purpose here was not to profit from the agreement, but to “insure” the future costs and delivery. If the price shot up to 150 instead, the total price would still settle at 100 in total. Which is the same as fire insurance; You may pay a premium for 30 years and never receive anything. But, if the house suddenly caught fire one day, the insurance company would pay out to cover any damage. This is how hedging with futures work. The examples show the basic principle of hedging, that the values lost or gained in the physical market, could be offset by the futures market, just like an insurance policy.

Although the markets have changed drastically since the beginning - the most traded contracts still involve physical delivery of goods. In addition, there exist thousands of derivate-based contracts which are financially settled. Using futures requires significantly less capital involvement, as you are only required to reserve funds required for the initial margin payment – and capital to meet the margin percentage of the instrument. The goal is to reduce the risk and uncertainty in price movements. The basic principles of hedging are to indulge positions in derivatives which in term should reduce the company’s exposure to certain elements – the basis risk of the commodities in this situation.

The idea is to reduce the risk of price fluctuations in the underlying asset that you either must sell or buy (Hull, 2015). The general hedge ratio is given in equation 1 (Ederington, 1979):

$$S_t = \propto \; + \beta F_t + \; u_t \tag{1}$$

Where ‘S_t’ represents the spot price changes of the underlying asset, and ‘F_t’ the corresponding change in the future price for hedging – both values in percentage. The optimal hedge is found by estimating beta values (β) for the futures contracts in relation to the spot price of the underlying asset.

Hedging can be a straightforward process, and with very predictable assets and with derivatives in perfect symbiosis. But there is a factor which is crucial to understand. And that is the difference between the future and the actual asset. In many situations, the futures price may not be aligned with the spot - and the difference is known as the basis. There are several reasons why this exist. For instance, there may be a slight difference between the underlying asset and the futures contract. The contract may be required to settle before expiry; not allowing the basis to converge, causing some basis risk to occur. This is especially important when hedging in similar instruments, known as cross-hedging (Hull, 2015).

Cross-hedging is a method where you purchase a derivative or other instrument which has either very high or very low correlation with the underlying asset. It is especially useful if there are no directly linked contracts traded at a decent volume for the asset. A highly correlated derivate with similar price movements would be beneficial to use as a cross-hedge. By cross-hedging with financial derivatives, you may reduce the risk of variance in the underlying asset (Alizadeh et al. 2004; Carter, 2015).

The alternative to exchange traded futures contracts are over-the-counter (OTC) derivatives, for instance a swap-spreads, forwards or options. They are potentially much more detailed to each specific situation, and may be adapted in many ways and forms. The cons of these derivative agreements are the unspecified parts and costs. For a bank or financial institution to issue an OTC deal, they may require larger financial margins and security. And due to their specified nature, they could be less attractive, as the potential risk reduction would enforce higher costs to the firm. Since these types of contracts as they are traded OTC and not on an exchange, it’s hard to compare them with standard exchange traded derivatives (Hull 2015). Studies on the jet fuel market using OTC heating oil contracts did in fact produce a significant increase in firm value for airline companies. Since shipping firms are relatively homogeneous like airlines, there could be some potential risk reduction available by using OTC bunker derivatives.

3 PREVIOUS LITERATURE ON USING FUTURES TO HEDGE PRICE RISK

In the following chapter, previous literature and studies concerning subjects related to this paper will be reviewed. This is to provide a foundation to discuss the findings of the thesis and provide perspective on the results. This will include both papers on risks in shipping, and bunker price risk together with literature and papers on hedging in general. As the theory directly linked to hedging bunker oil price risk is limited to a few papers and studies, some closely related papers reviewing similar scenarios for other commodities, like jet fuel, will also be included. Further, the review will not include any papers that may contain information which could be considered obsolete due to age, unless they are either the only source of information, or provide important aspects for this thesis. The thesis will also refrain from reviewing economic theory which is considered general knowledge amongst parties interested in this study.

The first part of the literature review will look at previous studies and theories which makes up the groundwork for hedging risks using futures. In 1979, one of the foundations of today's framework for hedging was published in the Journal of Finance. The Ederington framework explains how you can hedge your positions by estimating values using a mathematical approach to minimize the variance of a portfolio using futures (Ederington, 1979). This approach to estimating an optimal hedge is commonly used, but the transformation of the framework is important to understand to grasp how the framework functions. The method of the framework will be reviewed in full in chapter seven.

Another paper was published a few years later by Dennis Carlton. The paper goes into detail of how and why to use futures to hedge your position. This corresponds greatly with how Ederington explains the price changes of futures and how to reduce the risk linked to price fluctuations. He created a framework for analysing futures markets by creating five factors to; *"identify the most important features that a commodity traded on a futures exchange should possess to be successful"* (Carlton, 1984 p. 242).

The five factors are as follows; (A) The uncertainty of price changes gives provides incentives for parties to hedge their positions or speculate on price changes. Futures would be unnecessary if the price would never fluctuate. (B) Price correlation between futures with deliveries in different specifications increase the value and appeal of futures markets. (C) Large potential number of interested participants and structure ensures a stable and liquid futures market. (D) The total market values of the product will influence the importance. The larger the values, more incentives for speculation and hedging occurs. (E) Market prices are a result of free market forces and not limited or enforced by regulations. The factors provide a framework for estimating whether the market for a commodity or asset has sufficient atmosphere to successfully develop a functioning futures market. For instance, several futures markets have suffered from low liquidity, which makes it unappealing for both hedgers and speculators.

Building on the principles established by Ederington, the basics of hedging is further explained by others (Hull, 2015; Carter, 2015). They explain the importance of calculating the minimum variance portfolio to account for the basis risk involved when the futures contract is not perfectly aligned with the underlying spot asset. It also goes in detail of how hedging may be performed and the downsides of hedging, as well as the nature of cross-hedging.

The second part of the literature review will explore previous studies on how to reduce risk in the shipping market. Several studies have looked at the total cost implication of fuel for shipping firms (see Gjølberg & Johnsen, 1986; Alizadeh et al, 2004; Wang & Teo, 2013) and found it to represent between 40-60% of the total variable cost. A study on hedging and network planning (Wang & Teo, 2013) showed the importance of planning and hedging fuel costs. Especially for vessels shipping normal goods with frequent docking, as this is more fuel intensive than keeping a relatively constant march speed. Menachof & Dicer (2001) found in their study that it would reduce overall risk and improve overall stability by implementing hedging. This would in term remove risk from surcharges to fuelling and make the pricing more predictable by securing prices far ahead in time. This thesis will assume that the intended recipient will have taken these, and perhaps other valid risk factors not directly related to fuel costs into consideration. The thesis will focus solely on the direct price risk linked to the cost of fuel for shipping vessels related to the fluctuations in the prices themselves.

A paper on hedging risk in shipping (Gilleshammer & Hansen, 2010) found that by hedging in futures traded on Imarex, risk in shipping could be drastically reduced. The paper concluded that freight derivatives could reduce freight rate variance with 38.5% to 76.1%. More interestingly, hedging in bunker derivatives could reduce variance with up to 91.3%. Although the Imarex exchange is no longer in business, this is interesting for comparison with other studies that the thesis will address later. Another study (Samitas & Tsakalos, 2010) also concluded that shipping firms could reduce risk using freight and bunker derivatives – especially during financial crises. Looking at similar commodity studies could also be comparative to how to efficiently hedge the risks involved.

Korkeamäki et al. (2016) is one of many studies which has examined the effects of hedging risk in airline by using derivatives. Jet fuel, does not have exchange traded futures contracts directly linked to the underlying commodity, making papers on the subject interesting for comparison. They found that some cross hedging in heating oil derivatives could provide an increase in firm value. Another finding was that the effectiveness of active hedging (time-varying hedging models) were lower than passive/conventional hedging. This corresponds well to findings made by other published articles (Kauvassanos & Nomikos, 2000; Gilleshammer & Hansen, 2010), which found that using time-varying models for hedging freight rates did not prove significantly better in terms of efficiency compared to more conventional hedging. In some respects, the increased variance reduction provided by these models were either negligible – or in some situations, lower than using passive hedging.

For directly hedging bunker oil price risk, there has been done a few studies on this subject. Gjølberg & Johnsen performed a study in 1986 on the possibilities for reducing risk in shipping related to bunker oil costs. They found heating oil futures were eligible to use as a hedging instrument for bunker oil. Hedging efficiency varied severely between the port and the period used. The American bunker ports (Houston, Los Angeles, New York) showed for the period okt.1979 to nov.1981 close to zero hedge efficiency. For the period of des.1981 to des.1984, efficiency was found at 0.26, 0.2, and 0.43. In Rotterdam and Japan however, there was no periodic difference. Rotterdam showed some (0.17, 0.11) while Japan did not (-0.03, -0.02).

A study of bunker efficiency and the adjustment factor was performed by Menachof & Dicer (2001) using several types of petroleum derivatives. One of the findings by examining futures in the period jan.1986 to aug.1990 was the high correlation between Rotterdam bunker oil and gasoil futures (London). The hedging efficiency (R^2) was estimated at 0.72 using a moving average hedge ratio. The results were far better than what was found in the 2004 article in Applied Economics, by Alizadeh, Kavussanos and Menachof (Alizadeh et al., 2004). The study looked at how to hedge bunker price fluctuations by cross-hedging in other petroleum instruments. The main purpose was to find petroleum futures which could be used to hedge bunker price fluctuations in Rotterdam, Singapore and Houston. In addition to estimating standard hedge ratios, this study also utilized a time-varying hedge ratio. To perform this study, futures on crude oil, gas oil, and heating oil from IPE, NYMEX and SGX was used.[1]

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[1] IPE – International Petroleum Exchange (London), NYMEX – New York Mercantile Exchange, SGX – Singapore Exchange

The results of this study showed a variety of different figures, with both an in and out of sample test. One clear indicator was that a näive hedge ratio of 1 did result in close to zero or below variance reduction, regardless of which futures used – so these results will not be discussed. As for the conventional and time-varying results, hedging Houston bunker spot price gave an estimated variance reduction of 0.95% to 14.28% out of sample. Rotterdam bunker estimated a hedging efficiency of between 10.78% and 43.14%. Singapore results were clearly worst at minus 5% to plus 18.57%. The conclusion was that there were significant limitations to the hedging ability of these futures for bunker oil. Although the crude oil IPE contract could provide a decent hedge (43.14%) for Rotterdam bunkers, this was not the case for the other two bunker prices.

Compared to studies for cross-hedging air fuel (Korkeamäki et al., 2016), bunker oil does not seem to compare to other petroleum products. One of the problems which were indicated similar was the low variance correlation of between the hedging instrument and the asset. A workaround for this issue are directly linked derivatives. Gilleshammer & Hansen (2010) as part of their study on the Imarex exchange, also analysed hedging bunker price risk by using derivatives traded on the exchange. These were, unlike in other studies, linked to the underlying asset much more directly.

They used Rotterdam 3.5%, NorthWestEurope 1%, Singapore 180 and 380 CST and US Gulf no. 63% sulphur as their underlying assets for bunker oil. With corresponding futures contracts on Imaxrex on the bunker spots, they also tested for cross-hedging in other petroleum derivatives; brent and WTI crude oil, gasoil and heating oil. Hedging in Imarex bunker futures show hedging efficiency ranging from 0.61 to 0.91, with most of at around 0.8. The bunker derivatives should in theory be highly correlated as they are supposed to mimic the movements of the underlying. The tests in cross-hedging however, revealed surprisingly good results – with efficiency from 0.37 to 0.78. The performance was significantly higher than what Alizadeh et al. (2004) found in their study. The fact that results differ this much would suggest that there are some difference depending on the test period. Both papers (Alizadeh et al. 2004; Gilleshammer & Hansen, 2010) used in addition to conventional calculations like Gjølberg & Johnsen (1986), time-varying hedge ratios. By utilizing time-varying hedge ratios based on GARCH-models instead of a conventional hedge ratio, they found a marginal increase in efficiency for cross-hedging with petroleum products This was not true for bunker derivatives. In that case, using time-varying ratios proved slightly worse for reducing variance.

To summarize; Time-varying models can prove to have some marginal benefit in variance reduction. The marginal gain could be offset by the increased transaction costs that follows a constant realignment of the derivative position, making it unappealing for hedging bunker prices (Alizadeh et al. 2004; Gilleshammer & Hansen, 2010). The findings of previous studies and literature indicates that hedging for bunker price fluctuations is possible, both by hedging in derivatives and by cross-hedging. There are some differences concerning the effectiveness of hedging in certain time periods, especially when using similar petroleum derivatives to cross-hedge. As there are very few studies on direct bunker derivatives; the assumption is that fuel oil futures should be suitable and highly correlated – but there might be periods where performance is slightly better than others.

4 RISK IN THE SHIPPING INDUSTRY

The maritime transport industries have been around as long as people have had the ability to travel using the seas. Findings dating back to the 6th and 7th millennia BC, show that people had developed sophisticated trade routes using the water as means of transportation (Carter, R.A. ,2006). Further along the lines of history, ships, boats and other types of vessels have been in use to carry people and goods to all corners of the world. It is still a vital part of transportation today, and makes up the majority of the shipped goods and wares globally.

As in every industry, we can divide risk into several categories. In the financial industry, risk is typically split into either systematic or unsystematic risk. In shipping there are the risks of piracy and of bad weather. However, the most crucial part is the operational risk (Gjølberg & Johnsen, 1986; Gilleshammer & Hansen, 2010) – the financial part of shipping goods. This thesis discusses two types of direct financial risk in shipping– income and cost uncertainty - both are equally important as part of the operational risk. Income uncertainty is linked to the freight rates; which are the source of income for the ship owner. To analyse this, indexes on freight rates are used as indicators of the rapid change and volatility in this market.

The Baltic Exchange produces indexes for different types of goods in shipping. By its name, it would indicate that it only serves the Baltic market. This is not the case. It is an exchange established in London, with a history that stretches back over 250 years, and covers global freight rates for the majority of goods shipped worldwide. Eight different freight indices will be used in this thesis to describe the uncertainty for ship owners[2]. These cover rates for everything from transporting dry bulk to LPG-gas. In table 1, descriptive statistics from all the indexes are shown. The data for these indexes have been downloaded from Datastream and are monthly.

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[2] The Baltic Exchange indexes; Dry Index (BALTICF), Panamax Index (BPANMAX), Handysize Index (BHANDSZ), Supramax Index (BSUPRAI), Capesize Index (BCAPESI), Clean and Dirty Tanker Index (BTRCLTI; BTRDITI) and the Baltic Freight LPG Index (BALTLPG).

Table 1: Descriptive statistics Baltic Exchange using monthly data (2008 – 2017)
Data source: Datastream, 2018

	BALTICF	***BPANMAX***	***BHANDSZ***	***BSUPRAI***	***BCAPESI***	***BTRCLTI***	***BTRDITI***	***BALTLPG***
Avg. Index value	1929.4	1883.4	757.0	1421.9	2966.2	677.6	827.6	50.8
Coefficient of variation	1.08	1.04	0.78	0.84	1.08	0.31	0.36	0.54
Min	314	282	216	299	174	349	474	15.3
Max	11458	9915	3278	6317	18920	1476	2143	131.5
Avg. Index change	-1.5 %	-1.4 %	-1.3 %	-1.5 %	-1.0 %	-0.4 %	-0.8 %	-0.4 %
Standard deviation	29.2 %	31.4 %	21.1 %	24.9 %	44.3 %	14.4 %	16.0 %	20.3 %
Min	-1.297	-1.155	-1.394	-1.537	-1.452	-0.381	-0.733	-0.688
Max	0.712	0.687	73.5	1.080	1.175	0.437	0.383	0.822

Table 1 shows the average values for the indexes, as well as the average monthly changes to the index. It also shows the CF, the standard deviation of change and the range of monthly values as well as the range of monthly changes.

The table shows the drastic change in income, which at its worst could cause the index to drop with 78.5% (-1.537) from one month to the next. Several indexes also show CF values above one, indicating very high volatility. Standard deviation ranged from 14.4% to 44.3% monthly. To illustrate this, the indexes are graphed. Below is the Baltic Dry Index. The period from 2008 – 2009 added to a graph by itself, as it did not illustrate regular changes in the index (due to the financial crisis). The rest of the indexes can be found in the appendixes.

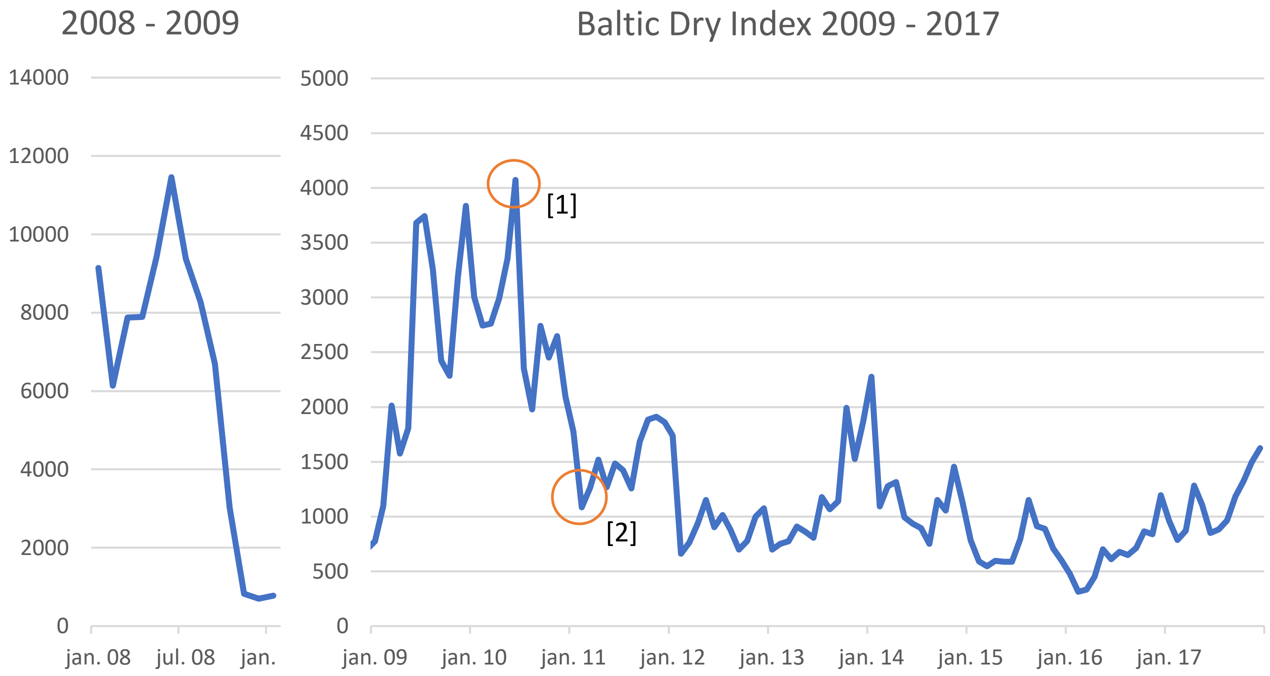

Figure 1: The monthly Baltic Dry Index (2008-2017)
Data source: Datastream, 2018

At its highest peak, the index rose to 11440 points in 2008. Just eight years later, the index reached a new low of only 317 points, which shows just how rough the changes to freight may be. Figure 1 emphasizes this – and illustrates the monstrous risk levels in shipping. Monthly changes would be expected to variate with 29%, but as table 1 showed, could easily increase or decrease drastically. On a yearly basis, this represents a standard deviation of 101%. This means that a ship owner could risk getting half as much for the same amount of shipped goods in just a few months' time, or even less. Take the period from June 2010 [1] to February 2011 [2]. The rates went from 4074 to 1084 in eight months. That means that produce value would be reduced by 75% in less than a year. There has previously been done significant work on identifying means of reducing direct income risk in terms of looking at freight rates (for instance; Gilleshammer & Hansen, 2010). Therefore, this thesis will not look into how we can directly reduce income risk, but focus on the second part of the operational risk; the costs.

Purchasing fuel is the main driver of cost. Today, this makes up between 40 and 60 percent of the total costs (Gjølberg & Johnsen, 1986; Alizadeh et al., 2004; Gilleshammer & Hansen, 2010), depending on the fuel price. Studies on optimization of routes, fuel consumption as well as making ships more efficient (Wang & Teo, 2013) will not take precedence. This thesis will assume that ships run as efficiently as possible, concerning fuel consumption and networking. Which leads to the part of the costs themselves.

Firstly, variance may be reduced using a variety of different methods. The most obvious one is to pre-purchase oil in large quantities and store it. Even if this provides a guarantee for the price, costs of storage would most likely offset any price benefit – and the method is impractical. The other method is using derivatives. By hedging in direct or indirect derivatives, the total price variation may be reduced. Futures on fuel could provide a more stable and predictable price, which would reduce the uncertainty of costs.

The second part which needs to be addressed is whether this is an actual issue for a ship owner. If fuel prices are highly correlated with freight rates, the increase in costs would be offset by the increased income. This would mean that there exists a natural hedge in the market – that increased operational risk in costs will be countered by reduced income risk. Issues are still present, regardless of the existence of a natural hedge. In shipping, cash flow is often an issue due to the large capital required to run a successful firm. The income and costs may be correlated well – but they may not occur simultaneously. To illustrate this with an example using the previously described period in figure 1. A shipowner purchases fuel in June 2010 [1] and enters a contract for completion in February 2011 [2]. Unless there has been a forward agreement on price, timing may still present an operational risk linked to costs. The owner would in this situation experience a mismatch, even if the variance is highly correlated Unexpected changes in fuel prices then equals operational risk for ship owners. Especially for those operating in the spot freight markets, but also for those with fixed rate agreements. Therefore, incentives to reduce cost risk would still be present.

This thesis will attempt to clear up these uncertainties by analysing the correlation between fuel and freight rates – to see if any natural hedge is present. This will show if the changes in freight rates corresponds with changes in fuel prices. Further, the thesis will analyse if it is possible to hedge the spread between the freight rates and fuel prices using futures. As the operational costs largely consists of freight rates and fuel prices, the spread between these makes up the operational risk. And in addition of hedging the cost variation directly, hedging the variation of the spread could be an alternative for reducing risk.

5 BUNKER OIL SPOT PRICE HISTORY

This thesis will analyse how to reduce the risk linked to costs by using bunker oil in the shipping industry as the main propulsion driver for large shipping vessels. There isn't any specific definition as to what bunker oil consists of, except that it is a form of fuel used by maritime vessels, consisting of some residual parts from the oil refining process and diesels. Many different terms are in use; bunker oil, bunker fuel, fuel oil, residual oil, maritime fuel etcetera. To clarify, residual oil is the leftovers from refining crude oil. It is the bottom slam leftovers from distillation of oil, which is then for the most part split into two groups. One which is mainly used for industry purposes, like asphalt, and one as fuel. The parts of this residual oil that can be used as fuel, are then defined as residual fuel oil or fuel oil. Fuel oil is the general term for all residual oils that can be used for generating power. This oil is thick with high viscosity, and therefore requires extensive heating before it can be ignited.

Bunker oil or bunker fuel is one of the extracts from this fuel oil. Bunker fuel is defined by the U.S. Energy Information Administration, hereafter referred to as EIA, as; "Fuel supplied to ships and aircraft, both domestic and foreign, consisting primarily of residual and distillate fuel oil for ships and kerosene-based jet fuel for aircraft" (U.S. Energy Information Administration, 2018). Bunker oil can be supplied in a multitude of manners, from barges to pipelines, as well as by other means. The common term in use for supplying ships with bunker fuel is generally known as bunkering. The term bunker originates from steam-powered ships, where they used bunkers at shore to store the coal used to create steam. After the discovery of oil as a propulsion substance, coal became inferior. Shipping no longer required large, strategically placed containers for storing coal at ports – these were then converted into oil containers instead.

The price of bunker oil makes up a large portion of the operation risk. Prices may also vary slightly in different markets and ports, which is also a risk momentum to take into consideration. The reasons for this is mainly the supply and demand, as well as the amount of storage available and the amount of oil in storage. But access and the type of bunkering may also impact the prices. The bunker oil price data used in this thesis originates from Rotterdam and Singapore[3], and is downloaded from Datastream.

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[3] Bunker price data used:

*Bunker oil 180CST Rdam U$/Mt
*Bunker oil 180CST Singapore U$/Mt
*Bunker oil 380CST Rdam U$/Mt
*Bunker oil 380CST Singapore U$/Mt

The reason for choosing these two ports as the core of this research, is that these are ports with large amounts of traffic. They are also geographically located on two different points of the globe which should be relatively representative for a larger scale, rather than using data from two ports located much closer in proximity. This means that there will be other factors which could influence the prices, like politics, trade embargoes, available supply / demand and substitution.

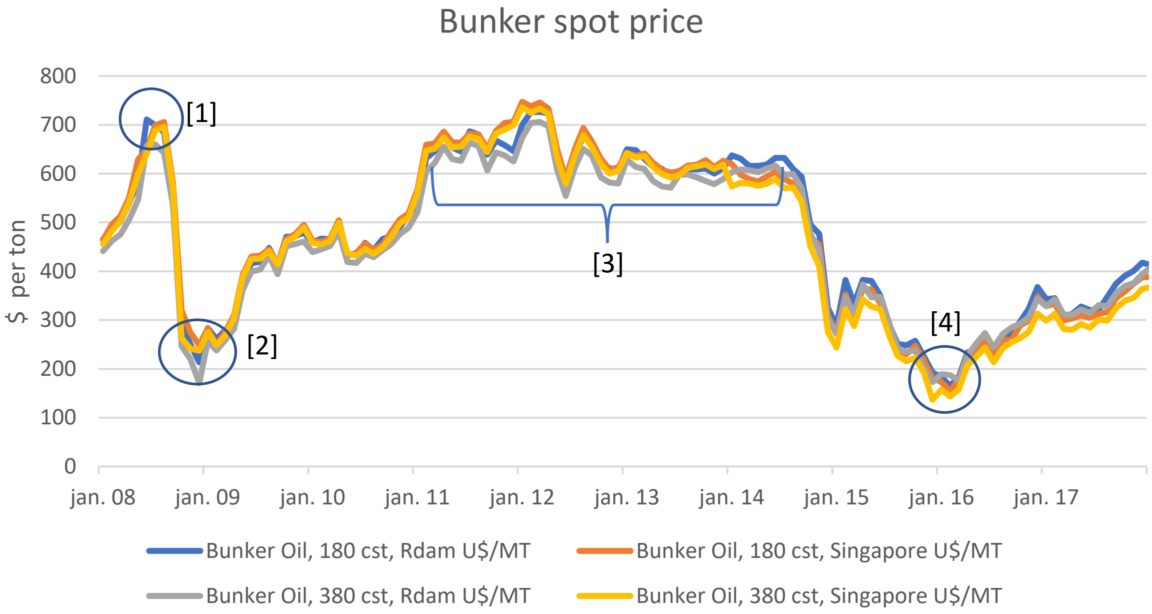

Figure 2: Monthly bunker spot prices (2008 - 2017) in US$ pr metric ton
Data source: Datastream, 2018

The graph above shows the development in the bunker spot prices over the last decade using monthly data. As we can see, prices have varied remarkably in this period, with a significant dive in mid-2008 during the financial crisis [1]. The prices dropped from around $700 per ton, down to around $200 per ton in a very short time [2]. For the next few years, prices inclined and remained stable [3] up until 2014, and then declined severely. This was mostly connected to the overall drops in crude oil prices and introduction of shale oil. This decline persisted until 2016 [4], when oil prices started to increase again (see figure 4).

5.1 PORT OF ROTTERDAM AND SINGAPORE

Rotterdam is the largest of all ports in Europe, and serves as one of the main bunker oil fuel supply lines in the world. This is an important part of the global market, and the main bunker supplier in Europe. The port handles almost 500 million tonnes of goods every year, and is the ninth largest port worldwide (Portofrotterdam.com, 2018). The prices in ports can vary slightly, as the oil is transported from different refineries. However, this also makes the fuel supply sufficient, which in turns causes stability. Stability will then ensure that prices does not fluctuate more than necessary – which benefits the users of bunker oil, the shipping companies.

Rotterdam is supplied from several different oil refineries, which enables the buyer to get oil from multiple sources, driving the price down compared to other smaller ports. In total, Rotterdam port sold 9.9 million cubic meters of oil– which translates to roughly 9.8 million tonnes of bunker oil in 2017.

The Asian port of Singapore is one of the largest ports in the world, surpassed only by the port of Shanghai. Strategically located, Singapore is a natural player in the shipping market. It comes as no surprise that the port is a large supplier of marine fuel. Bunker oil fuel sales volume in 2017 were over 50 million tonnes in Singapore alone, making the port the leading supplier on an international basis. Compared to Rotterdam, the Asian port sold more than five times the amount of fuel oil in 2017 (MPA, 2018) (Portofrotterdam.com, 2018).

5.2 BUNKER OIL DESCRIPTIVE PRICE DATA

The prices of bunker oil can, as discussed, vary slightly in the different ports, and may also vary with different types of bunker oil. This further strengthens the point that the micro-economic factors mentioned earlier, could influence how pricing of bunker oil is executed at different ports throughout the world. The size of the ship may also limit the possible ways of bunkering – some ports are too small for very large vessels – but this is not a factor for either of the two ports, as they both are able to handle the largest ships currently operational.

Table 2: Bunker oil price and price changes descriptive statistics (2008 – Jan. 2018)
Data source: Datastream, 2018

	Average	Coefficient of Variation	Min	Max
180 cst, Rotterdam	$474.3/mt	0.336	165.0	726.5
180 cst, Singapore	$472.5/mt	0.352	154.0	747.0
380 cst, Rotterdam	$455.6/mt	0.337	171.0	706.0
380 cst, Singapore	$458.7/mt	0.371	136.5	736.0
180CST Rotterdam monthly price changes	-0.10 %	11.4 %	-64.6 %	28.6 %
180CST Singapore monthly price changes	-0.15 %	11.0 %	-59.6 %	25.2 %
380CST Rotterdam monthly price changes	-0.07 %	12.2 %	-77.7 %	40.4 %
380CST Singapore monthly price changes	-0.18 %	12.0 %	-77.7 %	27.9 %

The average price in Rotterdam is $474.3 and $455.6 for 180 and 380 grades respectively, while Singapore prices average are $472.5 and $458.7. Average price shows that this price difference between 180 and 380 grade, is roughly 20 dollars. The coefficient of variation indicates that the prices change more in Singapore than in Rotterdam, with the relative variance slightly higher value than Rotterdam. The European port seems to fluctuate less (-0.10% and -0.7%) in this period compared to Singapore (-0.15% and -0.18%) – but Rotterdam seems to fluctuate within a larger price area. This would further emphasize the facts that were previously found. Rotterdam prices are less volatile on average, but tend to experience larger price changes. Whether this is due to scaling factors, supply or demand, or regional influences, is unknown.

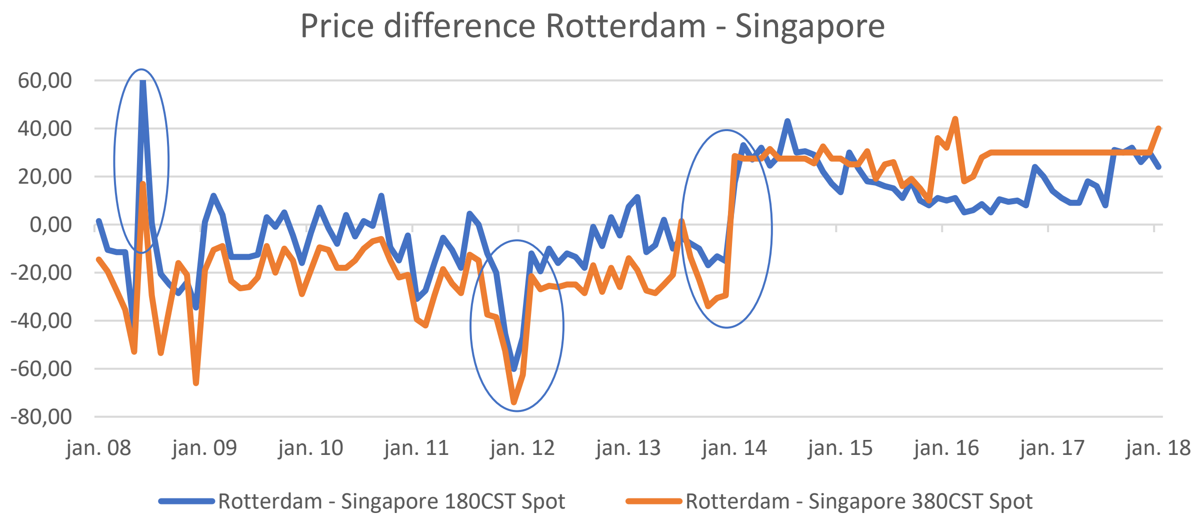

Figure 3: Price difference bunker oil Rotterdam-Singapore (2008 – 2017)
Data source: Datastream, 2018

For this period, the average price difference between Rotterdam and Singapore was shown in figure 3 at $1.75 for 180, while at -$3.2 for 380. While specific volume data for Rotterdam is unavailable, in Singapore, 75% of all bunker sales were in the cheaper 380 grade. Assuming that consumption preferences are the same, the 380grade would be a better indicator for the situation as a whole. This indicates that the prices in Rotterdam have been slightly lower on average than in Singapore.

Looking at the graphical display of the price difference, we can clearly notice several points that could explain why there is a difference in price and volatility. The first and obvious one, is in the middle of 2008. The financial crisis was imminent as a global affair, and impacted commodity prices overall to some degree. The prices in Rotterdam and Singapore port seems to react differently. The graph indicates that the two global ports are affected by the same global influences, but not simultaneously. Local factors may influence the time it takes before the prices react. This makes sense if apart from the price of crude oil, supply / demand, and other local influences are vital for determining the price of bunker oil. Take the three highlighted points in figure 3. These are examples of global situations which affect the prices in the different ports differently. The first shows a sudden spike in bunker oil price difference during a financial crisis. The second illustrates how the spread between different oil prices influences the price of bunker (see figure 4). The third mark shows that Singapore was much more impacted by the sudden decrease in oil prices in 2014, than the port of Rotterdam.

5.3 CRUDE OIL COMPARISON

The price of crude oil has been, like the price of bunker oil, fluctuating for the past decade. The two graphs below illustrate that there are similarities in the price movements of the two, which is only fair – considering that one originates from the other. The real question then arises; how similar are these two commodities – are the changes comparable, does one move more than the other and is there a direct link between the two?

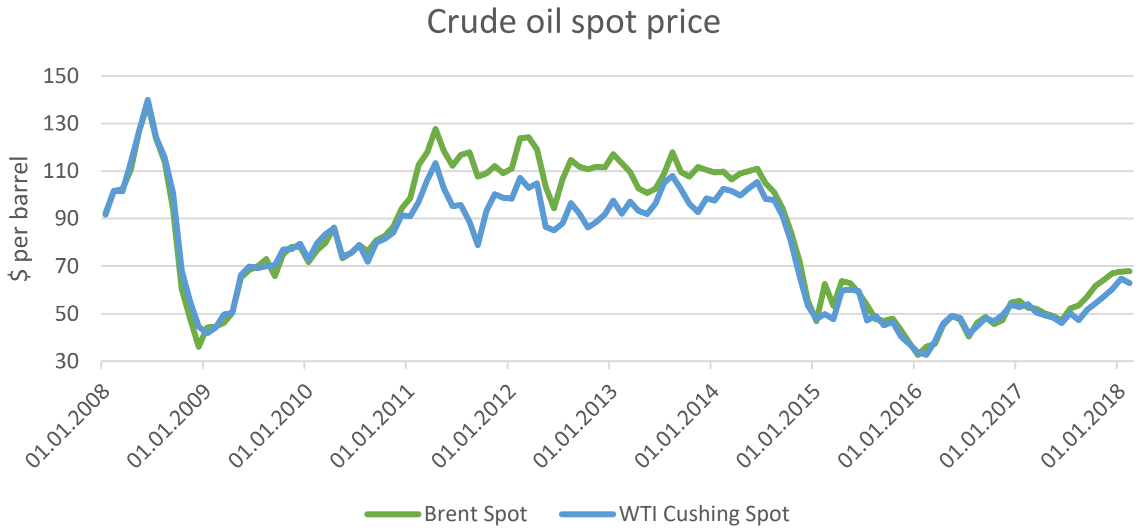

Figure 4: Monthly WTI & Brent Crude oil USD per barrel & bunker oil spot price USD per ton (2008-2017)
Data source: Datastream, 2018

Crude oil is split into two different categories, one that is North Sea oil – Brent, and the other WTI, which is the global oil originating from Cushing, Oklahoma (USA). For all purposes, their movements are similar, apart from some periods where the price of Brent oil is at a higher level than the price of WTI.

Table 3: Descriptive statistics of monthly bunker and crude oil prices (2008-2017)
Data source: Datastream, 2018

	Avg. price	Coefficient of Variation	Min	Max
Bunker Oil 180 cst Rotterdam	$474.3 / mt	0.336	165.0	726.5
Bunker Oil 180 cst Singapore	$472.5 / mt	0.352	154.0	747.0
Bunker Oil 380 cst Rotterdam	$455.6 / mt	0.337	171.0	706.0
Bunker Oil 380 cst Singapore	$458.7 / mt	0.371	136.5	736.0
Brent Crude oil spot	$82.1 / barrel	0.350	32.7	138.1
WTI Crude oil spot	$76.5 / barrel	0.319	32.7	140.0

Table 3 shows average prices, the coefficient of variance, and the range of each products spot price. Compared to the price of crude oil which is measured in the dollar price per barrel, bunker oil is traded per tonnage instead. By comparing the coefficient of variation, the standard deviation is divided by the mean, enabling comparison of the different measurements. As the table (2) shows, there are minor difference between bunker oil and WTI crude oil, indicating the lowest monthly relative variance (0.319) -while Singapore 380CST shows the largest (0.371). Brent oil variance is higher (0.35), and fits in between Rotterdam (0.336; 0.337) and Singapore (0.352; 0.371). Further, table 4 illustrates the price changes in percentages.

Table 4: Descriptive statistics of monthly bunker and crude oil price changes 2008-2017
Data source: Datastream, 2018

	Change	**Std.dev**	**Min**	**Max**
180CST Rotterdam	-0.10 %	11.4 %	-64.6 %	28.6 %
180CST Singapore	-0.15 %	11.0 %	-59.6 %	25.2 %
380CST Rotterdam	-0.07 %	12.2 %	-77.7 %	40.4 %
380CST Singapore	-0.18 %	12.0 %	-77.7 %	27.9 %
Brent crude oil	-0.26 %	10.5 %	-44.1 %	28.7 %
WTI crude oil	-0.29 %	9.7 %	-39.1 %	27.5 %

The values from table 3 indicated very large fluctuations in the bunker oil prices – but these are in fact lower in percentage on average than the crude oil price changes in table 4. Even though the changes are on average lower, the sudden drops in prices are much more drastic in bunker oil. This would indicate that the bunker oil price fluctuates less on average, but is prone to larger drops in prices. I will not over-analyse these numbers, but it would make sense as bunker in a specific area might be exposed to factors like supply and demand more than the overall global oil prices would. The changes in WTI compared to Brent indicates the same as crude oil compared to bunker. As the market size is larger, the deviations and spread are reduced – which in all matter makes sense. Further on, I will look at how the changes in bunker oil prices can be compared to the changes in crude oil price using regressions with the WTI price changes as the underlying test variable using the following model;

$$\Delta Spot_{Bunker} = \alpha + \beta_1 \Delta WTI + u_t \tag{2}$$

Where $\Delta Spot_{Bunker}$ is the monthly price changes in the each of the four bunker oil markets, and ΔWTI represents the monthly price changes in WTI Crude oil.

Table 5: Regressions on monthly bunker oil price changes vs monthly WTI Crude oil price changes (2008-2017)
Data source: Datastream, 2018

	Beta	R^2	SE
180CST Rdam	0.86	0.53	0.0735
180CST SG	0.84	0.55	0.0691
380CST Rdam	0.90	0.51	0.0813
380CST SG	0.88	0.51	0.0797

The results show that the changes in the crude oil price did impact the changes of bunker prices as expected but could only explain roughly half of the variance. As we can see from the descriptive statistics, the price of bunker oil has moved less in the past 10 years than the price of crude oil. This could mean that bunker oil is less influenced by economic factors than the price of oil. However, the prices of bunker oil are more volatile than the prices of crude oil. Like mentioned previously, this is most likely due to local factors more than global influence, which could be politics, supply and demand, storage or other limiting factors which may have an influence on the price changes.

5.4 VOLATILITY CHANGES OVER TIME IN BUNKER AND CRUDE OIL PRICES

Volatility is a well-known measurement of risk, or at least a measurement of how much something moves. To better illustrate the changes in volatility, I have made rolling windows backdated 12 and 6 months. The windows have included the bunker spot price changes as well as the changes to the WTI crude oil spot price.

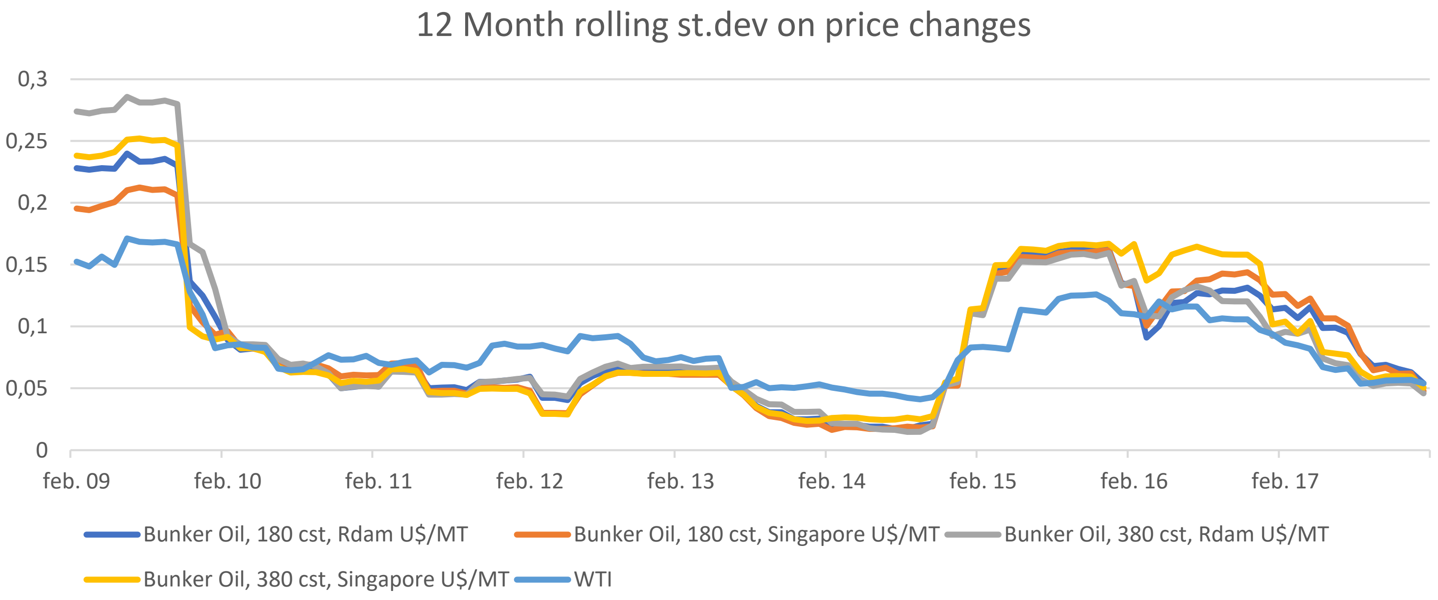

Figure 5: Bunker and crude oil rolling standard deviation window 12 months (2008-2017)
Data source. Datastream, 2018

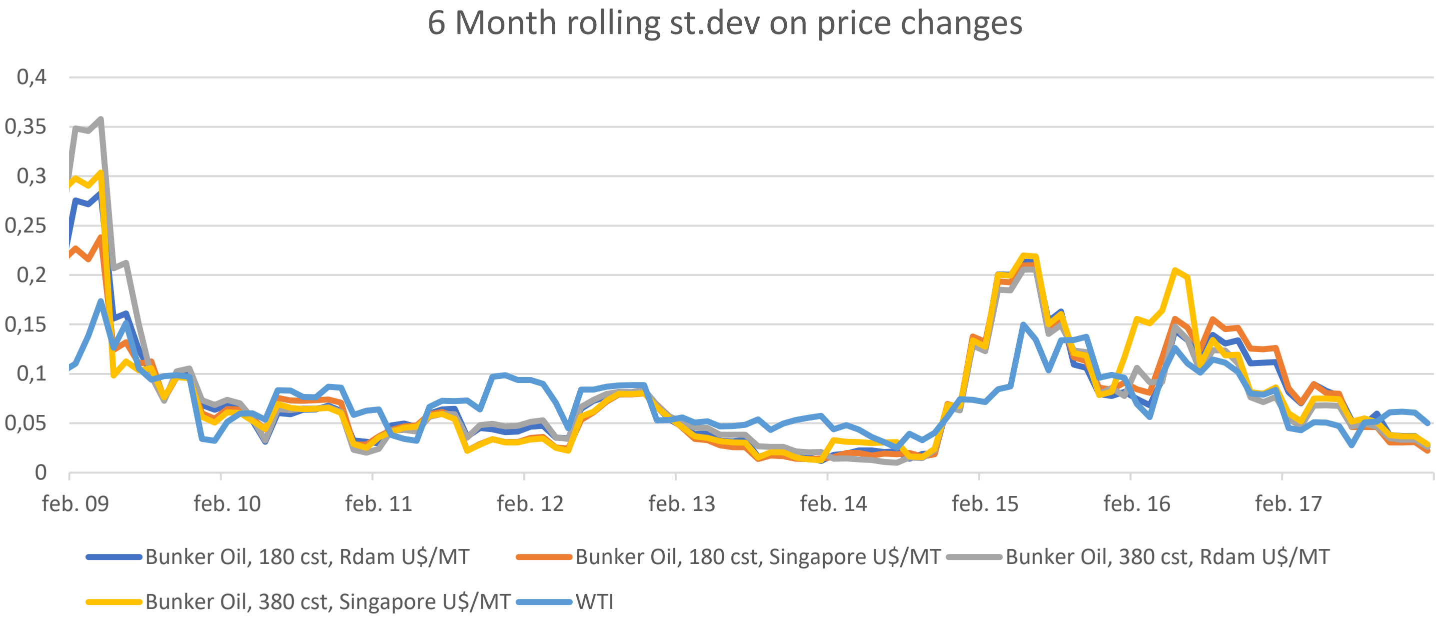

Figure 6: Bunker and crude oil rolling standard deviation window 6 months (2008-2017)
Data source: Datastream, 2018

Figure 5 and 6 shows that volatility is just slightly lower on average in Singapore than in Rotterdam, and that the Rotterdam curves match that of the crude oils more. The most important information to extract from these graphs are the way bunker oil fluctuates compared to the WTI.

Events which influence the price of oil seem to have a larger impact on the price of bunker oil than the price of crude oil. To illustrate, in the period around 2008-2009, and from 2014-2016, the volatility of bunker oil seems to fluctuate more drastically than it does for WTI. However, looking at the period in between, a more collected market seems to indicate that bunker oil has more stability while crude oil fluctuates more. The data here gives more evidence to the previous claims of influences from different sources. This supports the fundamentals which implicates other factors than the global oil price as the only influence for the local bunker oil price changes (Alizadeh et. al. 2004).

5.5 IS THERE A NATURAL HEDGE FOR BUNKER OIL IN FREIGHT RATES?

In the previous chapter, a natural hedge situation was introduced. Meaning that variation in fuel would be similar to that of freight rates. This would mean that an extra insurance on increased fuel costs would be present naturally by the increased income. Correlation is tested by analysing a correlation matrix with all inputs present. A high positive correlation would indicate that higher prices of bunker oil also means higher freight rates. On the other side, a high negative (-) correlation indicates that bunker prices are increasing while freight rates are decreasing. Both of these situations can act as a natural hedge, although a positive correlation presents more stability (and less fluctuations). The last possible outcome is that there is (relatively) low correlation between bunker and freight. That would mean that there are no natural hedging opportunities, as changes in one would not cause or indicate changes in the other.

Table 6: Correlation matrix for monthly freight indexes and bunker prices (2008-2017)
Data source: Datastream, 2018

	BALTICF	*BPANMAX*	*BHANDSZ*	*BSUPRAI*	*BCAPESI*	*BTRCLTI*	*BTRDITI*	*BALTLPG*
BALTICF	1,00							
BPANMAX	0,99	1,00						
BHANDSZ	0,98	0,98	1,00					
BSUPRAI	0,98	0,99	0,99	1,00				
BCAPESI	0,99	0,96	0,94	0,95	1,00			
BTRCLTI	0,67	0,67	0,70	0,69	0,64	1,00		
BTRDITI	0,75	0,74	0,77	0,75	0,73	0,85	1,00	
BALTLPG	-0,11	-0,14	-0,11	-0,11	-0,08	0,07	0,02	1,00
Bunker Oil, 180 cst, Rdam U$/MT	0,24	0,26	0,29	0,28	0,26	0,25	0,08	0,28
Bunker Oil, 180 cst, Singapore U$/MT	0,25	0,27	0,30	0,30	0,27	0,27	0,09	0,24
Bunker Oil, 380 cst, Rdam U$/MT	0,22	0,23	0,27	0,26	0,24	0,22	0,05	0,28
Bunker Oil, 380 cst, Singapore U$/MT	0,25	0,27	0,31	0,30	0,27	0,26	0,08	0,23

By looking at the correlation matrix of monthly freight rates and bunker oil prices in table 6, it clearly shows low correlation between fuel and freight rates. BTRDITI are not correlated at all (0.05 to 0.09), while others show a low correlation (0.22 to 0.31) with bunker prices.

Table 7: Correlation matrix for monthly freight index and bunker price changes (2008-2017)
Data source: Datastream

	BALTICF	*BPANMAX*	*BHANDSZ*	*BSUPRAI*	*BCAPESI*	*BTRCLTI*	*BTRDITI*	*BALTLPG*
BALTICF	1,00							
BPANMAX	0,82	1,00						
BHANDSZ	0,72	0,64	1,00					
BSUPRAI	0,77	0,73	0,93	1,00				
BCAPESI	0,86	0,55	0,44	0,47	1,00			
BTRCLTI	0,17	0,12	0,19	0,17	0,10	1,00		
BTRDITI	0,16	0,13	0,13	0,11	0,14	0,38	1,00	
BALTLPG	0,19	0,10	0,21	0,15	0,24	0,22	0,23	1,00
Bunker Oil, 180 cst, Rdam U$/MT	0,26	0,25	0,22	0,15	0,31	-0,02	0,10	0,26
Bunker Oil, 180 cst, Singapore U$/MT	0,27	0,27	0,23	0,19	0,29	-0,06	0,09	0,21
Bunker Oil, 380 cst, Rdam U$/MT	0,24	0,25	0,21	0,13	0,27	0,03	0,08	0,27
Bunker Oil, 380 cst, Singapore U$/MT	0,23	0,27	0,21	0,17	0,24	-0,05	0,02	0,22

The same results can be found by looking at table 7, which shows monthly changes between freight rates and bunker oil. Here just like in table 6, correlations are low between fuel and freight rates. Some (BTRCLTI, BTRCLTI) are not correlated (-0.02 to 0.10), while others show a low correlation (0.13 to 0.29) with bunker price changes.

In total, the data in table 6 and 7 shows that there is very low correlation between bunker oil and freight rates. This means that there is no indication for a natural hedge opportunity for bunker oil in freight rates.

6 THE ROTTERDAM AND SINGAPORE FUEL OIL FUTURES CONTRACTS

For this thesis, a selection of two futures contracts are chosen as tools for hedging. The futures contracts below are standardized contracts traded daily with monthly cash settlements. These are traded on CME-NYMEX[4] and can be traded for up to 6 years before settling. They are based on fuel oil products, the 3.5% higher sulphur fuel oil from barges in Rotterdam, and the 180CST low sulphur oil from Singapore. Both cease trading on the last day of the month, with settlement the first trading day of the next month – meaning the February contract will settle on the first trading day of March.

Table 8: Fuel oil futures contract specifics.
Source: CME

Contract	**European 3.5% Fuel Oil Barges FOB Rdam**	**Singapore Fuel Oil 180 cst**
Contract unit	1000 metric tons	1000 metric tons
Price quotation	U.S. dollars and cents per metric ton	U.S. dollars and cents per metric ton
Trading hours	Sun - Fri 6 p.m. – 5 p.m.	Sun - Fri 6 p.m. – 5 p.m.
Minimum price fluctuation	$0.0001 per metric ton	$0.0001 per metric ton
Product code	UV	UA
Listed contracts	6 consecutive years listed yearly	6 consecutive years listed yearly
Settlement method	Financially settled	Financially settled
Floating price	The Floating Price for each contract month is equal to the arithmetic average of the high and low quotations from Platts European Marketscan for 3.5% Fuel Oil under the heading "Barges FOB Rotterdam" assessment for each business day that it is determined during the contract month.	The Floating Price for each contract month is equal to the arithmetic average of the mid-point of the high and low quotations from the Platts Asia-Pacific Marketscan for HSFO 180cst (High-Sulfur Fuel Oil) under the heading "Singapore Physical Cargoes" for each business day that it is determined during the contract month.
Termination of trading	Trading shall cease on the last business day of the contract month	Trading shall cease on the last business day of the contract month
Position limit	NYMEX Position limits	NYMEX Position limits
Exchange rulebook	NYMEX 660	NYMEX 662
Block minimum	Block minimum thresholds (5)	Block minimum thresholds (5)
Vendor quotes		

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[4] Chicago Mercantile Exchange & Chicago Board of Trade, and New York Mercantile Exchange – part of the CME Group marketplace

6.1 FUEL OIL FUTURES PRICE DATA AND DEVELOPMENT

For the future price data, a selection from both the Rotterdam and the Singapore fuel oil future with three different time perspectives are chosen. Monthly data have been selected and downloaded using Datastream, and prices are spliced and divided into three groups; three, six and twelve months before the contract is due. This is to provide enough data for potential longer hedges as well as for shorter periods. Since these contracts are handled on a monthly basis, any shorter periods would almost move over into a spot position. In addition, longer than twelve months before settlement would mean that there are too many unknown factors to consider. Figure 7 and 8 show price data for the different contracts.

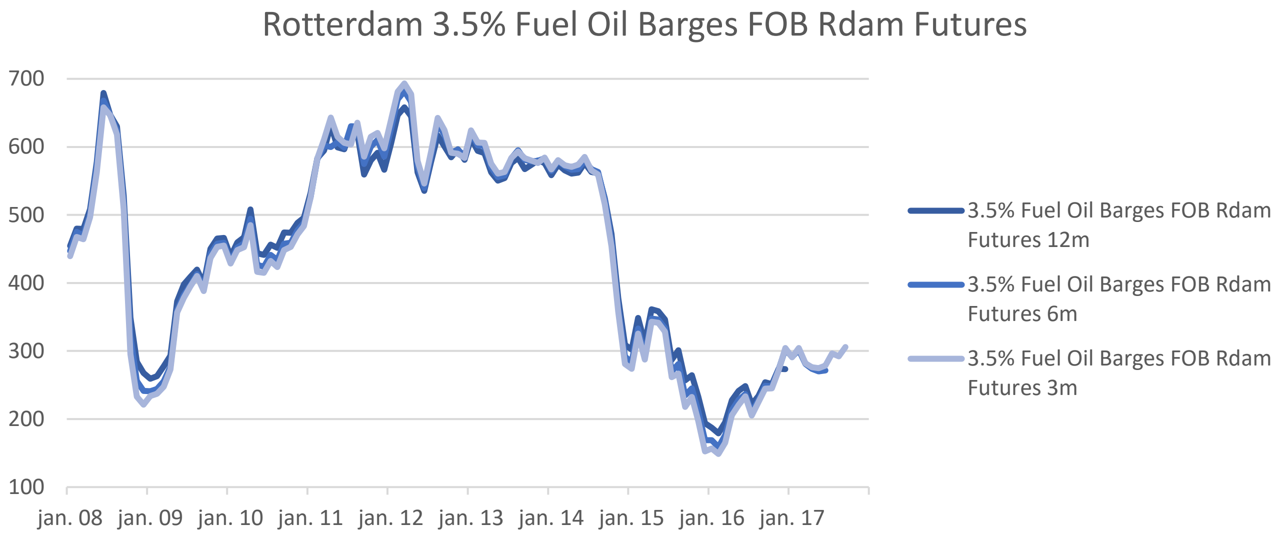

Figure 7: Rotterdam 3,5% fuel oil future price data (2008-2017) USD per ton, monthly cash settlement
Data source: Datastream, 2018

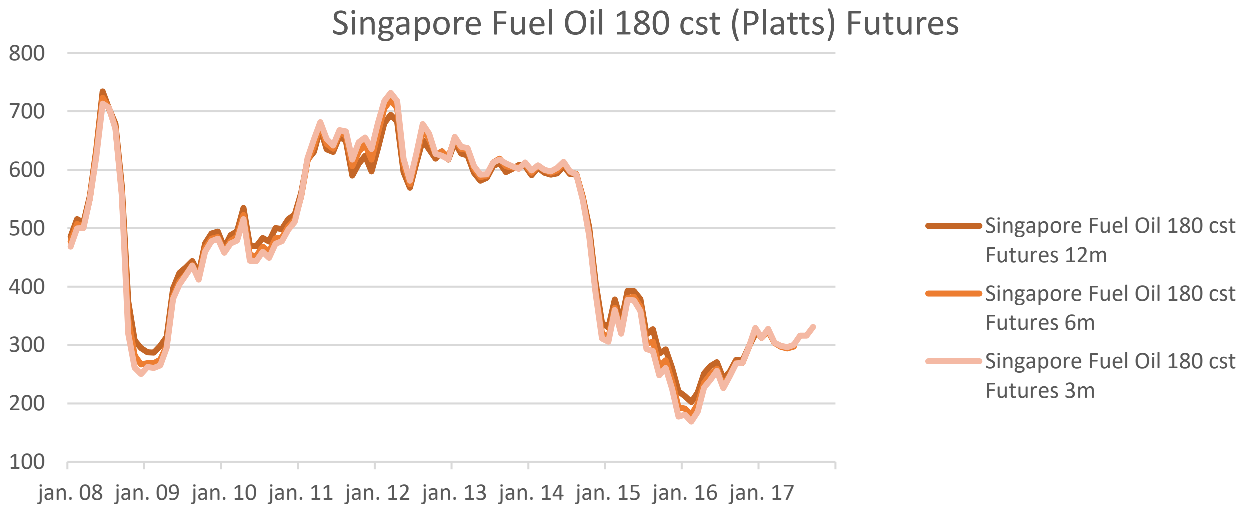

Figure 8: Singapore 180CST fuel oil future price data (2008-2017) USD per ton, monthly cash settlement
Data source: Datastream, 2018

The fuel future oil prices have changed just like the bunker oil prices have, over the last ten years. The price changes seem to be very similar to the curve in chapter five. Figure 7 shows the price development of the Rotterdam fuel oil futures with price data for 3, 6 and 12 months before settlement. Figure 8 shows the price changes in the Singapore fuel oil future for the same period with the similar settlement periods. Both are monthly prices, and apart from the occasional dip, it is hard to notice any major difference from the graphs (7, 8).

Table 9: Descriptive statistics fuel oil futures monthly price data (2008-2017)
Data source: Datastream, 2018

	Singapore Fuel Oil 180 cst Futures 12m	*Singapore Fuel Oil 180 cst Futures 6m*	*Singapore Fuel Oil 180 cst Futures 3m*	*3.5% Fuel Oil Barges FOB Rdam Futures 12m*	*3.5% Fuel Oil Barges FOB Rdam Futures 6m*	*3.5% Fuel Oil Barges FOB Rdam Futures 3m*
Average price U$/mt	$490.78	$476.98	$471.28	$460.44	4446.99	$441.00
Coefficient of Variation	0.295	0.328	0.342	0.305	0.338	0.354
Average price changes	-0.39 %	-0.42 %	-0.30 %	-0.47 %	-0.44 %	-0.31 %
Price change St. dev	8.70 %	9.39 %	9.93 %	9.02 %	9.78 %	10.43 %

Table 9 shows the average prices for the fuel oil futures with the corresponding price changes over the period. The coefficient of variance shows the relative variance of the futures data. Rotterdam futures are priced lower on average than in Singapore and have marginally larger price changes and volatility. Variance is also lower the further from maturity, regardless of origin – which does make sense. To further examine the statistics of the fuel oil data, a basis (price difference) is calculated. This gives information about the market, and the situation of the futures price – whether it's in contango or backwardation (Hull, 2015).[5]

Table 10: Price difference (basis) fuel oil futures and bunker oil spot monthly price data (2008-2017)
Data source: Datastream, 2018

Basis	*SG Futures 12m*	*SG Futures 6m*	*SG Futures 3m*	*Rdam Futures 12m*	*Rdam Futures 6m*	*Rdam Futures 3m*
Bunker Oil 180 cst Rdam U$/MT	2.3	-2.0	-3.9	-28.1	-32.3	-34.9
Bunker Oil 380 cst Rdam U$/MT	22.1	17.9	15.9	-8.2	-12.5	-15.0
Bunker Oil 180 cst Singapore U$/MT	1.8	-2.4	-4.3	-28.5	-32.8	-35.3
Bunker Oil 380 cst Singapore U$/MT	14.8	10.6	8.6	-15.5	-19.8	-22.3

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[5] Contango and backwardation refers to the state of the spot and futures price. Contango is the situation where the futures price is larger than the corresponding spot price (F>S). Backwardation is the opposite, when the price for future delivery is lower than the spot price (F<S).

As described in table 10, the basis does differ from the different markets in accord with the data in table 9. The Singapore futures (SG) are overall priced higher than the Rotterdam based future (Rdam). The data also reveals that there is a significant difference within the futures itself, as the basis changes over time (Hull, 2015). The Singapore futures basis is compared to 180CST shows a positive basis (F>S) twelve months before settle, and becomes increasingly negative towards settlement. The basis compared to 380CST shows a higher basis, which is reduced towards settlement, but is not negative.

The Rotterdam contract tells a different story. Here we find declining basis (negative) in every contract, with the 180CST negative basis much higher than the 380CST. This however, is consistent with data from table 9, showing Rotterdam futures at a lower average price than in Singapore. As this is based on a heavier oil type which is typically priced lower, this would make sense. The Singapore futures is based on 180CST fuel oil, which is why the price is more closely matched with the underlying bunker oil.

6.2 VIABILITY OF THE FUEL OIL FUTURES MARKET

The potential performance of the fuel oil futures market can be explained using the five factors (Carlton, 1984); uncertainty (A), correlation (B), liquidity (C), market value (D), and free market regulation (E). These will indicate why these futures could be used to hedge the price risk in bunker oil. Uncertainty (A); Bunker oil prices are an important factor for firms operating in shipping. With most of transportation still executed at sea, the demand for bunker oil as fuel will still be present if there is no efficient substitute for it. As supply and demand is constantly balancing, fluctuation in prices will occur. The produce is a result of crude oil refinement, and a biproduct of fuel oil production (see chapter 5). As most of the fuel oil is used for this purpose (MPA, 2018), the uncertainty in bunker oil will carry over to the fuel oil futures market as well. Further proved with the second factor, Price correlation (B): The value of futures is partially determined by either their correlation or lack of it in concern to the underlying asset. The matrix in table 8 below shows the results, with excess correlation factors removed.

Table 11: Price changes correlation matrix (2008-2016)
Data source: Datastream, 2018

	Singapore Fuel Oil 180 cst Futures 12m	*Singapore Fuel Oil 180 cst Futures 6m*	*Singapore Fuel Oil 180 cst Futures 3m*	*3.5% Fuel Oil Barges FOB Rdam Futures 12m*	*3.5% Fuel Oil Barges FOB Rdam Futures 6m*	*3.5% Fuel Oil Barges FOB Rdam Futures 3m*
Bunker Oil, 180 cst, Rdam U$/MT	**0,848**	**0,873**	**0,891**	**0,834**	**0,856**	**0,875**
Bunker Oil, 180 cst, Singapore U$/MT	**0,849**	**0,876**	**0,894**	**0,832**	**0,860**	**0,877**
Bunker Oil, 380 cst, Rdam U$/MT	**0,812**	**0,842**	**0,867**	**0,799**	**0,823**	**0,852**
Bunker Oil, 380 cst, Singapore U$/MT	**0,853**	**0,886**	**0,915**	**0,838**	**0,871**	**0,896**

Table 11 shows the correlation matrix in monthly fuel oil futures price changes and monthly bunker oil spot price changes in the period of 2008 to 2016.

As expected, the correlation between the futures and spot prices are highly correlated. Every correlation coefficient is in the range between 0.812 and 0.915. These rates are very high, although not perfect, just as anticipated.

With highly correlated market, the next step is to figure out the liquidity of these futures (C). They are currently traded on NYMEX, which should to some degree ensure liquidity, but actual trading volume is currently unknown. Many of these derivatives (Imarex and similar), have stopped trading after losing interest and liquidity. Previously stated, there should be plenty of interested parties wanting to secure their uncertainty. This should also indulge the interest of speculators, seeking to profit from the uncertainty instead. As the basis for futures markets explain (see Ederington, 1979; Carlton, 1984, Hull, 2015), it doesn’t matter if the futures are perfectly fitted to hedge the asset if there is no counterpart in the market. And counterparts will not engage in positions they may not be able to close.

Total market value (D): Like mentioned earlier in the analysis, there are many participants in the bunker oil market due to the scale of the shipping industry. They require fuel for their vessels, and it makes up a large percentage of their total costs. With currently no efficient option for replacing bunker oil, the value of hedging instruments are intact. As for the prices themselves, they are estimated by many factors, both global and local (E). Previously, I stated that bunker oil is a biproduct of crude oil. This means that bunker oil and fuel oil prices could be regulated by restrictions or limitation on crude oil (Gilleshammer & Hansen, 2010). Not to mention that environmental implication could restrict the use of certain types of bunker oil in the future. Overall, this futures market for fuel oil seems to be sustainable and suitable for hedging. Considering that they have been traded for over ten years on a large exchange should indicate that they have reasonable activity. If they can reduce the variance of bunker oil prices significantly; they could be considered successful futures (Carlton, 1984).

7 THE MINIMUM VARIANCE HEDGING METHOD

In a perfect world, you would have futures which mimic the movements of the underlying spot asset perfectly, and thus would always benefit from a näive hedge ratio of 1. This is usually never the case, and estimating a hedge ratio that finds the minimum variance of the asset is necessary There are several ways to derive the optimal hedge ratio. An Ederington framework has been used by others (Gilleshammer & Hansen, 2010) to find a mathematical solution (Ederington, 1979). This method has been mathematically shown equal to using OLS-regressions. This is a simplified explanation as to how the framework transforms to find the minimum variance: Firstly, you find the change in price from period one to period two on the underlying spot asset, which is then a return from one period to the next; $S(P_2\text{-}P_1)$. The same measure is performed for the future asset which are to be used to hedge your position; $F(P_2\text{-}P_1)$, which makes the total return:

$$Portfolio\ return = S(returnSpot) + F(returnFuture) \tag{3}$$

This makes up a total return (as Ederington calls it) of a portfolio. The next step is to find the variance of the given portfolio which will then be equal to the variance of both S and F times their respective return, as well as the covariance between the two:

$$Var(Portfolio) = S^2\sigma_S^2 + F^2\sigma_F^2 + 2SF * Cov(S,F) \tag{4}$$

For the portfolio variance to be minimized, the framework need a measure of how large the position of the hedge should be. Ederington uses the notation of little ‘b’ – and will be noted with a ‘b*’ for the optimal ratio. The returns of each is removed, only the variance of each price set is left. The hedge amount is then introduced into the previous formula and expressed:

$$Var(Portfolio) = \sigma_S^2 + b^2\sigma_F^2 - 2b * Cov(S,F) \tag{5}$$

To minimize the risk, the optimal hedge ratio (b*) must be found. This is done by finding the first derivative of the previous equation with respects to the hedge ratio equal to zero. Once this is done, the equation may be solved to find the optimal hedge ratio:

$$\frac{\partial Var(Portfolio)}{\partial b} = 2b\sigma_F^2 - 2Cov(S,F) = 0 \tag{6}$$

$$b^* = \frac{Cov(S,F)}{\sigma_F^2} = Correlation(S,F) * \frac{\sigma_S}{\sigma_F} \tag{7}$$

Equation 7 will then show the relationship between the covariance of the two assets, divided by the variance of the hedge instrument, and the correlation of the two can locate the ratio of which to hedge the portfolio most optimally to minimize the total variance. This relationship gives us information about how much variance this hedge would have reduced. As the hedge effectiveness is a measure of how much the hedged portfolios variance differs from the unhedged, spot position (Ederington notes this as ‘e’), where Var(portfolio*) represents a minimum variance portfolio. This simplified equation is noted like this:

$$e(HedgeEfficiency) = 1 - \frac{Var(Portfolio^{*})}{Var(Spot)} \tag{8}$$

The mathematical approach is then to find the minimum variance, by noting the Var(Portfolio*) equal to equation 5 with equation 7 inserted;

$$Var(Portfolio^{*}) = S^2\left(\sigma_S^2 + \frac{Cov(S,F)^2}{\sigma_F^2} - 2\frac{Cov(S,F)^2}{\sigma_F^2}\right) = S^2\left(\sigma_S^2 - \frac{Cov(S,F)^2}{\sigma_F^2}\right) \tag{9}$$

To explain the mathematics, take the last notation of the formula and multiply the expression within the parenthesis with the squared price changes and set the expression equal to zero. The formula then takes the form of a two-sided equation. Subtract S^2 * Cov(S, F)^2 / and multiply with σ^2_F, on both sides. This leaves the expression noted like this:

$$S^2Cov(S,F)^2 = S^2\sigma_S^2\sigma_F^2 \tag{10}$$

Divide the left side with the right, denote redundant variables and the equation becomes:

$$\frac{Cov(S,F)^2}{\sigma_S^2\,\sigma_F^2} = \rho^2 = e(HedgeEfficiency) \tag{11}$$

Equation 11 shows the transformed formulation which translates to the squared population coefficient, more commonly known as the correlation between the underlying asset and the hedge instrument squared. Further, we can compare this to how you can estimate optimal hedge ratios and measure hedge efficiency by using OLS and achieving the same results. This mathematical approach was created by others based on Ederington’s work (Gilleshammer & Hansen, 2010). First you note the total value of a hedged portfolio (12) and the notation for changes from period one to period two (13):

$$P_t = S_t - b * F_{t,T} \tag{12}$$

$$\Delta P_t = \Delta S_t - b * \Delta F_{t,T} \tag{13}$$

Where ‘P’ represents the total value of the hedged portfolio, total value changes as ‘ΔP’, the spot and future prices as ‘S’ and ‘F’, with their respective price changes as ‘ΔS’ and ‘ΔF’. The standard OLS regression equation is noted as:

$$\Delta S_t = \alpha_0 + \beta_1 \Delta F_{t,T} + u_t \quad (u_t \sim idd(0, \sigma^2)) \tag{14}$$

The regression equation (14) can then be placed within the equation for changes in the total hedged portfolio value (15):

$$\Delta P_t = \Delta S_t = \alpha_0 + \beta_1 \Delta F_{t,T} + u_t - b\Delta F_{t,T} = a_0 - (b + \beta_1)\Delta F_{t,T} + u_t \tag{15}$$

This equation (15) transforms, just like the Ederington framework, into a minimum risk portfolio (16) where σ^2_U equals the residual variance. This is further derived with respects to ‘b’ to find the variance of the portfolio in equation 17, setting the expression equal to zero:

$$Var(Portfolio) = \beta_1^2 \sigma_{\Delta F}^2 + b^2 \sigma_{\Delta F}^2 + 2b\beta_1 \sigma_{\Delta F}^2 + \sigma_U^2 \tag{16}$$

$$\frac{\partial Var(Portfolio)}{\partial b} = 2\beta_1^2 \sigma_{\Delta F}^2 - 2b^2 \sigma_{\Delta F}^2 = 0 \tag{17}$$

When we solve this equation (18), we prove that the optimal hedge ratio in Ederington’s framework (b*) is equal to the beta (β_1) value estimated in OLS regressions:

$$b^* = \frac{2\beta_1^2 \sigma_{\Delta F}^2}{2\sigma_{\Delta F}^2} = \beta_1 \tag{18}$$

As the optimal hedge ratio has been derived, finding the efficiency of the hedge is done with basis in equation number 8;

$$e = 1 - \frac{Var(\Delta P_t^*)}{Var(\Delta S_t)} = \frac{\beta_1^2 \sigma_{\Delta F}^2 + b^{*2} \sigma_{\Delta F}^2 + 2b^* \beta_1 \sigma_{\Delta F}^2 + \sigma_U^2}{\sigma_{\Delta S}^2} \tag{19}$$

The beta value (β_1) is equal to the optimal ratio(b*) (16), and we may therefore drastically reduce the expression (19) without redundant variables. This leaves us with the residuals squared divided by the total sum of squares; the R-squared value (R^2).

$$e = 1 - \frac{Var(\Delta P_t^*)}{Var(\Delta S_t)} = 1 - \frac{\sigma_U^2}{\sigma_{\Delta S}^2} = R^2 \tag{20}$$

The equation (20) proves mathematically that the estimated variance reduction in the Ederington framework is equal to the estimated R^2 values found by performing a regression analysis with the spot price changes as the Y-variable, and the futures price changes as the X-variable. When estimating these values, we find the ratio of which the two futures contracts are possible hedging instruments for reducing the variance in bunker oil prices. The minimum variance hedge ratio is the coefficient of the slope when placing the changes in spot bunker oil prices and changes in fuel oil future prices 3, 6 and 12 months from delivery. The ratio will then determine how many futures contracts to purchase for the hedge to be optimal and minimize the variance.

Using OLS for estimating the hedge ratio, another value is estimated in the process. This is the residual sum of the squares, divided by the total sum of all squares – the R^2 value. The value explains the amount of variance which the model considers, or how well the estimated regression actually matches the observations. This in other terms translates to the hedging efficiency of the overlaying futures contract for the underlying asset, as explained in the Ederington framework. Hedging efficiency is used to measure the reduced risk in terms of reduced variation when the estimated hedge ratio is used.

While hedging effectiveness have been analysed in previous literature, there is not a clear winner in terms of the most effective way to reduce the overall risk in commodities. A time-varying hedge approach was tested in freight derivatives (Kavussanos & Nomikos, 2000) and in crude oil products (Alizadeh et. al, 2004; Gilleshammer & Hansen, 2010). Their findings seemed to indicate a slight advantage over a constant hedge ratio – though marginally. This thesis will therefore argue that spending time and resources on performing more advanced calculations and constantly rebalancing the hedge, would in a real-life scenario result in a less effective hedge. A näive (-1) hedge was clearly worse in every situation, and could increase the risk rather than providing a reduction. Therefore, this thesis' will perform a constant hedge regression analysis to measure risk reducing properties of fuel oil derivatives with the following model;

$$\Delta Spot_{Bunkeroil_t} = \alpha + \beta_1 \Delta Future_{Fueloil_{t,T}} \tag{21}$$

where bunker oil spot price changes are on the left, and the fuel oil future price changes are on the right side of the model.

An actor in the shipping industry might not only be concerned about prices in one port, but bunker prices overall (Gjølberg & Johnsen, 1986). As an example, the thesis will try to illustrate and analyse the effectiveness of hedging a pool of average bunker prices from the two ports, containing Rotterdam and Singapore price for both 180CST and 380CST on the left side as the dependable variable. This is based on the standard regression model with two variables for futures prices, utilizing futures contracts price data from more than one port. This could lead to a problem with multicollinearity. However, the model's usage is to analyse if using several fuel oil futures to hedge an average of bunker prices, could lead to increased hedge efficiency in the period 2008 to 2016. The model will be noted as;

$$\Delta AvgSpot = \alpha + \beta_1 \Delta Future_{Singapore} + \beta_2 \Delta Future_{Rotterdam} + u_t \qquad (22)$$

$\Delta AvgSpot$ are the changes in the average bunker oil spot prices, consisting of prices from Rotterdam and Singapore, both 180CST and 380CST. $\beta_1 \Delta Future_{Singapore}$ represents the Singapore 180CST fuel oil future price changes, and $\beta_2 \Delta Future_{Rotterdam}$ are the Rotterdam 3.5% fuel oil futures price changes. The futures price data used are three months before contract settlement.

8 ANALYSIS OF FUEL OIL HEDGING PERFORMANCE

This chapter will analyse the hedging performance of fuel oil futures listed on NYMEX. The chapter presents results of the analysis which shows the performance of the fuel oil futures specified in previous chapters. The analysis measures the hedging effectiveness of the futures contracts, with a constant estimated hedge ratio hedge ratio.. Further, the periods will be split up into two smaller samples to see if there has been any change in hedging performance over time. Lastly, the hedging performance of regression model involving contracts from Rotterdam and Singapore will be compared to the standard model. The intention here is to examine if using a mix of futures could outperform using a single-future strategy.

First, the performance of each contract is estimated is estimated using the minimum variance hedge estimation (Ederington, 1979). This will show the performance of each of the contracts for hedging bunker prices in both ports individually. This was estimated using the model (21);

$$\Delta Spot_{Bunkeroil_t} = \alpha + \beta_1 \Delta Future_{Fueloil_{t,T}} \tag{21}$$

$\Delta Spot_{Bunkeroil_t}$ represents the monthly price changes of bunker oil, and $\Delta Future_{Fueloil_{t,T}}$ the monthly price change of the fuel oil futures contract.

The model is estimated separately for both fuel oil prices. Individual regressions for price changes three, six and twelve months from maturity on the price changes of bunker oil. This estimated beta values (β) and adjusted-R^2 values which represent the hedge ratio and the hedge efficiency of each contract. The test period is selected based on the data available. To simplify the period for comparison, February 2008 to December 2016 is selected, as price data for contracts twelve months out were at that time available. This also ensures that all the periods have an equal amount of data points to reduce any potential confusion. Results are found in table 12.

Table 12:
Fuel oil hedging performance on bunker oil price changes with different times to maturity (2008-2016)
Data source: Datastream, 2018

	3 months		6 months		12 months	
	Singapore 180CST	Rdam 3.5%	Singapore 180CST	Rdam 3.5%	Singapore 180CST	Rdam 3.5%
Rotterdam Bunker oil 180CST						
Hedge ratio (β)	1.036	0.968	1.084	1.020	1.164	1.105
Hedge efficiency (R^2)	0.792	0.763	0.760	0.730	0.717	0.692
Standard Error (SE)	0.0515	0.0523	0.0591	0.0602	0.07109	0.0714
Rotterdam Bunker oil 380CST						
Hedge ratio (β)	1.086	1.016	1.127	1.058	1.201	1.141
Hedge efficiency (R^2)	0.749	0.724	0.706	0.674	0.656	0.635
Standard Error (SE)	0.0489	0.0498	0.0563	0.0570	0.0681	0.0690
Singapore Bunker oil 180CST						
Hedge ratio (β)	1.000	0.934	1.046	0.987	1.121	1.060
Hedge efficiency (R^2)	0.798	0.768	0.765	0.738	0.718	0.689
Standard Error (SE)	0.0610	0.0609	0.0705	0.0712	0.0843	0.0838
Singapore Bunker oil 380CST						
Hedge ratio (β)	1.123	1.047	1.162	1.096	1.236	1.172
Hedge efficiency (R^2)	0.835	0.802	0.784	0.757	0.725	0.700
Standard Error (SE)	0.0484	0.0505	0.0592	0.0602	0.0738	0.0744

Table 12: Hedging performance data for Rotterdam and Singapore bunker oil 180CST and 380CST prices using Singapore 180CST fuel oil futures and Rotterdam 3.5% fuel oil futures, 3, 6 and 12 months from settlement. All contracts show the optimal conventional hedge ratio, and a conventional hedging efficiency for variance reduction in the period from February 2008 until December 2016. The table also show the estimated standard error for the beta variables.

Table 12 shows variance reduction for hedging bunker oil price changes. The hedge ratio is estimated very close to one – with contracts further from settlement showing some increase in beta values. The rate of variance reduction ranges from 69.2% to 79.4% for the 180CST oil, and 63.5% to 75.1% for 380CST bunker oil in Rotterdam. In Singapore bunker oil, efficiency ranges from 68.9% to 80% for 180CST, and from 70% to 83.5% in 380CST. The reduction in variance also increases the closer the contract is to the settlement date, which is to be expected (Hull, 2015). The Singapore fuel oil contract performs slightly better than the Rotterdam contract for reducing variance in the Rotterdam bunker oil market. Results are the same for Singapore. The main difference is that efficiency is higher in Singapore for the 380CST bunker oil, while opposite in Rotterdam, hedging 180CST oil is slight more effective. Regardless, the Singapore fuel oil future explains more of the variance in bunker oil overall and outperforms the Rotterdam contract.

8.1 HEDGING PERFORMANCE IN DIFFERENT TIME PERIODS AND WITH DIFFERENT VARIABLES

Hedging for the entire time span showed good results, but to analyse the data further, I split the data into two groups. One from 2008 to 2012, and another from 2013 up to 2016. The purpose it to locate if there has been any change in hedge efficiency, and if there for instance could be periods where hedging would be more beneficial than others.

Table 13:
Periodic fuel oil hedging performance on bunker oil price changes with different times to maturity (2008-2012)
Data source: Datastream, 2018

	2008-2012					
	3 months		6 months		12 months	
	Singapore 180CST	Rdam 3.5%	Singapore 180CST	Rdam 3.5%	Singapore 180CST	Rdam 3.5%
Rotterdam Bunker oil 180CST						
Hedge ratio (β)	1.081	1.050	1.133	1.098	1.188	1.167
Hedge efficiency (R^2)	0.866	0.854	0.833	0.805	0.781	0.773
Standard Error (SE)	0.0452	0.0472	0.0505	0.0545	0.0578	0.0588
Rotterdam Bunker oil 380CST						
Hedge ratio (β)	1.196	1.160	1.241	1.199	1.288	1.265
Hedge efficiency (R^2)	0.794	0.781	0.749	0.719	0.686	0.680
Standard Error (SE)	0.0647	0.0667	0.0714	0.0756	0.0799	0.0807
Singapore Bunker oil 180CST						
Hedge ratio (β)	0.994	0.959	1.041	1.008	1.092	1.066
Hedge efficiency (R^2)	0.881	0.857	0.846	0.817	0.794	0.777
Standard Error (SE)	0.0389	0.0427	0.0442	0.0482	0.0511	0.0532
Singapore Bunker oil 380CST						
Hedge ratio (β)	1.116	1.068	1.155	1.113	1.203	1.169
Hedge efficiency (R^2)	0.868	0.830	0.813	0.777	0.753	0.729
Standard Error (SE)	0.0462	0.0525	0.0551	0.0602	0.0634	0.0663

Table 13: Shows hedging performance data for bunker oil prices using fuel oil futures, 3, 6 and 12 months from settlement. All contracts show the optimal conventional hedge ratio, and a conventional hedging efficiency for variance reduction in the period from February 2008 until December 2013 with corresponding standard error values for the betas.

Hedging in the first period (2008-2012) reveals increased efficiency as shown in table 13. At most, the difference from the whole period was at 9.1% (0.866 – 0.763) when hedging Rotterdam 180CST with the 3.5% fuel oil future with 3 months to settle. The average increased hedging efficiency was 5.8% compared to hedging for the entire period.

Table 14:
Periodic fuel oil hedging performance on bunker oil price changes with different times to maturity (2013-2016)
Data source: Datastream, 2018

	2013-2016					
	3 months		6 months		12 months	
	Singapore 180CST	Rdam 3.5%	Singapore 180CST	Rdam 3.5%	Singapore 180CST	Rdam 3.5%
Rotterdam Bunker oil 180CST						
Hedge ratio (β)	0.974	0.866	1.019	0.924	1.134	1.024
Hedge efficiency (R^2)	0.684	0.643	0.653	0.626	0.618	0.575
Standard Error (SE)	0.0646	0.0687	0.0677	0.0703	0.0710	0.0749
Rotterdam Bunker oil 380CST						
Hedge ratio (β)	0.931	0.835	0.966	0.880	1.071	0.971
Hedge efficiency (R^2)	0.679	0.651	0.638	0.617	0.598	0.562
Standard Error (SE)	0.0625	0.0651	0.0663	0.0682	0.0699	0.0729
Singapore Bunker oil 180CST						
Hedge ratio (β)	1.012	0.902	1.058	0.961	1.172	1.057
Hedge efficiency (R^2)	0.698	0.662	0.666	0.641	0.625	0.581
Standard Error (SE)	0.0649	0.0687	0.0683	0.0707	0.0723	0.0765
Singapore Bunker oil 380CST						
Hedge ratio (β)	1.134	1.020	1.175	1.077	1.294	1.183
Hedge efficiency (R^2)	0.788	0.761	0.739	0.725	0.684	0.654
Standard Error (SE)	0.0577	0.0613	0.0639	0.0657	0.0703	0.0737

Table 14: Shows hedging performance data for bunker oil prices using fuel oil futures like table 9. An optimal conventional hedge ratio, standard errors, and conventional hedging efficiency for variance reduction in the period from January 2013 until December 2016.

The second period (2013-2016) in table 14 shows quite the opposite, with reasonable less hedging efficiency overall. At maximum, the difference shows a 12% decrease in hedging effectiveness, with an average of 8% decreased performance. If we compare the first period to the second instead of the overall, we find that the average increased hedging efficiency is 13.7% for 2008-2012 compared to 2013-2016 for these fuel oil contracts. The performance is not bad, especially hedging the 380 Singapore bunker oil spot price. Values for the period stretches from 57.5% to 78.8% efficiency. Although this analysis shows a severe difference in variance reduction properties, the beta values have only changed moderately, and are still close to one for most of the contracts. As this periodic analysis should only emphasize the findings from the overall period, the Singapore 180CST contract shows the best performance, regardless of the length to maturity or bunker oil price origin.

The results of the test using both Singapore and Rotterdam fuel oil futures to hedge an average of bunker oil prices in the respective ports proved interesting. Using the model from chapter 7 (equation 21) with two independent variables with coefficients, gave the following results in terms of hedging performance (equation 22):

Table 15: Hedging performance of the average bunker pool using both fuel oil futures simultaneously (2008-2016)
Data source: Datastream, 2018

$$\Delta AvgSpot = \alpha + \beta_1 \Delta Future_{Singapore} + \beta_2 \Delta Future_{Rotterdam} + u_t \quad (22)$$

	Average bunker price hedge model	
	Singapore Fuel Oil 180 cst Futures 3m	3.5% Fuel Oil Barges FOB Rdam Futures 3m
Hedge ratio (β)	2.14	-1.04
Standard Error (SE)	0.388	0.369
Overall model hedge efficiency (R^2)		0.85

Table 15 shows the hedging efficiency and the hedge ratios of the model (22) using a mix of both futures from Singapore and Rotterdam, with prices 3 months from settlement.

The hedging performance is shown to be better than hedging using a single contract for a single bunker price. There is a potential to lose some of the benefit if the recipient is not equally dependent on the variation in the average pool. It still performs better than the single contracts for this period in terms of generating overall variance reduction. With a hedge ratio of 2.138 and -1.035 for the contracts, this could potentially smooth out much of the local variance in the different markets. There is still the issue of multicollinearity which could be part of causing the results, due to the high correlation between the contracts.

8.2 FREIGHT-TO-BUNKER SPREAD

As part of the thesis, one objective was to locate if there were any natural hedging opportunities. Still, an analysis of the spread from freight indexes to bunker oil could show yet another use for fuel oil futures to hedge operational risk. The spread is found by taking the monthly changes of the freight index and subtracting the change in bunker oil price changes. To simplify, only changes in Singapore 380CST bunker oil is used as to measure the spread. The hedging efficiency of fuel oil is tested using the three-month Singapore 180CST fuel oil futures contract. These variables are then placed into the standard regression model:

$$\Delta Spread_{Freight-Bunker} = \alpha + \beta_1 \Delta Future_{Singapore} + u_t \tag{23}$$

Results of the analysis are in table 16 below.

Table 16: Fuel oil futures hedging performance on the freight-to-bunker spread changes (2008-2016)
Data source: Datastream, 2018

	Freight Index	Spreads						
	BALTICF	BPANMAX	BHANDSZ	BSUPRAI	BCAPESI	BTRCLTI	BTRDITI	BALTLPG
Hedge ratio (β)	-0.41	1.21	-0.58	1.20	-0.22	0.19	-0.16	0.64
Hedging efficiency (R^2)	0.01	0.28	0.03	0.22	-0.01	-0.01	-0.01	0.00
Standard Error (SE)	0.297	0.196	0.294	0.227	0.538	0.546	0.571	0.567

As table 16 clearly shows, the hedging performance of fuel oil futures when used to hedge the freight-to-bunker spread is marginal at best. Some (BPANMAX; BUPRAI) showed a hedge efficiency (R^2) of 0.28 and 0.22 respectively, could have some usage – though this requires more analysis to be conclusive. The rest of the spreads showed closed to zero decrease in variation by using fuel oil futures.

9 DISCUSSION

The findings in the thesis indicate good performance of the fuel oil contracts compared to results found by others hedging bunker oil risk in petroleum products. These studies found decent efficiency using gasoil, heating oil and crude oil derivatives. (Gjølberg & Johnsen, 1986; Menachof & Dicer, 2001; Alizadeh et al., 2004). Cross-hedging in other petroleum derivatives could be utilized, but were outperformed by hedging directly in bunker derivatives (Gilleshammer & Hansen, 2010). They used more directly linked derivatives, which should logically perform better (Hull, 2015). In chapter 5.3 and 5.4, the bunker prices were compared to crude oil by looking at changes and the rolling volatility. As bunker is a biproduct of crude oil, it is only natural that a great deal of the variation could be explained in the major oil. But as addressed earlier in the same chapter, there are many factors which influence the local and global bunker oil price but does not have the same impact on crude oil (and vice versa). This further strengthens the validity of the results and explain why previous studies would not find hedge efficiency close to the results found in this thesis and by others which hedge directly in bunker oil derivatives (Gilleshammer & Hansen, 2010).

The hedge performance of fuel oil contracts found in the analysis indicated the same as the preliminary examination performed in chapter 6.2. High correlation between bunker oil spot price changes and fuel oil futures changes also resulted in good hedging performance. For the whole period, the hedging efficiency ranged from 0.635 to 0.835. Overall, the Singapore 180CST fuel oil contract did outperform the 3.5% European based Rotterdam contract. This was also true for the periodic hedge estimations (2008-2012; 2013-2016). The different time periods which were analysed also revealed interesting information. The rate of which hedging is effective, seems to increase drastically in the first period, compared to the second. If this is due to the financial crisis (Samitas & Tsakalos, 2010), or if this is simply due to different variance is hard to say. Both periods have large fluctuations in the rolling variance (see figure 6 and 7), although the period of uncertainty seems to be more severe in 2013-2016 than in 2008-2012 (even though with the drastic price fluctuations). The one thing that seems clear is that there is a time-difference in the efficiency of the hedge, making certain periods more lucrative to hedge – which is hard to predict for future risk management.

One interesting moment here is the ratios (beta values). Although changing slightly, they are still estimated close to one, especially for the Singapore contract. The meaning behind this could illustrate the problems with the futures. High correlation between the futures and spot price changes will estimate high beta values; but the amount of variance reduction achieved (R^2) is much lower – indicating that less of the variance in fuel oil can be explained in the variance of bunker prices. Since this is especially true for Rotterdam, over time, more of the fuel oil could be used for other purposes than mainly producing bunker. More production of other marine oils could for instance lead to a variance spread. This could also indicate that there are storage factors which should be taken into consideration. Low/high supply of bunker would mean that prices could move differently than the source. This was discussed in previous chapters regarding crude oil, and could to some extent also be relevant for fuel oil.

Further, the analysis examines the hedging performance of the average of bunker prices in the two ports. The combined model (see table 16) shows a decent increase compared to hedging a single bunker price in using only one contract the period. This could be a good way to remove both local and global variance in the bunker, especially for vessels which purchases fuel in more than one location. One important factor to be aware of; the increased transaction costs could, as with time-varying hedging (Kauvassanos & Nomikos, 2000; Alizadeh et al. 2004; Gilleshammer & Hansen, 2010) reduce the effectiveness of the hedge. This is because the increase in efficiency could be offset by the required capital to execute several futures contracts for each unit of bunker oil which needs to be hedged.

The potential of hedging in fuel oil contracts seems to be very positive, and the futures seem to inherit the right properties to reduce operational risk. The analysis also revealed results from attempting to estimate hedge performance values for the freight-to-bunker spread. With results close to zero with only a couple of R^2-values distinguishingly above. This indicates that the potential to hedge the spread is practically non-existent. The thesis also raised the topic of a natural hedge situation for the freight rates. Chapter 5.5 presents correlation data between freight indexes and bunker oil prices – and between the monthly changes. Results showed that there is no indication of a natural hedge. With the low correlation from the analysis of fuel oil futures for the spread hedge – the freight rates do not seem to have any relation with either bunker or fuel oil. This indicates that there is no possibility to for either freight rates or bunker oil to hedge one another.

To summarize the discussion; no natural hedge was found in freight rates for bunker oil. There seem to be no relationship between the two. And to reduce operational risk, fuel oil futures should be used to hedge the underlying assets directly. The fuel oil futures seem to perform comparable to other studies (Gilleshammer & Hansen, 2010), with the best hedge efficiency three months out at roughly 80% variance reduction. The Singapore fuel oil futures contract performed better than the similar Rotterdam contract, regardless of time period and maturity. An important note is the low decrease in hedging efficiency for contracts with longer time to maturity. This allows companies which have an interest of hedging bunker price changes over longer periods to secure their costs without significant losses compared to shorter hedges.

10 CONCLUSION

The purpose of this thesis was to investigate how fuel oil futures could be used to reduce price risk in bunker oil. The analysis found that using fuel oil for hedging bunker oil price changes gave predictably good results. Conventional hedge ratios close to one, with hedging efficiency around 80% for the contracts closest to maturity. This is somewhat comparable, though lower than found in studies of directly hedging with bunker derivatives. The relationship between freight rates and bunker oil prices was inadequate to find any natural hedge in the two. Neither was there any findings which supported a possible freight-to-bunker spread.

Fuel oil futures have the proper characteristics to hedge bunker oil price fluctuations. The effectiveness varied somewhat depending on the time period, which corresponds with findings from previous studies on bunker oil. The hedging performance decline with time to maturity shows that the variance reduction would still be sufficient even twelve months from settlement. On a total basis, using a single Singapore 180CST fuel oil futures contract proved to be best suited overall for hedging bunker oil risk in both Singapore and Rotterdam – regardless of time to maturity. This means that the fuel oil futures analysed in this thesis, could provide good variance reduction and be a viable option for reducing bunker oil price risk.

10.1 FOLLOW UP STUDIES

Studies on hedging performance have been done for many different commodities, indices, currencies and other derivatives for a very long time. There is the option “*to test the unbiased hypothesis*” (Gilleshammer & Hansen, 2010) – if the prices of fuel oil futures could work as a tool to predict the future spot prices of bunker oil. Studies on other derivatives could also be of interest, as there are exchange traded swaps and options on fuel oil – could they be more efficient than futures? Another possibility for further review would be to examine OTC-contracts directly on bunker oil. This does require access to data on specific contracts which could be hard to come by, but could give insight on how these contracts could be used for hedging bunker risk and comparing them to the results found in this thesis for instance

In many situations, hedging in other petroleum derivatives would lead to the same conclusion as previous studies (Gjølberg & Johnsen, 1986; Alizadeh et al, 2004); that they would not be as efficient to reduce variance due to the impact of global and local factors which influences bunker prices. This makes way for micro economic studies on the different factors which would influence prices in different ports; for instance, event studies on the variance which is not explained by changes in crude oil prices.

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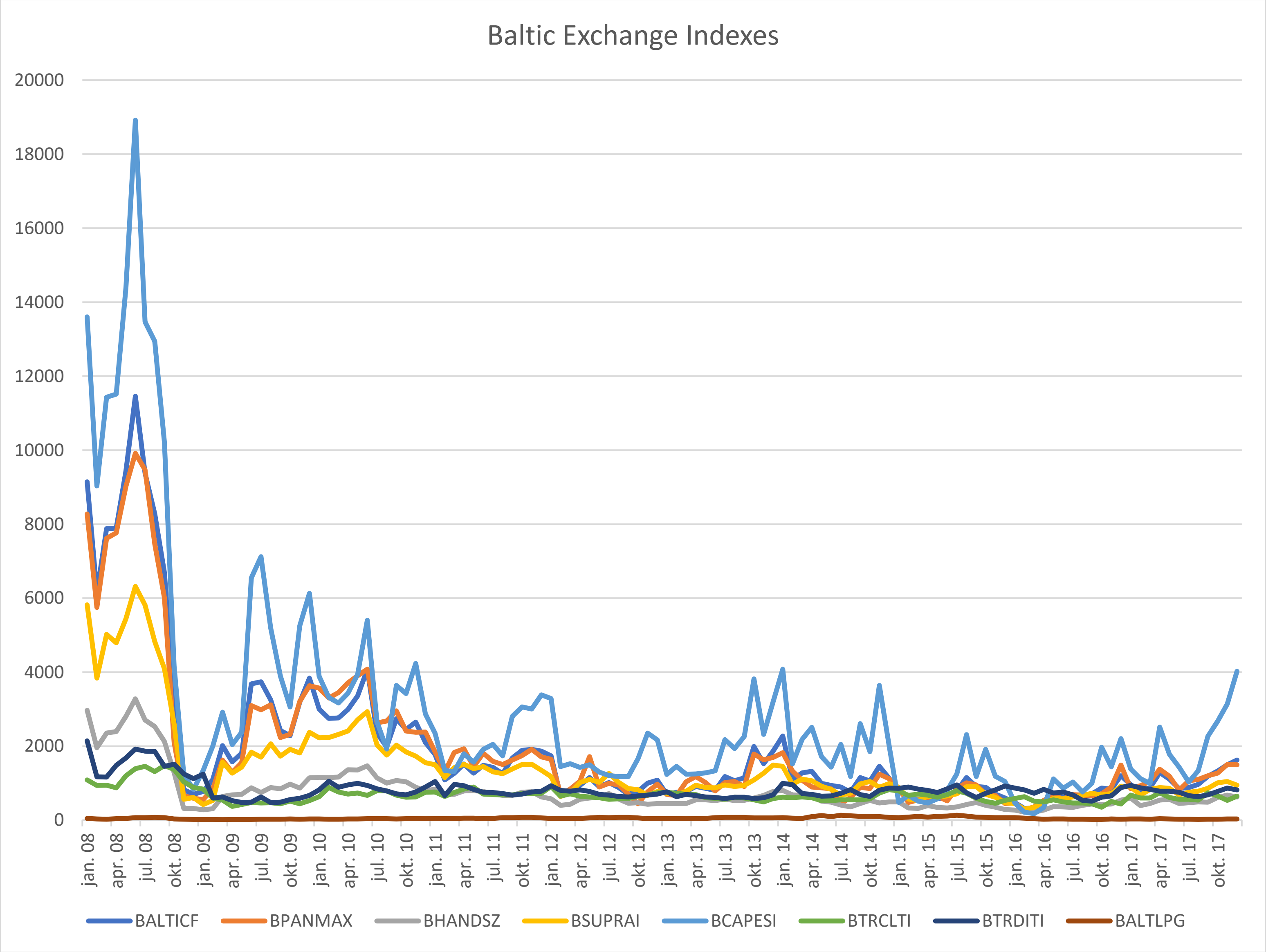
APPENDIXES

APPENDIX 1:

BALTIC EXCHANGE INDEXES FROM 2008 TO 2017



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