NORGES HANDELSHØYSKOLE
Bergen Spring Semester, June 18th 2010

Hedging Risks in Shipping Using Futures Contracts Traded on Imarex

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MSc. Economics and Business Administration

Specialization: Financial Economics

Master thesis

NORGES HANDELSHØYSKOLE

"Uncertainty is the only certainty there is, and knowing how to live with insecurity is the only security" – John Allen Paulos

Abstract

This thesis has studied the hedge performance of some of Imarex's futures contracts for freight and bunker. It starts with a presentation of the shipping market and fundamental theory regarding futures and forward contracts and hedging. This is followed by discussions and analyses surrounding sampling intervals, splicing and choice of contracts.

In-sample studies show a hedge effectiveness ranging from 38.5% to 76.1% for dry-bulk, 42.6% to 45.9% for tanker and 74.3% to 91.3% for the bunker contracts. There are small or no benefits from using time-varying hedge ratios through EWMA, both through in- and out-of-sample studies for freight. The viability of Imarex's futures contracts is discussed through seven criteria for efficient futures markets. For bunker prices, increased cross-hedge effectiveness from using oil futures is found, compared with the results of Alizadeh et al. (2004).

Acknowledgements

We would like to thank Imarex and its employees for all the help they provided us with, especially Erlend Engelstad and Anders Nordahl. We would also like to thank Christer Ødegård at Platts and Michael Ackerman at the Baltic Exchange. Discussions and tips from Professor Petter Bjerksund and Professor Siri Strandenæs were invaluable in the writing of this thesis. Moreover, we would like to thank all friends and fellow students for their support, both moral and otherwise.

We would especially like to thank our advisor, Professor Steinar Ekern, for his constructive feedback throughout the process.

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Table 1 Futures Contracts Used in the Thesis

Category	Underlying product	Contract
Dry-bulk:	Capesize	C4 and C7
	Panamax	P2A, P3A and PM4TC
Tank:	Dirty	TD3
	Clean	TC2
Fuel Oil:	Rotterdam 3.5% FOB:	RMD380FO
	North West Europe 1% FOB	NWE10FO
	Singapore 180 CST FOB	SPO180FO
	Singapore 380 CST FOB	SPO380FO
	US Gulf no. 63% sulphur FOB	USG30FO
Cross Hedge:	ICE Brent crude	ICECO
	ICE Gasoil	ICEGO
	ICE Heating oil	ICEHO
	NYMEX Heating oil	NYMHO
	NYMEX Crude oil	NYMCO

This is a copy of Table 7 from Section 2.5, where the contracts are discussed in detail. This table is added here to provide an overview of the contracts and their abbreviations.

1. General notes

1.1 Introduction

Seaborne transport has been the most important form of transportation of goods for centuries. In the last hundred years, ships have increased spectacularly in both size and efficiency. Moreover, from being an entrepreneur industry where the captain often was the owner, and only had a few ships at the most, the industry today is characterized by large corporations with wide-ranging vessel fleets.

The shipping sector is one of the world's most risky and cyclical industries. The freight rates are highly influenced by the overall world economy, as are the bunker prices. Moreover, shipping firms are exposed to foreign exchange and interest rate risks due to the globalization and capital structure of the industry. The latter two risks have had highly liquid derivative markets for a quite some years. In contrast, the freight and bunker risk have been harder to manage. To expand the risk management toolbox, Imarex, an Oslo Stock Exchange listed marketplace for freight and bunker futures, opened in November 2001. This thesis will examine the hedge performances of some of these futures contracts.

But should a firm hedge? This question is frequently debated in the financial risk management theory. Miller and Modigliani argue that a firm should *not* hedge risk exposure, given some modifying assumptions. They argue that as long as the investor can replicate the hedging strategy the firm cannot add value by managing risk. In practice we see that firms do focus on risk e.g. Grieg Shipping states in their 2008 annual report[1]: *"The group uses various financial derivates to manage its financial market risk. This includes forward contracts, options, interest rate swaps and freight forward agreements (FFA)"*. In other words, the assumptions underlying this theory do not hold in practice. However, the assumptions give a direction on where to look for value adding risk management. This thesis will briefly discuss the Miller-Modigliani Theorem and elaborate on how the shipping industry can reduce and manage their risks through Imarex's futures for freight and bunker fuel.

The thesis investigates the optimal hedge performance for a numerous of freight and bunker oil futures contracts through various strategies for hedging. The findings are compared with results from other futures markets.

[1] See http://www.grieg.no/kunder/grieg/griegmma.nsf/lupgraphics/GSG2008web.pdf/$file/GSG2008web.pdf

1.2 Objectives

The goal of this thesis is to investigate the hedge effectiveness of Imarex futures contracts for freight and bunker fuel. Freight and bunker prices are some of the greatest sources for risk to which an agent in the shipping industry is exposed, and therefore natural to consider for hedging. The thesis will look at the hedge performance of Imarex's contracts on the freight routes PM4TC, P2A, P3A, C4, C7, TD3 and TC2 as well as the bunker contracts for NWE10FO, RMD380FO, SPO380FO, USG30FO and SPO180FO. The thesis will also try to explain why or why not the futures contracts provide good hedge instruments for their underlying prices.

The potential hedge effectiveness of the futures contracts on Imarex has been studied before, however little or no research has been done on the futures bunker contracts. One of the objectives of this thesis is therefore to contribute with empirical studies on the bunker contracts' potential hedge performance, and provide a cross-hedge analysis to compare with previous studies.

1.3 Parties Involved

This part will present the various parties which are relevant to the thesis. These are: Imarex, NOS, the Baltic Exchange and Platts.

Imarex – The International Maritime Exchange

The International Maritime Exchange ASA (Imarex) is a regulated market for freight derivatives and bunker fuel oil derivatives. It opened for trading the 2nd of November 2001, is publicly listed on the Oslo Stock Exchange, and is regulated by Finanstilsynet (the Financial Supervisory Authority of Norway)[2]

NOS – Norsk Oppgjørssentral

NOS (Norsk Oppgjørssentral) is the leading clearing house for freight markets and a specialist clearing provider to the commodities market. It is the clearing house for all Imarex derivatives. NOS merged with Imarex on the 1st of September 2006. Since 2001, NOS has invested significant resources in building a cleared ship freight derivatives market. It has also expanded into clearing service in the emerging seafood market, as well as launched a clearing service for the combined Nordic and German power markets.

The Baltic Exchange

The Baltic Exchange is the only independent source of maritime market information for trading and settling physical and derivative contracts[3]. It provides underlying indices for Imarex's futures contracts. Today, the Baltic Exchange focuses on providing freight market information, dispute resolution and a light regulatory framework for the shipping market[4].

Platts

Platts is a leading provider of energy and metals information[5]. They serve as a provider of the underlying indices for Imarex's bunker fuel oil derivatives. The company is headquartered in New York, but has offices all over the world, such as in Singapore, London and Huston. Platts is a division of The McGraw-Hill Companies listed on the New York Stock Exchange (NYSE).

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[2] Source: http://www.exchange.imarex.com/about-us/
[3] For a complete history and more information on The Baltic Exchange, please see www.balticexchange.com .
[4] Source: http://www.balticexchange.com/default.asp?action=article&ID=395
[5] See the company's webpage for further information. http://www.platts.com/AboutPlattsHome.aspx.

1.4 Outline

Chapter two describes the shipping market in general and divides the market into four sub-markets; the freight market, sale and purchase market, newbuildings market and the demolition market. The chapter also gives a brief description of the dry-bulk, tank and bunker markets in more detail. Finally the chapter introduces a supply and demand model for shipping freight. Moreover, it discusses the key risks in shipping and gives a detailed description of the various futures contracts used in this thesis.

The **third chapter** gives a fundamental introduction to the theory of risk management. First, the question of why firms hedge is discussed in light of the shipping market. Second, the theory on price formation in the forward and futures markets is discussed in detail, emphasizing the non-existence of the cost-of-carry relationship for freight rates. Third, the chapter explains how conventional and time-varying hedge ratios are calculated using OLS regression and Exponential Weighted Moving Average (EWMA) estimations. Finally, the chapter gives a literature review on research which has focused on the hedge efficiency in the freight and bunker markets.

The **fourth chapter** discusses the data series used in the thesis. First, descriptive statistics are presented to describe the nature of the sample. Second, discussions are made on how to splice the futures data series into a continuous series. Third, the consequence of choices of sampling intervals is analyzed and the seasonality in the data is discussed. Finally, the chapter discusses the choice of monthly, quarterly or yearly contracts and the arithmetic average properties of the futures contracts.

The **fifth chapter** presents the results from the study. The chapter is divided into A and B, analyzing the freight and bunker market respectively, starting with an analysis of the in-sample results followed by an out-of-sample comparison. The chapter also tries to answer why the hedge efficiency is lower for non-storable goods. The bunker analysis also provides a cross-hedge analysis using futures contracts traded out-side of Imarex.

Chapter six is the conclusion and **seven** presents a bibliography.

2. Shipping

The International Maritime Organization states that 90% of the world trade today is done by seaborne transport[6]. In 2008, 8,168 million tons were transported internationally compared to 2,566 in 1970[7]. The sizes of the transporting ships have grown exponentially as well: In Adam Smith's book *"The Wealth of Nations"*, he enthusiastically writes about ships that: "carries and brings back 200 tons weight of goods" (Smith, 1776). Today, the largest dry-bulk vessels carry goods of 180,000 dwt (dead weight tons), almost a thousand times the weight which made Adam Smith so enthusiastic. The remarkable expansion in seaborne trade has over the years made the industry highly specialized, where the demand for different transportation purposes has made each ship unique. The ships have different sizes and technology, making them suited to transport a variety of goods. This thesis will focus on the dry-bulk and tank sub-industries, since these sub-sectors represent the most active parts of the freight market. Together they added up to 71.2% of the world total tonnage in 2008[8]. The thesis will also focus on the fuel oil (bunker) market. Bunker costs are said to contribute to almost 50% of voyage costs (Stopford, 2008, p. 160).

In order to realize the importance of financial risk management in shipping, this chapter is meant to give a basic introduction of the industry itself. To get a pedagogical arrangement, the shipping market is divided into four sub-markets, which afterwards are used as a baseline for the discussion of different key risks surrounding the shipping market. In order to investigate the changes experienced over the time period analyzed in this thesis, concerning hedge ratio and hedge performance, it is important to have a deeper understanding of how factors affect each category of vessels. Therefore, the next section discusses the dry-bulk and tank markets exclusively, as well as the bunker market. The chapter ends with a description of the characteristic supply and demand curves experienced in shipping, and a deeper discussion of the different contracts chosen for this thesis.

2.1 The Four Shipping Markets

To easily fathom the complexity of the shipping industry, Stopford (2008 chapter 3) divides the shipping market into four parts: the freight market, the sale and purchase market, the newbuildings market and the demolition market. The interactions between the different

[6] See http://www.imo.org/includes/blastDataOnly.asp/data_id%3D18900/IntShippingFlyerfinal.pdf
[7] The total transportation of goods can be divided in 1 834.1 million tons of crude oil, 915.3 of other oil products and 5 418.6 million tons where transportation of dry cargo.
[8] See http://www.unctad.org/en/docs/rmt2009_en.pdf , page 37

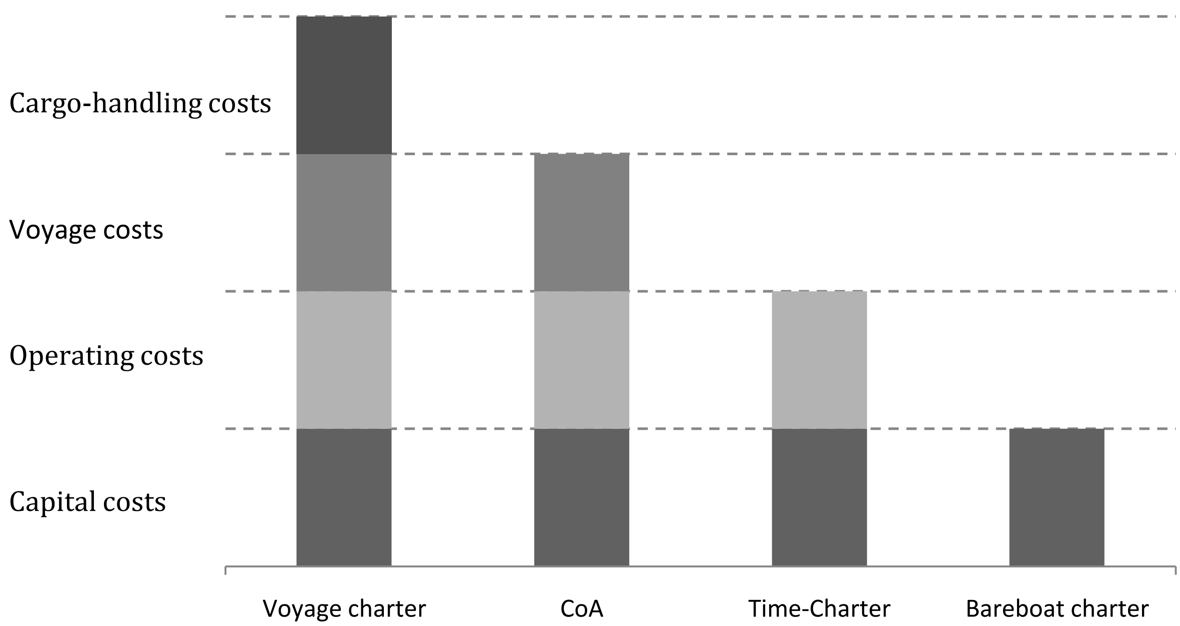
markets are important to be aware of in order to recognize the shipping market cycle. The markets are presented in the section below.

2.1.1 Freight Market

Baltic Shipping Exchange opened in London in 1883[9] and marked the beginning of the development of the freight market known today. The freight market is a marketplace where ship owners and charterers meet to sell and buy freight. As the market developed there are today separate markets for different ships. These markets will in the short-run experience independent fluctuations, but in the long-run these changes tend to converge, because the same agents tend to be in several markets. In addition, it takes time for different vessels to move around from harbor to harbor, which divides the global market into regional markets in the short-run.

A "charter party" is an agreement between a charterer and ship owner, where the ship is either chartered for transport of goods on a single voyage, or the ship as a whole is hired for a period of time. The freight market consists of four main types of these agreements: voyage charter, contract of affreightment, time-charter and bare boat. In Figure 1 these contracts are presented graphically. The figure shows how the costs are distributed between the ship owner and the charterer. The four main contracts are discussed in detail in a section below.

Figure 1 Cost Distributions for Different Charter Contracts.



This figure is adapted from Alizadeh & Nomikos (2009, p. 44). *The size of each cost is not correctly dimensioned and does therefore not represent the relative size of the cost.*

[9] See Stopford (2008, p. 81)

The risk complexity in the shipping industry has made it appropriate to operate with different types of freight contracts. Each contract has detailed specifications concerning the costs and legal requirements, and hence also the risks related to the transport of goods.

A voyage charter contract is a contract where goods are transported from a load port to a discharge port and the ship owner is therefore responsible for all costs on this journey. This includes voyage costs e. g. bunker fuel, port charges, pilotage and canal dues, but also cargo-handling costs, which includes costs related to loading, stowage, lightering and discharging of the cargo[10]. The agreement is linked to a specific route, and the amount of cargo is transported for a fixed price per ton and should arrive on the due date.

A contract of affreightment (CoA) gives the ship owner more room to operate more efficiently, because the due date is more flexible than for the voyage contract. In a CoA the ship owner agrees to carry a *series* of cargo parcels at a fixed price per ton. One example could be if a charterer needed to transport eight consignments of 60 000 tons of grain from North America to Far East over a four month period. This could be solved by using a CoA for all the 480 000 tons of grain.

A time-charter is when a charterer hires the ship over a longer time-horizon. The ship is hired with crew, but the charterer is responsible for fluctuations in voyage costs. On the other hand, the ship owner is responsible for operating and handling costs. The charterer will have the full operational control, but leaves out the management and ownership to the ship owner.

A bare boat contract is when only the financial costs are covered by the ship owner. The charterer then has the full operational control over the ship, without owning it. The owner of a ship might be a professional investor that doesn’t want to operate the ship, but for investment purposes considers it like any normal asset giving a risky cash flow.

In Section 2.5 the contracts are discussed in detail. It is important to note that the tanker contracts are written on voyage contracts, while the dry-bulk contracts are time-charter agreements.

2.1.2 The Sale and Purchase Market

The second hand market for ships is known as the sale and purchase market. The participants in this market represent the same mix of shipbrokers, owners and speculators as in the freight market. The direct link between the sale and purchase market is therefore through the freight

[10] See Alizadeh & Nomikos (2009, p. 44)

rates, which represent the future income of the ship (asset). Fuel prices, age, inflation and ship owners' expectations of the future are also important factors determining the second hand price of a ship.

The second hand price of a specific ship follows a downward trend in the long-run, because new technology is achieved and the ships suffer from normal depreciation. However, it is useful to note that second hand prices follow the shipping cycles. This means that increased freight rates increase the second hand value of the ship in the short run.

2.1.3 The Newbuildings Market

The newbuildings market differs from the sale and purchase market in the sense that it trades ships that don't exist yet. The ships have to be built before they can be delivered to the customers. The delivery time is, in a normal market, between 2-3 years, creating a time-delay lag which is discussed in Section 2.3. The design of each ship is often unique, and only a few ship yards produce standardized ships. This heterogeneity makes it hard to estimate a single index for newbuilding prices, and this issue influences the other shipping markets as well. When a newbuilding contract is discussed, the price, technical specifications of the vessel, terms and conditions and financial issues have to be agreed upon. Stopford (2008, p. 110) argues that newbuilding prices are just as volatile as second-hand prices and that they tend to follow each other quite closely.

2.1.4 The Demolition Market

When the ship cannot be sold in the second-hand market any longer, the ship is sent for demolition. The demolition yards are located in low-cost markets in the Far East such as India, Pakistan, Bangladesh and China. The scrap from the ships are recycled and used as raw materials in production of other goods. In particular, the steel is melted and used in new constructions. Hence, the demolition prices are also influenced by the current steel prices.

2.2 Different Sub-Industries

As already mentioned, the shipping industry has developed into several sub-sectors. This section describes two of these markets: the dry-bulk and tank market. In the end of this section a short description of the bunker market is provided, as it is necessary to have some background information for the analyses in chapter 5.

Please see Section 2.5 for a detailed description of the different vessels and contracts.

2.2.1 Dry-Bulk Market

The dry-bulk market is the market for merchant ships designed to transport unpacked bulk cargo, e.g. iron ore, coal, grain and bauxite. In 2008 the dry-bulk vessels added up to approximately 35% of the total world tonnage[11]. Table 2 shows how the different commodities are distributed on each type of ship.

Table 2 Cargo and Routes of Different Size Dry-Bulk Vessels (Total Shipment per Commodity)

	Commodities (percentage of total shipments)				
(shipment in 2008)	Iron ore (844 mmt)[12]	Coal (814.5 mmt)	Grain (323.3 mmt)	Bauxite & Alumina (83.5 mmt)	Phosphate rock (32 mmt)
Capesize	70%	45%	7%	-	-
Panamax	22%	40%	43%	45%	20%
Handy	9%	15%	50%	55%	80%

	Routes for different commodities		
	Iron ore	**Coal**	**Grain**
Capesize 100,000 – 180,000 dwt	• Brazil to West Europe and Japan and China • W. Australia to West Europe, Japan and China	• E. Australia to Far East, Japan and West Europe • South Africa to West Europe and Far East	• Argentina and River Plate to Near East, and East Europe
Panamax 50,000 dwt - 79,999	• Brazil to West Europe and Japan • Australia to West Europe and Japan	• North America to Japan and West Europe • E. Australia to Far East, Japan and West Europe	• North America to Far East, West Europe and Near East

This table is adapted from Kavussanos & Visvikis (2006b, p. 38) *as their Table 1.2. The table is modified to only contain information about the Capesize and Panamax routes. For details about the Handy please see Kavussanos & Visvikis* (2006b, p. 38). *Mmt is million metric tons.*

Up to 98 percent of all iron ore is used for steel production. Brazil, together with Australia, stands for two thirds of the world's export, with China as the main buyer[13]. Hence, the world seaborne trade of iron ore will be strongly influenced by the Chinese economy and steel prices. The Capesize vessels will have higher cost efficiency on longer routes due to its size. This may explain why Capesize vessels do 70% of the transportation of iron ore.

The transportation of coal is more equally distributed. Capesize and Panamax vessels split the market 45-40, leaving only 15% for the Handy vessels[14]. Coal is also used in steel production,

[11] See http://www.unctad.org/en/docs/rmt2009_en.pdf , page 38
[12] See http://www.unctad.org/en/docs/rmt2009_en.pdf, pages 22-24
[13] See http://www.unctad.org/en/docs/rmt2009_en.pdf page 92. The numbers for coal and grain are also from the same report.
[14] Handy is defined as 25,000 – 49,999 dwt. For other ship sizes, see table 7.

but, dependent on the quality, it serves as an important source of energy for the fuel industry as well. The highest demand for coal is found in Japan, summing up to a total of 185.8 million tons in 2008, with Europe at second place consuming 141.1 million tons. The world's biggest exporters of coal are Australia and Indonesia, together covering 58% of the total export.

The biggest exporter of grain is USA with a total share of 44%, with Argentina (11%) and Canada (9%) next on the list. The list of the biggest importers is more fragmented, because grain is needed in food production all over the world. Stopford (2008, p. 26) presents a shipping cost function showing how the price per ton is related to the parcel size. The cost function declines exponentially when the parcel size increases, revealing economy of scale by using larger ships. The same pattern is seen in Table 2 above where the distribution of commodities on ships follows the exact same pattern proposed by the cost function.

This thesis will focus on the Panamax and Capesize ships. They account for the most liquid parts of the futures markets and suffer from a higher risk level than smaller sized vessels[15]. When the size of the ships increases, the number of available ports and channels declines. This makes the ships less flexible, and therefore also more risky. For that reason risk management in Panamax and Capesize companies might be more important than for companies with fleets of smaller vessels.

2.2.2 Tank Market

The tank market is the market for tankers transporting dirty and clean petroleum products. Dirty petroleum products are crude oil and heavy persistent oils. Clean petroleum consists of oil products free of traces of dark persistent oils, e.g. gasoline. Like the dry-bulk market, the tank market added up to approximately 36% of the world shipping fleet in 2008[16]. A similar table to Table 2 is presented below showing the diversity of cargo and routes for different size of tank vessels. Since the main focus for this thesis is the Very Large Crude Carrier (VLCC), this will be the centre for discussion.

[15]Alizadeh & Nomikos (2009, p. 78-80) compare the volatility of freight rates dependent on the vessel's size. They argue that due to operational inflexibility the larger vessels have a higher volatility.
[16] See http://www.unctad.org/en/docs/rmt2009_en.pdf , page 37

Table 3 Cargo and Routes of Different Size Tank Vessels

	Commodities (percentage of total shipments)		
	Crude oil	Dirty products	Clean products
ULCC/VLCC	60%	-	-
Suezmax	30%	5%	0%
Aframax	10%	35%	20%
Panamax and Handy	0%	60%	80%
ULCC/VLCC	• Middle East to USEC, W. Europe and Far East		

Table 1.3 in Kavussanos & Visvikis (2006b, p. 39). *The table is modified to only contain information regarding the VLCC. Please see the reference for further information about the other the tank vessels. ULCC = Ultra Large Crude Carrier.*

The number of regions exporting crude oil is limited, as is the number of regions importing[17]. At the same time there are strong restrictions associated with the capacity of a given port and the technical specifications of the tanker. The size of the vessels itself makes it suitable only for certain routes. The VLCC is defined with a size of 260,000 dwt in the Imarex contract specifications. The VLCC only transports crude oil, and its main routes follow the trading paths from the oil exporters in the Middle East to the importers in the USA and Western Europe. The total trade of crude oil is influenced by the state of the world economy, in recent years also to a larger extent by rising environmental considerations. In 2008 North America accounted for 27% of the world's consumption of crude oil, taking the next biggest share of the pie together with Asia Pacific (30%) and Europe (24%).

2.2.3 Bunker Market

The maritime transportation industry relies heavily on fuel. Stopford (2008, p. 160) argues that fuel oil accounts for approximately 50% of voyage costs for a typical ship owner[18]. The fuel oil market operates with different classes, where the classes known as residual fuel oils or heavy fuel oils are used by larger ships. This thesis will identify the fuel oil used by ships as bunker fuel.

The markets for bunker are separated geographically, with Rotterdam, Singapore and Houston as the main markets, although other individual markets exist all over the world. The co-movements between these markets are significant, although short-term differences might arise[19]. In 2004, the average volume of bunker fuel was 16 million tons per annum in

[17] For detailed statistics on the world's oil consumption, production, imports and exports sorted by country please see the following EIA (U.S Energy Information Administration) database. http://tonto.eia.doe.gov/country/index.cfm.
[18] Fuel oil costs 47% plus diesel costs 7%
[19] Section 5.B.2.4 presents a correlation matrix proving the co-movements in the main bunker fuel market. The correlations are above 0.78 for all the markets included in the matrix.

Singapore. Rotterdam and Huston had respectively 8 million and 5.5 million tons per annum. Singapore has, with its strategically important geographical position, become the prime benchmark for the world bunker fuel market.

Bunker fuel is also known as residual fuel, because it is the remains after the distillation of crude oil[20]. The bunker fuel is characterized as a dark viscous liquid, almost solid in normal room temperature. According to Kavussanos & Visvikis (2006b, p. 287) there exists two basic grades of fuel oil: Intermediate Fuel Oil (IFO) 180cst (centistokes[21]) and IFO 380cst. Grade 180 indicates a 7-15% distillate content, compared to 2-5% for grade 380. The fuel has higher energy if the distillate content is high. In 2002, 60% of the world trade in bunker fuel was in IFO380, IFO180 accounted for 30%, while the remaining 10% was Marine Diesel Oil.

2.3 Supply and Demand for Shipping Freight

The price dynamics in the shipping freight market is rather complex and needs a detailed description, as the dynamics may affect the results from regression analyses. Stopford (2008, p. 115) argues that ten variables can describe the demand and supply side in the shipping market. These variables are presented in the table below:

Table 4 Ten Variables in the Shipping Market Model

Ten variables in shipping market model	
Demand	*Supply*
1. The world economy	1. World fleet
2. Seaborne commodity trades	2. Fleet productivity
3. Average haul	3. Shipbuilding production
4. Political events	4. Scrapping and losses
5. Transport costs	5. Freight rates

This table is adapted from Stopford (2008, p. 115)

The *demand* curve is characterized as inelastic for a given level of demand, because goods need to be transported from A to B almost regardless of the costs. The demand level can be explained by the five variables for demand listed in Table 4. Since 90% of world trade is done by ship transportation, a change in the growth rate of the world economy will severely affect the demand for seaborne transport. The shipping transportation industry is highly influenced by the business cycles, and these will lay the foundation of the shipping market cycles[22]. The shipping industry also relies on the global trading pattern. The rise of the Chinese economy might change the traditional routes, leading to a permanent shift in the demand curve. The

[20] For a graphical illustration of crude oil qualities please see http://www.chevron.com/products/sitelets/pascagoula/refiningprocess/distillationcolumn.html.

[21] Centistokes is a measure of the viscosity ("thickness") of the fuel oil.

[22] Shipping cycles was introduced by Stopford (2008) and refers to the business cycles experienced in shipping.

demand for seaborne trade is also sensitive to political events such as wars and other political “revolutions”, e.g. various wars between Israel and Egypt have temporarily closed the Suez Canal.

The *supply* side of the shipping market is influenced by the limitations in the world fleet in the short time horizon. If the capacity utilization moves against maximum, the need for newbuildings rises. Normally, it takes between 2-3 years before an ordered vessel is finalized[23]. This time-lag leads to shorter periods of spiking freight rates. However, when the newbuildings enter the freight market, the rates are expected to drop. The supply of seaborne transport also relies on fleet productivity, where new technology can make the ships faster and the port time lower. Technology also affects the production of ships. Better production facilities might lower the delivery time on new ordered vessels.

Stopford (2008, p. 146) presents a diagram explaining the supply and demand for freight rates. A modified version of this diagram is presented below:

Figure 2 Supply and Demand Curves in the Shipping Market in the Case of Low Utilization

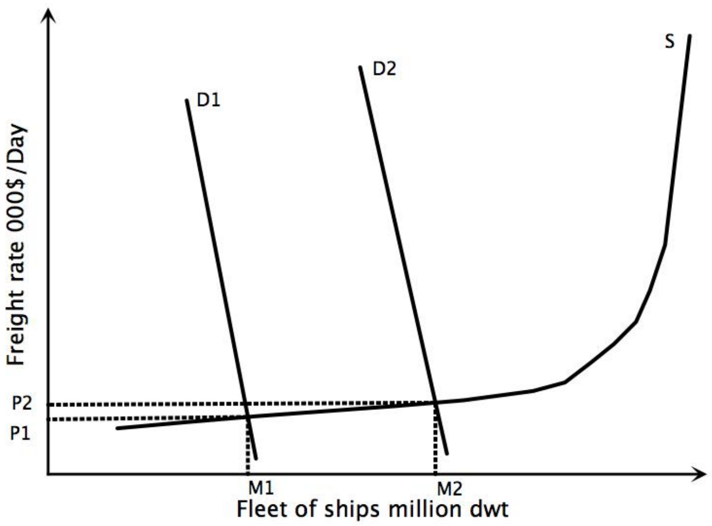


Figure 2 illustrates a situation where there is a lot of free capacity. The size of the total fleet of ships available is far greater than the demand, and the prices for freight are therefore rather low. Assume now a demand shock which causes the demand to shift from D1 to D2. The total use of ships measured in dwt moves from M1 to M2. The change in the price of freight is

[23] An analogy can be made to the housing market where the supply-curve in the short-run shares similarities with the shipping market. Construction of new houses takes time and will therefore cause short-term spikes in the housing prices.

comparatively small, increasing from P1 to P2. If the utilization had been higher, a proper illustration would look like Figure 3.

Figure 3 Supply and Demand Curves in the Shipping Market in the Case of High Utilization

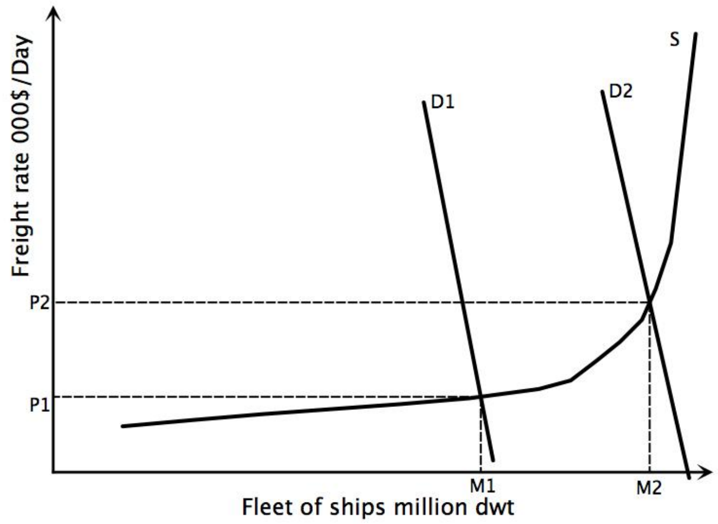
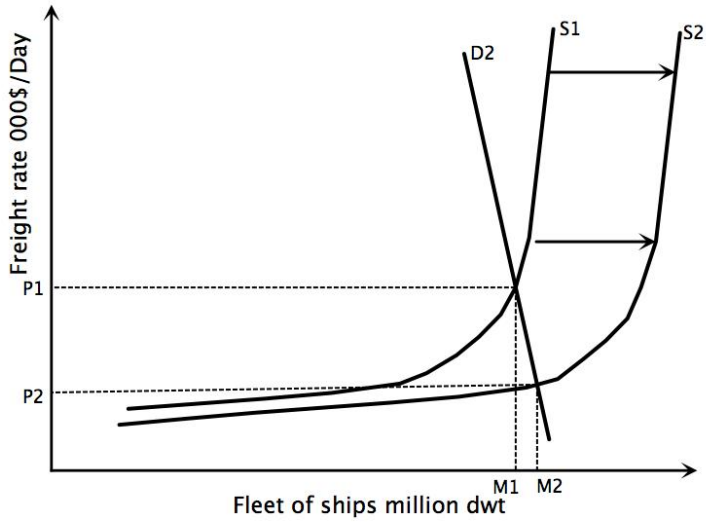


Figure 3 clearly shows that a demand shock at the same size as the one described above will give a higher impact on the price if the utilization is higher. This is due to the convexity of the supply curve. When the demand increases from D1 to D2, the demand moves closer to the maximum capacity of the total fleet of ships. In the short term the total number of ships will be constant, and this will, combined with the inelastic demand curve, increase the price dramatically. When the agents in the shipping market discover the high demand for seaborne transport they will order newbuildings from the ship yard. As mentioned, the delivery time for a new ship is normally between 2-3 years. Therefore it will take time before the level of supply and demand reaches a long-term equilibrium. Figure 4 shows how the supply curve shifts to the right when the newbuildings enter the market.

Figure 4 Increased Supply Due to Newbuildings



The introduction of newbuildings makes the price drop back to levels that might be even lower than the long-term equilibrium. The long-term equilibrium is indicated by supply curve where the world fleet is constantly changing. In the long-term, the supply will meet the demand in such way that the price is equal to the marginal cost. When the utilization again is low, this might cause lay-ups and a higher level of scrapping. This example briefly describes the shipping cycle. The interaction between the four shipping markets is easy to see and the links to risk is sensible. The next section will go deeper in describing the key risks surrounding the shipping industry.

2.4 Key Risks in Shipping

This thesis will focus on key risks in shipping, with special focus on risks related to freight and bunker prices, as these are regarded as the most important factors in the shipping industry. Moreover, the existence of derivatives for these prices on Imarex makes it interesting to study how well they work for hedging these risks.

However, although freight and bunker risks are the most prevalent risks in shipping, they are not the only ones by far. In addition to several others, important ones to mention are interest rate risks, currency (exchange rate) risks and vessel value risks. Table 5 summarizes the different risks that might be considered as the most important ones, as well as the different derivatives available for hedging these risks.

Table 5 Key Risks in Shipping with Respective Risk Management Tools

	Futures	Forwards	Swaps	Options
Freight risk				
Dry-bulk	X			X
Tanker	X			X
Bunker risk	X	X	X	X
Vessel value risk				
New ship price				
Sales and purchase		X		
Scrapping		X		
Currency risks	X	X	X	X
Interest rate risks	X	X	X	X

Table 5 shows the different derivatives available for the different underlying risks as of April 2010. The table is a summary of the derivatives mentioned available for the risks as mentioned in Kavussanos & Visvikis (2006b).

Vessel value risks are the risks related to new ship prices, sales and purchase (second hand prices for ships) as well as scrapping-prices (demolition). As mentioned earlier in Section 2.1.2, Stopford (2008, p. 110) argues that the market for new ships and second hand ships are highly synchronized, whereas the price for scrapping is correlated with steel prices.

Kavussanos & Visvikis (2006b, p. 308) report that "*It is argued that because vessels are the main asset which shipowners hold in order to provide their freight service to the market, and since the sums involved in holding these assets are the largest item in the shipowner's cash-flow, changes in their values can make all the difference in terms of ending up with a profit or loss from their investments in the shipping sector.*" This illustrates the importance of the prices of both new and old ships, as well as scrapping prices, for a shipowner. There are no derivatives available today for hedging new ship prices, although purchasing contracts for new ships often include real options for additional ships. For hedging second hand prices for vessels however, one derivative is available through the Baltic Exchange, namely the Sales & Purchase Forward Agreement. This is an OTC forward contract which covers both the dry-bulk and the tanker markets, and is settled against the Baltic Sale and Purchase Assessment (BSPA). The BSPA is an assessment made by ten panelists on five-year old vessels.

The Baltic Exchange also offers a Baltic Demolition Assessment, which may be used for hedging exposure to scrap prices. This is an assessment on the demolition values of bulk carriers and tankers. For interested readers, please see Kavussanos & Visvikis (2006b) chapter 5 for more information.

The shipping industry is a global industry, meaning that an agent in the industry will probably have to face different currencies in his day-to-day operations, i.e. he is exposed to currency risks. An example could be a ship owner who has to pay management costs in Norwegian kroner, but has revenues fixed in U.S. dollars. This means that the ship owner is exposed to fluctuations in the USD/NOK exchange rate. Table 6 shows a selection of exchange rates, and how they have fluctuated in the past. Notice the great variation in exchange rates in the NOK/USD and the EUR/USD, with respectively 15% and 12% annual standard deviations. Also note that the price for one dollar, measured in Euros, has varied from 0.827 to 1.601 since 2000. These numbers illustrate the potential currency risks an unhedged agent would be exposed to.

Table 6 Statistics on Currencies

	NOK/USD	EUR/USD	RMD/USD	GBP/USD
Average	6.99	1.19	7.86	1.70
Minimum	4.94	0.82	6.78	1.37
Maximum	9.58	1.60	8.28	2.11
Annual std.dev	0.15	0.12	0.023	0.12

Table 6 shows exchange rates from January 3rd 2000 to April 16th 2010 (from July 22nd 2005 for RMD/USD). Averages, minimums and maximum values are calculated from level form, while the standard deviations are based on simple returns. Source: federalreserve.gov.

The shipping industry is by far not the only industry subject to currency risks, and it is therefore not surprising that a wide range of derivatives is available for hedging them. Swaps, options, forwards, futures and hedging through the money markets are some of the derivatives available to agents in the shipping industry. Interested readers should explore Kavussanos & Visvikis (2006b) chapter 6 for further reading on currency risks and hedging in shipping. An excellent non shipping approach on hedging currency risk may be found in Kolb & Overdahl (2010).

Ships are very capital intensive, and it is therefore not uncommon that the leverage of a vessel is 80-90% of its total value[24]. Shipowners are therefore highly sensitive to changes in the interest rates on these loans. Changes in the interest rates on any loans will therefore tend to have a significant effect on the cash flows of a shipping company. As with currency risks, there exists a wide variety of derivatives, available through different sources (financial institutions and exchanges), which may be used for hedging purposes. Kavussanos &

[24] See Kavussanos & Visvikis (2006b, p. 339)

Visvikis (2006b) cover this risk parameter in chapter 7. For a non-shipping approach, please see Kolb & Overdahl (2010) chapter 10.

The risks mentioned above are not a complete list of the risks involved in shipping. Political events, such as wars or trade barriers, or natural crises, such as tsunamis or hurricanes, are just some of the many factors which affect an agent in the shipping industry, bringing even more uncertainty to perhaps the most volatile industry in the world

This thesis will not explore these risks any further, but any agent in the shipping industry looking to hedge exposures would do well to look into these, as well as the risks on which the thesis focuses.

2.5 Futures Contracts Analyzed in This Thesis

The futures contracts used in this thesis are traded on Imarex, except for the contracts used in the cross-hedge analysis for bunker fuel. These are downloaded from Datastream and come from International Petroleum Exchange (IPE) and New York Mercantile Exchange (NYMEX). This section is meant to give a reasonable clarification of the contracts used, to give a basic understanding of the nature of the contracts. For an analysis of the dataset, please see chapter 4.

The thesis uses futures contracts written on three types of markets: dry-bulk, tank and fuel oil. The cross-hedge futures are showed in a separate category for a better pedagogical impression. Table 7 shows how each of the contracts is divided into each category.

Table 7 Futures Contracts and Specifications

Category	Underlying product	Contract
Dry-bulk:	Capesize	C4 and C7
	Panamax	P2A, P3A and PM4TC
Tank:	Dirty	TD3
	Clean	TC2
Fuel Oil:	Rotterdam 3.5% FOB:	RMD380FO
	North West Europe 1% FOB	NWE10FO
	Singapore 180 CST FOB	SPO180FO
	Singapore 380 CST FOB	SPO380FO
	US Gulf no. 63% sulphur FOB	USG30FO
Cross Hedge:	ICE Brent crude	ICECO
	ICE Gasoil	ICEGO
	ICE Heating oil	ICEHO
	NYMEX Heating oil	NYMHO
	NYMEX Crude oil	NYMCO

Freight Route	Size	Description
C4	150,000 dwt	Richards Bay – Rotterdam
C7	150,000 dwt	Bolivar – Rotterdam
P2A	74,000 dwt	Skaw Gibraltar – Far East
P3A	74,000 dwt	South Korea – Japan Pacific R/V
TD3	260,000 dwt	Arabian Gulf – East (Japan)
TC2	37,000 dwt	Continent – USAC (New York)

Source: Imarex webpage: http://www.exchange.imarex.com/products/contract-specifications/ (10.05.10) and specifications on the NYMEX and ICE web pages. See also Kavussanos & Visvikis (2006b, p. 172). *Continent refers to anywhere on the European continent except for the Mediterranean.*

Dry-bulk

PM4TC, P2A and P3A are dry-bulk futures contracts with Baltic Exchange as the provider of the underlying index. These contracts are linked to the Panamax ships with a size of 74,000 dwt. C4 and C7 are Capesize vessels at 150,000 dwt. The price is quoted as USD/day and the lot size is one day. The lot size implies that it is a time-charter futures contract. P2A is linked to the Skaw Gibraltar/Far East route, whereas the P3A goes from South Korea to Japan. The PM4TC contract is constructed as an index contract with equal weight on P1A, P2A, P3A and P4. However, P1A and P4 are not traded in the futures market because of lack of interest from the market agents. C4 is linked to the route from Richards Bay (South Africa) to Rotterdam and C7 is from Bolivar to Rotterdam. This thesis focuses on the monthly-based contracts with delivery from the first index day of the month to the last index day of the month. Imarex also trades quarterly and yearly contracts. The settlement price is the *average* spot prices for the underlying product in the delivery period. Both the choice of monthly contracts and the effects of a settlement price equal to the average spot price in the delivery period are discussed in chapter 4.

Tank

The TD3 contract is a dirty tank futures contract written with Baltic Exchange as the provider of the underlying index. In contrast to the dry-bulk futures, the TD3 contract is a *voyage* futures contract. The contract is priced for a VLCC (Very Large Crude Carrier) vessel at the size of 260,000dwt. The price is quoted in Worldscale points[25] and one lot is equal to 1,000mt. The settlement price is calculated in the same way as for the Panamax contracts, as an average price for the delivery period. The TC2 contract is a clean tanker futures contract also written with Baltic Exchange as the underlying. TC2 is also a voyage futures and the vessel is characterized as a MR (Medium Range Tanker) at the size of 37,000 dwt. The TC2 is linked to the continent – USAC route. As with the TD3, the price is quoted in Worldscale points and one lot is equal to 1,000 mt.

Bunker futures

The bunker contracts differ in respect to the quality and geographical location. The five contracts traded on Imarex represent the main harbor hubs in the world. The quality is equal to 180 CST and 380 CST for the contracts with delivery in Singapore. 1%, 3% and 3.5% from the specifications above indicate the sulphur level in the fuel oil. A higher level of sulphur will cause more damage to the engine than a lower level. The contracts are also specified to be FOB, or Free-on-Board, which is an important contract specification for a ship-owner. The prices are quoted in USD/mt[26].

The Imarex futures contracts are financial futures, meaning that no physical delivery takes place, which are cleared through NOS.

[25] The worldscale is presented in Appendix A.1

[26] One exception is USG30FO which is quoted in USD/bbl. The USG30FO time series is converted into USD/mt to make the contracts more comparable.

3. Risk Management

Financial risk management can be considered as the policies and practice to identify, analyze and control unacceptable risk. One way to control unwanted risk is to use financial derivatives. According to Duffie (1989, p. 3) the trade in futures contracts can be traced back to India and Greco- Rome to about 2000 B.C. Since the 1970's the financial markets have experienced a tremendous growth. They have been getting more advanced, introducing a wide number of exotic contracts to both control and speculate on risk. This thesis will focus on the use of futures contracts from a hedger's view.

The following section will first give a theoretical background as to why firms should hedge. To get a pedagogical structure the focus will start out on forward contracts. The forward contracts are easier to analyze because there is no daily settlement. Thus the next section will discuss forward contracts, how they work, and compare forward and futures contracts. The last two sections will show how futures and forward contracts may be used for hedging with different models for calculating hedge ratios.

3.1 Why Firms Hedge

The famous Miller-Modigliani theorem (Miller & Modigliani, 1958) implied that risk management will not add any value to a firm. Although originally applied to a firm's choice of capital structure, it could also be used to discuss risk management. The theorem was, however, based on a number of assumptions, such as no *bankruptcy costs, taxes, transaction costs* or *asymmetric information*. The assumptions are often not fulfilled in practice. Nevertheless they serve a suitable framework for discussing why risk management in real life makes sense.

Section 2.4 described the shipping market as highly capital intensive and argued that fluctuations in vessel prices could give a significant impact on the profitability of the firm. If a shipping company goes *bankrupt*, large costs are associated with selling off ships and terminating operations. Ship owners may be forced to sell their assets below market price. Hedging could lower the probability of incurring these financial distress costs, thus raising the value of the firm for investors. In addition, hedging may smooth out incomes and costs, making the cash flows more predictable and the company's investment plans easier to implement.

The presence of *taxes* may also create value for risk-managing firms through several sources. Firstly, higher debt levels increase tax savings through debt shields. Secondly, it is known that some countries treat gains and losses differently from a tax perspective. While taxing gains fully, some firms find that they are not able to write off losses on their tax to the same extent as they are taxed gains. Smoothing out losses and gains may therefore prove valuable.

Transaction costs are perhaps the most important reasons why firms should hedge, and not the investor. Access to exchanges such as Imarex is expensive and complicated, and therefore only relevant for specialized shipping companies. Moreover, the risks any given firm are exposed to tend to paint a complex picture, which the executives of that firm might understand to a further extent. However, McDonald (2006, p. 106) argues that the presence of transaction costs also creates some of the main reasons why firms should not hedge. He lists the following examples of why transaction costs and complexity may cause a firm to be disinclined towards hedging:

- High transaction costs makes hedging too expensive
- Assessing costs and benefits of a given strategy requires costly expertise
- The firm must monitor transactions and have managerial controls in place to prevent unauthorized trading
- The firm must be prepared for tax and accounting consequences of hedging. This may, especially, complicate reporting.

Hedging may also prove strategically important, as a firm may be able to follow long-term strategies better, as underinvestment may be avoided. It also makes sense for family companies to hedge. The owners are often not well-diversified and hedging might therefore reduce unwanted risk.

One last reason why firms hedge is that it mitigates agency costs (*asymmetric information*). Which part of performance improvement is due to manager efforts, and which part is due to external circumstances, such as changes in bunker or freight prices, becomes more visible, thus mitigating agency costs.

This list of reasons why firms should hedge is however not complete[27].

3.2 Forward Contracts

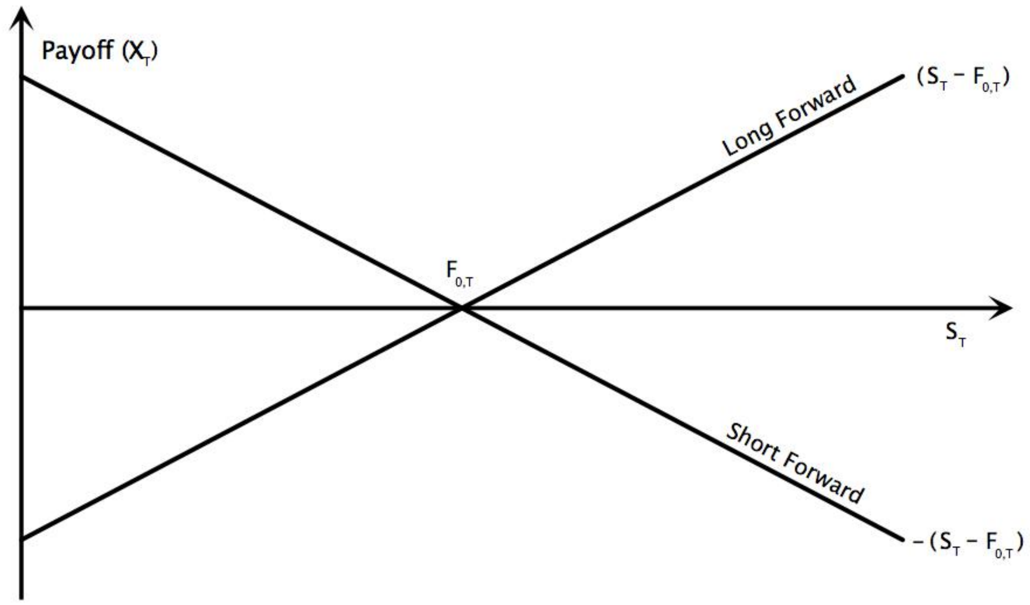
A forward contract is an agreement to buy or sell an asset at a certain future point in time at a certain price. Forward contracts are traded in the OTC[28]-market, usually between two

[27] Please see any text book on corporate finance for further information.

financial institutions, or a financial institution and a client. At maturity the buyer of the forward contract receives the underlying asset. The delivery details are specified up front with clear specifications of features such as regarding Free-on-Board (FOB), quality, location and time. The contracts used in this thesis are traded on Imarex, NYMEX and IPE, all of which are only financial exchanges, meaning that no physical asset switches hands in the end of the period. Only the net profit (loss) goes through a clearing house and to the client.

To get a general intuition first consider a forward contract written on any asset. Graphically the payoff of holding a long or a short forward position is shown in Figure 5.

Figure 5 Payoff From a Long and a Short Forward Contract



A long forward (Hedge): Buying a forward contract is referred to as a long forward contract. The cash flow from a long forward contract gives a positive payoff if the asset price (S_T) at the end of the period (time T) is higher than the contract price (F)[29]. This can be expressed mathematically as $S_T > F_{0,T}$ where S is the price of the underlying asset at time T and F is the contract price agreed upon when settling the contract.

[28] Over-the-Counter

[29] When the forward contract is entered the delivery price (In Hull (2009) notated as K) is set equal to the forward price. During the life time of the forward contract the delivery price stays the same, but the forward price changes. This leaves the value of the forward contact either positive or negative. See Hull (2009, pp. 107-108).

A short forward (Hedge): Selling an asset that is not originally owned is referred to as shorting. The cash flow from a short forward contract gives a positive payoff if the contract price (F) is higher than the price of the underlying asset (S) at time T ($S_T < F_{0,T}$).

The forward contract can be used to hedge risk exposure from the underlying asset for a specific point in time. Consider for example a ship owner concerned about the future price of fuel oil in Singapore. An increase in the fuel oil will reduce the profitability, and since the ship owner knows the exact date, quality and location needed, he turns to the futures market to hedge his exposure. To hedge the risk of fluctuations in the fuel oil price, the ship owner can short futures contracts. At maturity the short futures contract and the long exposure to the underlying fuel oil will lead to a fixed price, equal to the price of the futures contract today. *Please note* that in Section 3.4 the terminology hedge effectiveness is introduced, and explains how hedge effectiveness relates to the example above.

3.2.1 Forward Price for Investment and Consumption Assets

When looking at forward contracts, it is important to distinguish between investment assets and consumption assets. Hull (2009, p. 99): *"[W]e can use arbitrage arguments to determine the forward and futures price of an investment asset from its spot price and other observable market variables. We cannot do this for consumption assets.*" An investment asset is an asset held for investment purposes, such as stocks, bonds, gold and silver. In contrast, a consumption asset is an asset you normally hold for consumption. This can be copper, oil or steel, which is an important factor in many production cycles. Assets such as gold or silver can both be consumption and investment assets, because they are both used in production and held for investment purposes. When this is the case they have to be held by a *significant number* of users to be classified as an investment asset.

The following theory assumes[30] there are no transaction costs. It also assumes the market participants are subject to the same set of tax rates on all net profits and that they can borrow and lend money at the risk-free rate. Furthermore, it assumes the market is efficient[31] - market participants will take advantage of all arbitrage opportunities.

[30] See Hull (2009, p. 101) for an in-depth analysis.
[31] The efficient market hypothesis is an important property in modern finance. It states that asset prices reflect relevant information (Hull 2009, p 780)

3.2.2.1 Forward Price for an Investment Asset

An important question for all market participants is how to determine the correct (fair) forward price. For an investment asset a generalized pricing formula can be expressed as Equation (1) (Hull Eq. 5.1) below.

$$F_{0,T} = S_0 e^{rT} \quad (1)$$

Where S_0 is the price of the underlying asset at time *0*. The underlying asset is categorized as an investment asset which provides no income[32]. T is the time to maturity, r is the risk-free rate and $F_{0,T}$ is the forward price from time *0* to T. This relationship is an arbitrage statement. If $F_{0,T} > S_0 e^{rT}$, the forward price is overvalued, and arbitrageurs will then buy the underlying asset and sell the forward contract. This will yield a risk free return equal to $F_{0,T} - S_0 e^{rT}$. If $F_{0,T} < S_0 e^{rT}$, the forward price is undervalued and arbitrageurs will buy the forward contract and sell the underlying asset. This can be shown using an example from the stock market. Consider a stock trading at a current stock price (S_0) at \$10. In the one year forward contract is trading at \$10.30 and the risk free interest rate is 5%. In this case $10.30 < 10e^{5\% \times 1}$, meaning that the arbitrageur should sell stock in the spot market, place the money in the bank earning a risk free return and buy a forward contract. This arbitrage strategy is explained in Table 8.

Table 8 Forward Price Arbitrage Example

t=0	***t=T***
Sell the stock in the spot market:	Buy back the stock at the uncertain price S_T at time *T:*
$+S_0 = +10$	$-S_T$
Enter forward contract with a present value equal to zero	The cash flow from the forward contract at time T:
0	$-(F_T - S_T) = -(10.30 - S_T)$
Put the money from the stock sale in the bank earning 5% interest rate.	The value on the bank account at time T:
$-S_0 = -10$	$S_0 e^{rT} = 10e^{5\% \times 1} = \$10.51$
0	$\mathbf{10e^{5\% \times 1} - 10.30 = \$0.21}$

The calculations in the table above are made on the following assumptions: $S_0 = \$10$ *r*= 5% $F_{0,T} = \$10.30$ $T = 1$

The risk free return on the arbitrage strategy is \$0.21, which is the difference between the theoretical price and the observed market price.

[32] If the underlying asset provides a known income, such as dividend, the pricing formula is written as: $F_{0,T} = S_0 e^{(r-q)T}$ where q is here a continuously paid dividend rate related to the current spot price. (Hull Eq. 5.3)

3.2.1.2 Forward Price for a Consumption Asset

Consumption assets differ from investment assets in that they are more often subject to storage costs. Moreover, these assets are owned with intention of consumption[33], which gives the consumption assets a convenience yield[34]. Equation (1) (Hull Eq. 5.17) can be rewritten to incorporate both storage costs and convenience yield in the following way:

$$F_{0,T} = S_0 e^{(r+u-y)T} \tag{2}$$

Here u is the storage cost and y is the convenience yield, both expressed as instantaneous proportions of the spot price. Consider once again the arbitrage example above. If an arbitrage opportunity arises, it should quickly disappear because traders buy the undervalued security and sell the overvalued. Thus the supply and demand will change such that the market reaches equilibrium. The owners of consumption assets normally plan to use the asset at some point in time. Forward contracts cannot be consumed and that's why owners of these assets are reluctant to sell their asset. The result is that the forward contract might be undervalued without arbitrageurs managing to exploit the price difference. This is expressed in Equation (3) (Hull Eq. 5.16):

$$F_{0,T} \leq S_0 e^{(r+u)T} \tag{3}$$

3.2.2 Valuing Forward Contracts

Due to the arbitrage example above, the initial value of the forward contract have to be zero. However, the very first minute it starts trading the value will change. Using the same notation as above and by letting *f* be the *value* of the forward contract today, the relationship at time *t* can be written as (Hull Eq. 5.4):

$$f_t = (F_{0,T} - F_{t,T})e^{-r(T-t)} \tag{4}$$

Equation (1) states that $F_0 = S_0 e^{rT}$. If Equation (1) is put in for F_0 in Equation (4) the result is expressed in Equation (5) (Hull Eq. 5.5).

$$f_t = S_0 - F_{t,T} e^{-r(T-t)} \tag{5}$$

[33] These assets are often used in production. For example fuel oil is used in "production" of freight.
[34] Convenience yield is what the owner of the underlying asset earns by holding the underlying asset, but does not accrue the owner of a futures or forward contract on the underlying asset. The oil market is said to be influenced by a high degree of convenience yield due to the flexibility of having oil stored. A ship owner cannot produce freight unless he got fuel oil available.

The value of the forward contract can therefore be interpreted as the net present value (NPV) of the forward price.

3.2.3 Cost-of-Carry

The cost-of-carry relationship is important for a well-functional forward market, because the cost-of-carry function rules out many types of arbitrage. Pricing of forward contracts can also be seen from a cost-of-carry point of view. For storable assets, the price of a forward contract written on the same asset is equal to today's spot price plus the *costs to carry* it forward in time. Such costs include financial costs, but also other costs such as storage, insurance and transportation. Arbitrageurs act quickly in this market to eliminate gaps between the theoretical futures price and the observed market price. Cost-of-carry is explicitly formulated in Equation (6) (Hull Eq. 5.18).

$$F_{0,T} = S_0 e^{cT} \tag{6}$$

In the equation, *c* is defined as the cost-of-carry[35]. This equation holds for investment assets only. In these equations it is assumed that it is possible to go short in the underlying asset and the owner has no reservation of doing so. Therefore, to incorporate the yield of owning the asset for consumption assets, the convenience yield has to be taken into account, as shown in Equation (7) (Hull Eq. 5.19) where y is the convenience yield.

$$F_{0,T} = S_0 e^{(c-y)T} \tag{7}$$

Cost-of-carry arbitrage opportunities will arise if the relationship above is violated. Consider for example a consumption asset, say Fuel Oil 3.5% FOB Barges traded in Rotterdam (RMD380FO), where the spot price is \$457/mt, the cost-of-carry is 6%, the convenience yield is 7% and the time to maturity is one year. The futures contract is currently traded on Imarex at \$460. In this case $F_{0,T} > S_0 e^{(c-y)T}$ because 457$> 460e^{(6\%-7\%)\times 1}$. Therefore, an arbitrageur may buy the fuel oil in the spot market and carry it forward. At the same time he secures the forward price by selling a forward contract. At maturity he can raise a riskless profit of $\$457 - \$460e^{(6\%-7\%)\times 1} = \$1.58$. It should be noted that the convenience yield is hard to measure in practice, and the return from the convenience yield might differ amongst users.

The trade discussed above is possible if the arbitrageur can store the underlying asset. However, some commodities are non-storable, such as freight, electricity or bananas (for

[35] Cost-of-carry is defined as cost of interest plus any other cost associated with carrying the asset forward.

longer time horizons). Kavussanos & Visvikis (2006a) argue that freight services used as the underlying for freight futures contracts are non-storable. This implies that futures contracts on freight are *not* linked through the cost-of-carry relationship found for storable assets. The unbiased hypothesis suggests that futures and forward prices can be used as estimates on the future spot price at maturity. Hence, futures and forward prices serve as *expectations* of the future market price. This means that even though the cost-of-carry arbitrage is not possible, forward prices are linked to the underlying assets through an expectation hypothesis. The expectation hypothesis suggests that the forward price is the expected future price at the maturity of the contract. Equation (8) shows the expectation hypothesis mathematically.

$$F_{t,T} = E_t(S_T) \tag{8}$$

Several studies investigate the unbiased hypothesis in the freight futures markets. To verify the formula above Kavussanos et al. (2004) tested the BIFFEX futures market for whether or not the forward price could be used as an unbiased estimate of the future spot price. One way to test this is to use a least square regression model formulated in Equation 9.

$$S_T = \alpha_0 + \beta_1 F_{t,T} + u_t \tag{9}$$

Where: $u_t \sim Norm(0, \sigma^2)$

The formula is a linear equation where u_t is white noise with the expected value of zero and α_0 and β_1 are estimated through ordinary linear regression. If the futures contract is an unbiased estimate of the spot price then $\alpha_0 = 0$ and $\beta_1 = 1$. The relationship was also tested using vector error correction modeling, proposed by Johansen (1988), which could reliably test for unbiasedness. From these tests Kavussanos et al. (2004) found that the unbiased hypothesis depends on market characteristics, the chosen trading route and the time to maturity of the derivative. More specifically, the results showed that one- and two-months prices prior to maturity are unbiased estimates of the future spot price in all the routes investigated in the article. The prices three-months prior to maturity shows mixed results. The P2 and P2A prices are unbiased predictors of the realized spot price, but the P1 and P1A are biased predictors[36].

Rasmussen & Tversland (2007) found that the one month to maturity futures contracts on Imarex were unbiased predictors of the spot month at maturity, but could not conclude anything on two or three months to maturity, due to a small data sample and residual diagnostics problems.

[36] See chapter 2.5 for detailed description of each route.

The most recent paper investigating the market efficiency in the freight futures market was written by Goulas & Skiadopoulos (2010). This study also looks at the Imarex futures market and uses the various major freight indices to test the unbiasedness hypothesis. They conclude that futures prices can be forecasted and trading strategies yield a profit even when including transaction costs. This indicates that the unbiasedness hypothesis does not hold and hedge efficiency might be affected due to mispricing of futures contracts.

The issue of a non-existing cost-of-carry relationship is also discussed in chapter 5.

3.2.4 Forward vs. Futures Contracts

The theory so far has elaborated on the formation of forward prices. However, this thesis will focus on futures contracts. Table 9 summarizes the differences between forward and futures contracts.

Table 9 Differences Between Futures and Forward Contracts

Forward	Futures
Private contract between two parties	Traded on an exchange
Not standardized	Standardized contract
Usually one specific delivery date	Range of delivery dates
Settled at end of contract	Settled daily
Delivery or final cash settlement usually takes place	Contract is usually closed out prior to maturity
Some credit risk	Virtually no credit risk

The table is adapted from Hull (2009, p. 39).

Futures contracts are traded on an exchange, such as Imarex and NYMEX. For that reason, futures contracts are standardized and are normally listed for a range of different delivery dates. These differences make the futures contracts more liquid and easier to trade compared to forward contracts. From a financial point of view it is essential to know that futures contracts are settled daily, compared to forward contracts which only have cash settlement at maturity. This is done trough NOS, which, to a large extent removes the credit risk often associated with forward contracts. The pricing formulas introduced above are meant to describe price formation of forward prices. The difference between forward and futures prices arise because futures contracts have daily settlements. The daily gains and losses are carried forward at a risk free interest rate, compared to forward contracts where the gain and loss is recognized when the contracts expire. In markets with a positive interest rate the value of a futures position will differ from that of a forward position. If the contract prices have increased on average after the contract was entered, the futures price will exceed the price of the forward contract. On the other hand, a decrease on average will lead to the value of the futures contract to be lower than the forward value. Duffie (1989, p. 227) argues that: *"This effect [interest on daily settlements], is not accounted for properly, cause one to underestimate the effective standard deviation of futures profits and losses, and therefore can cause over-hedging. The effect turns out to be rather mild for short hedging periods and low interest rates, and can be corrected by tailing the hedge…"*. The thesis will from now on assume the interest rates to be low[37], such that the futures and forward prices are approximately the same. Hereafter the notation used for forward contracts will be used for notating futures contract.

3.3 Hedging Using Futures and Forward Contracts

This section will look into the challenges of hedging freight and bunker risks with futures and forward contracts. First, the concept of basis and basis-risk is discussed, followed by a short description of contango and backwardation. Second, a deeper discussion of constant and time-varying hedge ratios is provided. Finally, a literature review forms the expectations of what should be expected in the results in chapter 5.

3.3.1 Basis and Basis-Risk

The difference between the spot price of the underlying asset (S_t) and the price of the futures contract ($F_{t,T}$) is known as the basis (B_t). More specifically[38]:

$$B_t = S_t - F_{t,T} \tag{10}$$

The example in the beginning of Section 3.2 illustrates a simple scenario where there is no uncertainty as to the exact shipment date and quality needed. In practice however, the delivery date might be uncertain. There are also situations were a ship owner wants to hedge freight risk for a Capesize 100,000 dwt, while the Imarex Capesize freight contracts are based on a Capesize 150,000 dwt. In the freight futures market there might also be uncertainty surrounding the route, and a ship owner might use one of the futures contracts available to hedge a different route. All these are examples of what can cause a basis[39].

If the asset that is being hedged and the futures contract used are written on the same underlying asset, the basis has a tendency to converge towards zero when the expiration date approaches. However, as time goes by the spot and the futures prices do *not* necessary change

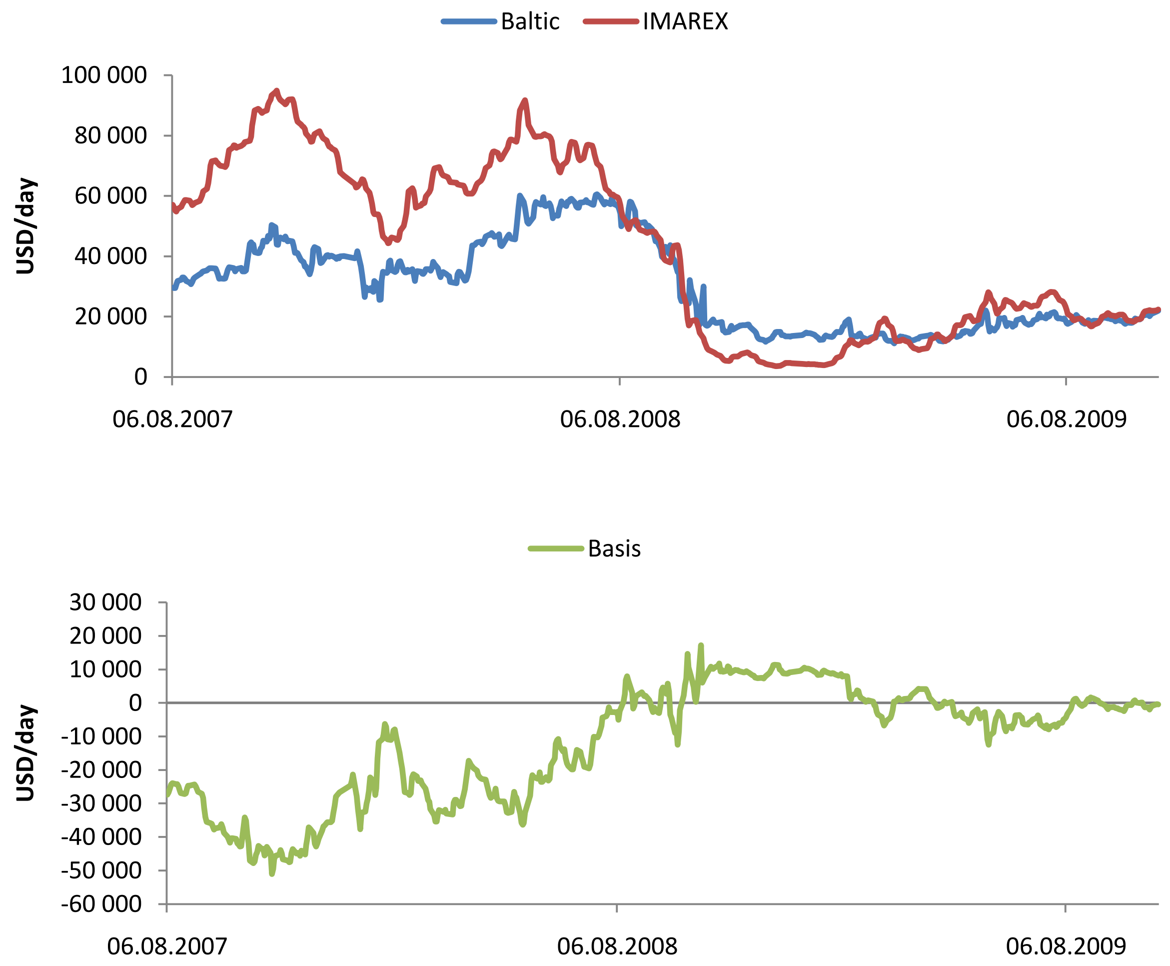
[37] The assumption of low interest rates is somewhat of an over-simplification. Cox et al. (1981) show mathematically that futures and forward prices are equal if the interest rate is known.

[38] Stoll & Whaley(1993, p. 48) defines the basis as $B_t = F_{t,T} - S_t$. Equation 10 is based on Hull (2009, p. 51).

[39] More specifically these examples refers to different types of cross hedging. Changes in convenience yield and storage costs might cause time basis, introduced later in this section.

by the same amount. This is important to understand in relation to hedge effectiveness introduced later in Section 3.4. The basis for PM4TC October 2009 contract is plotted in Figure 6 below.

Figure 6 Basis for PM4TC October 2009 Contract, from 06.08.2007 to 20.10.2009 (Maturity)



The blue line indicates the spot price of the underlying asset, while the red line specifies the futures price. The futures prices are provided by Imarex showing the actual futures prices for an October 2009 PM4TC contract from 06.08.2007 to 20.10.2009. The price of the underlying asset is provided by the Baltic Exchange for the same time period. The green line is the basis and is calculated as the price of the underlying asset minus the futures price at a given point in time.

As can be seen from Figure 6 above, the basis changes over the horizon of the futures contract. In the beginning of the contract the basis is clearly negative, implying a relatively higher futures price. At maturity the basis is approximately equal to zero, backing up the theory described above. This is the case even if the futures contract is correctly priced and there are no arbitrage opportunities. In the example above, the price of the underlying asset and the futures price reflect the same commodity. Therefore the basis can be assumed to be a consequence of what's known as the *time basis*. This is because of the combination of cost-of-carry and convenience yield which gives the contract a time value. The composition of cost-of-carry might change over the horizon of the contract and therefore lead to changes in the basis. When the asset to be hedged differ from the asset of the underlying it is called a *cross hedge*[40]. One example of a cross hedge was made above where a ship owner had a Capesize 100,000 dwt but had to use a contract specified for Capesize 150,000 dwt. A better example can be taken from the aircraft industry where there are no jet fuel futures available. The hedger needs to do a cross hedge using other futures reacting in a similar way as jet fuel to changes in the market conditions. As a rule: a cross hedge is suitable as long as the correlation is not equal to zero. With respect to the value of time and cross hedging the basis may be rewritten as:

$$Basis = Time\ basis + Cross\ hedge\ basis \tag{10}$$

Basis risk

Basis risk refers to unexpected *changes* in the basis, meaning changes in the relationship between the underlying asset and the futures contract. Kavussanos & Visvikis (2006b, p. 89) argues that the basis risk can be described by Equation (11) (Kavussanos &Visvikis Eq. 2.1)[41]:

$$\sigma^2(\Delta B_t) = \sigma^2\left(\Delta S_t - \Delta F_{t,T}\right) = \sigma^2(\Delta S_t) + \sigma^2\left(\Delta F_{t,T}\right) - 2\rho_{SF}\sigma(\Delta S_t)\sigma(\Delta F_{t,T}) \tag{11}$$

Since the basis risk is defined as changes in basis Equation (11) is based on changes not levels. In Equation (11) the notation follows as above and $\rho_{SF}$is the correlation coefficient between the underlying asset and the futures contract. Kavussanos & Visvikis claim that the basis risk mainly depends on the correlation between futures and spot prices. If the correlation is high the basis risk is lower. Hull (2009, p. 53) argues that practitioners will face more basis-risk due to uncertainty in delivery date, the hedge may require the contract to be closed out well before the expiration date and the asset the hedger wants to hedge might not be exactly the same as the underlying asset for the contract. He also states that basis risk increases as the time difference between hedge expiration and delivery month increases. He suggests choosing a delivery month that is as close as possible but after the expiration of the hedge. The result of changes in the basis will give a market participant in a short position a loss when the basis

[40] The cross hedge basis may also be referred to as the "Space and grade basis" which might be a more precise definition. See Stoll & Whaley (1993, p. 32).
[41] The notation in this equation is changed to be aligned with previous notation.

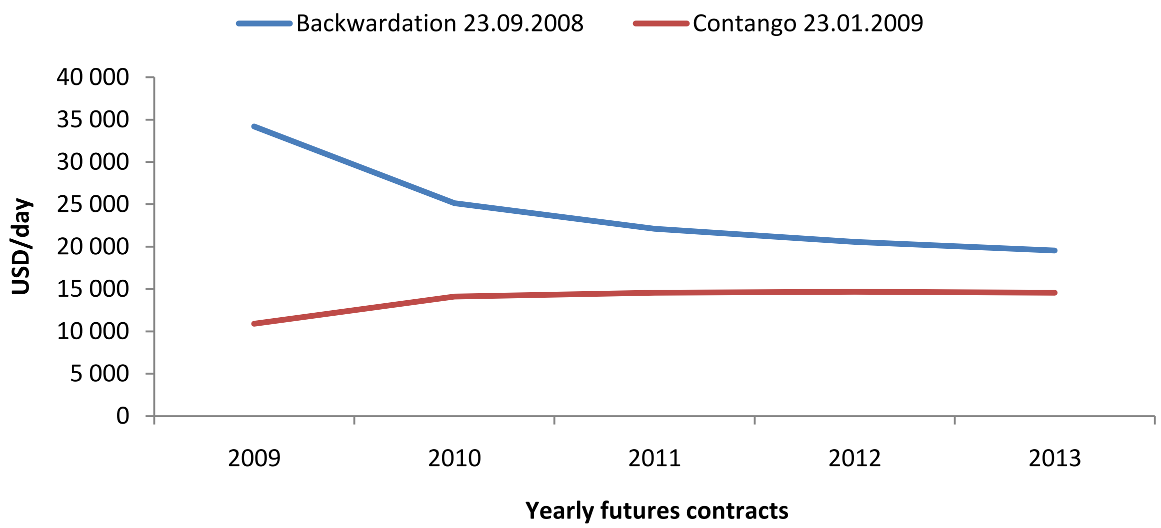
widens. On the other hand, a decrease in the basis will lead to a positive return for an agent holding a short position.

The relationship between the basis, hedge ratio and hedge effectiveness is explained in the Section 3.4.

3.3.2 Contango and Backwardation

The basis is much more predictable than individual rates of spot and futures contracts. For that reason the basis provides important information of the market conditions. Another useful indicator is the term structure of futures prices. An upward sloping forward curve where more distant futures prices are higher is referred to as contango. Backwardation is a downward sloping futures curve, i.e. forward prices more distant in time are lower[42]. This is illustrated the graph below.

Figure 7 Contango and backwardation in the PM4TC futures contract



The futures data is provided by Imarex. The graph shows the futures curve at two different dates, 23.09.2008 and 23.01.2009. The blue line indicates backwardation. The red line shows contango.

Contango and backwardation is an important indicator, because of the expectation hypothesis described in Section 3.2.3. As can be seen from Figure 7 the shortest contracts seem to have a higher volatility compared with the longer contacts. From 23.09.2008 to 23.01.2009, the contract with delivery in 2009 fell 68.1% compared with only 25.5% for the 2013 contract. This implies a higher volatility in the short end relative to the long end. If observations from the summer of 2008 are included (observations before the financial crisis) the market is in

[42] Contango can be mathematically explained as $F_{t,T} > E_t(S_T)$

even steeper backwardation. The freight market turned in the summer of 2008 after a boom lasting several years. This *might* indicate that the freight term structure can be used as an estimate of market movements, a quality also found for other yield curves (Estrella & Trubin, 2006). An analysis of the prediction power of the yield curve is however beyond the scope of this thesis.

3.4 Different Models for Optimal Hedge Ratio Calculations

The futures contract written on the underlying asset is said to be an unbiased estimate of the future spot price. The futures price and the price of the underlying do not, however, move in lock-steps. For that reason it might be optimal to use a hedge ratio not equal to one[43]. This is because the asset you want to hedge is fluctuating more (or less) compared with the asset underlying the hedging vehicle.

This section will discuss different methods for estimating the optimal hedge ratio between futures contracts and the unhedged, asset and derive a formula for calculating the hedge effectiveness. The hedge efficiency used in this thesis is referred to as the *potential* hedge efficiency in Charnes & Koch (2003)[44].

3.4.1 The Ederington Framework

The first framework introduced to address the problem of different changes in spot and futures prices was made by Ederington (1979). He presented a framework for calculating optimal hedge ratios and their hedge effectiveness for futures contracts. The following is a description of how the formulas are derived:

Let S_t denote the value of the hedged item while F_t denotes the value of the future contract at time t. The hedge ratio, h, defines the amount of the hedged item to be bought or sold for every one of the hedged item, i.e. if *h=1.2*, then one should short *1.2* future contracts for every contract in the hedged item. The combined value of the hedged portfolio (P_t) at time *t* then becomes:

$$P_t = S_t - hF_{t,T} \tag{12}$$

The change in value of this portfolio from time *t-1* to t is then defined as:

[43] A hedge ratio equal to one is known as a naïve hedge ratio. This is explained later in this chapter.
[44] They also introduced *attained* hedging effectiveness which referrers to the risk reduction *actually* achieved by the company's choice of hedge ratio and futures contract. In order to compare hedge efficiency among different contracts potential hedge efficiency makes more sense.

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

where $\Delta P_t = P_t - P_{t-1}$, $\Delta S_t = S_t - S_{t-1}$ and $\Delta F_t = F_{t,T} - F_{t-1,T}$. The variance of the hedged portfolio may then be expressed as:

$$\sigma_{\Delta P}^2 = \sigma_{\Delta S}^2 + h^2\sigma_{\Delta F}^2 - 2h\sigma_{\Delta S,\Delta F}, \tag{14}$$

where $\sigma_{\Delta S,\Delta F}$ is the covariance between ΔS_t and $\Delta F_{t,T}$.Since the goal for hedgers is to minimize risk, the expression for the optimal hedge ratio may be found by doing the following steps: Take the first derivative of Equation (14) with respect to *h*:

$$\frac{d\sigma_{\Delta P}^2}{dh} = 2h\sigma_{\Delta F}^2 - 2\sigma_{\Delta S,\Delta F} \tag{15}$$

Then set Equation (15) equal to zero and solve for *h*. Expression 5 is then the expression for the optimal hedge ratio h^*:

$$h^* = \frac{\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta F}^2} = \rho_{\Delta S,\Delta F}\frac{\sigma_{\Delta S}}{\sigma_{\Delta F}} \tag{16}$$

Ederington then uses the percent reduction in the variance from the unhedged portfolio to the hedged portfolio as a measure of hedge effectiveness (*e*). This may be expressed as:

$$e = 1 - \frac{\sigma_{\Delta P}^2}{\sigma_{\Delta S}^2}, \tag{17}$$

Where $\sigma_{\Delta P}^2$ denotes the minimum variance of a hedged portfolio. $\sigma_{\Delta S}^2$ may be expressed as Equation (14) with *h*=0. Inserting Equation (14) into expression 17 gives:

$$e = 1 - \frac{\sigma_{\Delta S}^2 + h^2\sigma_{\Delta F}^2 - 2h\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta S}^2} = \frac{\sigma_{\Delta S}^2 - \sigma_{\Delta S}^2 - h^2\sigma_{\Delta F}^2 + 2h\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta S}^2} = \frac{-h^2\sigma_{\Delta F}^2 + 2h\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta S}^2}$$

To find the hedge effectiveness using the optimal hedge ratio, Equation (16) is substituted into the previous equation. This gives:

$$e = \frac{-\left(-\frac{\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta F}^2}\right)^2\sigma_{\Delta F}^2 + 2\left(+\frac{\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta F}^2}\right)\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta S}^2} = \frac{\frac{\sigma_{\Delta S,\Delta F}^2}{\sigma_{\Delta F}^2}}{\sigma_{\Delta S}^2}$$

The hedge effectiveness may therefore be expressed by Equation (18), which is equal to the square of the correlation coefficient between the change in the spot price and the future price:

$$e = \frac{\sigma^2_{\Delta S,\Delta F}}{\sigma^2_{\Delta F}\sigma^2_{\Delta S}} = \rho^2 \quad (18)$$

3.4.2 Deriving Optimal Hedge Ratio and Hedge Effectiveness Using OLS

Another approach of deriving the optimal hedge ratio and hedge effectiveness is trough a Classical Linear Regression Model. As can be shown, this model will give the same estimates as the Ederington framework, and a link between the two can be explained mathematically.

Following an equivalent notation as above, the Classical Linear Regression Model is defined using the following equation:

$$\Delta S_t = \alpha_0 + \beta_1 \Delta F_{t,T} + u_t \quad (19)$$

Where: $u_t \sim iid(0, \sigma^2)$

Inserting Equation (19) into Equation (13) gives:

$$\Delta P_t = \Delta S_t = \alpha_0 + \beta_1 \Delta F_{t,T} + u_t - h\Delta F_{t,T} = \alpha_0 - (h + \beta_1)\Delta F_{t,T} + u_t \quad (20)$$

The variance of the risk minimizing portfolio is then changed to:

$$\sigma^2_{\Delta P} = \beta_1^2 \sigma^2_{\Delta F} + h^2 \sigma^2_{\Delta F} + 2h\beta_1 \sigma^2_{\Delta F} + \sigma^2_u \quad (21)$$

To minimize the variance of this portfolio, derive Equation (21) with respect to h and set equal to zero:

$$\frac{d\sigma^2_{\Delta P}}{dh} = 2\beta_1 \sigma^2_{\Delta F} - 2h\sigma^2_{\Delta F} = 0$$

Solving for h gives the optimal hedge ratio:

$$h^* = \frac{2\beta_1 \sigma^2_{\Delta F}}{2\sigma^2_{\Delta F}} = \beta_1 \quad (22)$$

The optimal hedge ratio is thus the slope coefficient from the regressing ΔS_t and ΔF_t, β_1.

Finding hedge effectiveness through a regression analysis is then done by still using the hedge effectiveness defined as Equation (17), and expressing it as:

$$e = 1 - \frac{\beta_1^2 \sigma_{\Delta F}^2 + h^2 \sigma_{\Delta F}^2 - 2h\beta_1 \sigma_{\Delta F}^2 + \sigma_u^2}{\sigma_{\Delta S}^2}$$

As proven earlier, the optimal hedge ratio, h^*, is equal to β_1. This is inserted into the above equation:

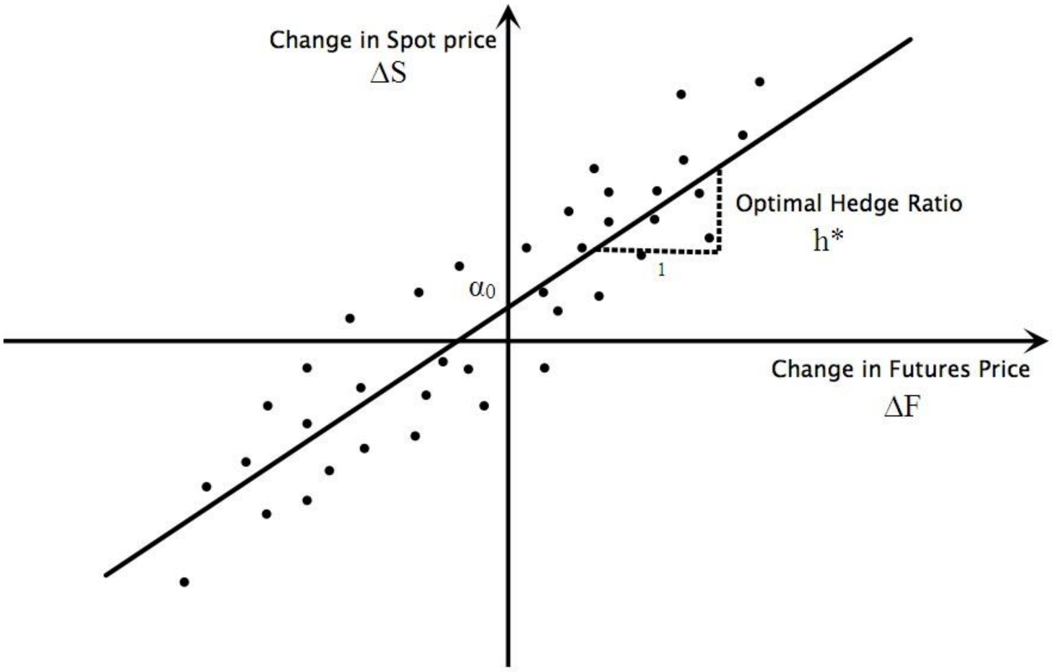
$$e = 1 - \frac{\beta_1^2 \sigma_{\Delta F}^2 + (\beta_1)^2 \sigma_{\Delta F}^2 - 2(\beta_1)\beta_1 \sigma_{\Delta F}^2 + \sigma_u^2}{\sigma_{\Delta S}^2}$$

This shortens to Equation (23), which shows that the hedge effectiveness is equal to the coefficient of determination, R^2.

$$e = 1 - \frac{\sigma_u^2}{\sigma_{\Delta S}^2} = R^2 = 1 - \frac{RSS}{TSS} \tag{23}$$

In the OLS estimations RSS is the residual sum of squares and TSS is the total sum of squares. R^2 is therefore a measure of how well the estimated regression lines fits the actual observations.

Figure 8 Optimal Hedge Ratio and Regression



The plot is only hypothetical and is inspired by Hull (2009, p. 56)

Figure 8 presents the relationship between hedge ratio, hedge effectiveness and basis graphically. The beta coefficient is the optimal hedge ratio, R^2 describes the hedge efficiency and the intercept is the basis.

Figure 9 shows graphically an example of the relationship between the hedge ratio and the variance of the portfolio (blue line). The example illustrates the variance of a combined portfolio of spot and futures prices for NWE10FO bunker fuel. The red line shows the variance of the spot prices (513.3215), and the red line shows the minimum variance possible during that period (2005-2009) using a hedge ratio of 0.921[45]. Taking positions in the futures contracts of above 1.83 or below 0 will result in a higher variance of the combined portfolio than in the spot prices alone (speculation). Any hedge ratio between 1.83 and 0 indicates hedging.

Figure 9 Illustrating the Hedge Ratio

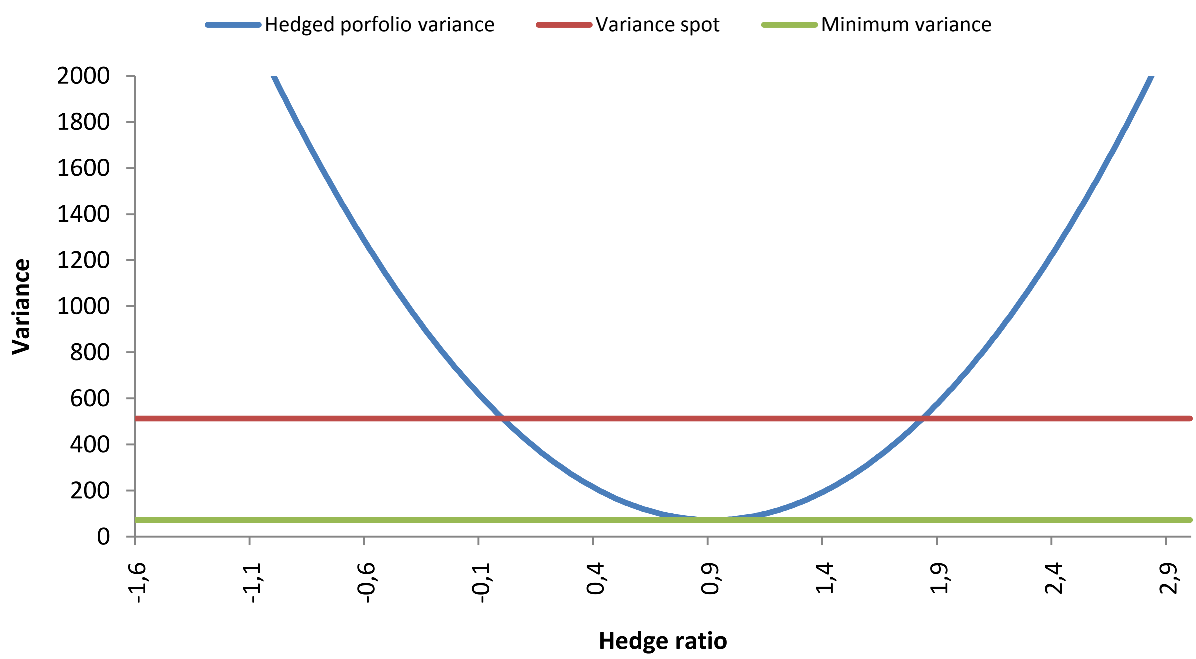


Figure 9 illustrates the hedge ratio using the NWE10FO futures contract. The underlying spot prices are provided by Platts.

3.4.3 Optimal Number of Contracts

Finding the optimal number of futures contract to use is a matter of finding the futures contract that gives the least basis risk when accumulated in a portfolio with the spot price. Let Q_A be the size of the position being hedged and Q_F be the size of *one* futures contract, both

[45] 0,921 is the optimal hedge ratio presented in table 28.

measured in units. The optimal number of futures contracts (N^*) is given by Equation 24 (Hull Eq. 3.2).

$$N^* = \frac{h^* Q_A}{Q_F} \tag{24}$$

3.4.4 Tailing the Hedge

Section 3.2.4 investigates the difference in futures and forward prices, and specifies the interest earned on the marked-to-market[46] cash as the main obstacle when comparing futures and forward prices. For the same reason positions needed to hedge a futures are smaller than for a hedge in a forward contract. If the same amount of contracts are used in both cases the futures position will be overhedged. Dealing with this problem is called tailing the hedge. The equation below (Hull Eq. 3.3) shows similarities with Equation 24. However, V_A and V_F measures now the *dollar* value of the position being hedged and the dollar value of one futures contract.

$$N^* = \frac{h^* V_A}{V_F} \tag{25}$$

Both Equation 24 and 25 include the same hedge ratio. Thus, the discussion in this thesis will focus on the estimation of the hedge ratio and leave out the method of tailing the hedge.

3.4.5 Underlying Assumptions for Ordinary Least Squares (OLS)

The Classical Linear Regression Model (CLRM) is based on five assumptions concerning the errors from the regressions (u_t). If these assumptions hold, the estimators from the regressions will be the Best Linear Unbiased Estimators (BLUE) of their true values. An estimator is BLUE if it has the minimum variance among the class of estimators. If the assumptions do not hold, this may have consequences for the results.The assumptions are:

1. The errors have zero mean: $E(u_t) = 0$
2. The errors have a constant and finite variance over all values of t: $Var(u_t) = \sigma^2 \; \forall t$
3. The errors are statistically independent of one another: $Cov(u_i, u_j) = 0, \forall \; i \neq j$
4. No relationship between the residuals and the explanatory variables: $Cov(u_t, x_t) = 0$
5. The errors are normally distributed: $u_t \sim N(0, \sigma^2)$

[46] Futures contract uses daily settlements.

More on these assumptions may be found in most econometric books, such as Brooks (2002). Assumption 1 is easily remedied by including a constant term, and assumption 4 is considered beyond the scope of this thesis to look into, and these will therefore not be given any further weight. Tests for assumption 2, 3 and 5, including numerical examples, may be found in Chapter 5.A.1 and 5.B.1.

3.4.6 Time-Varying Hedge Ratio - Exponentially Weighted Moving Average Model

The Ederington framework assumes a static relationship between the price of the futures contract and the underlying asset. In practice this is seldom observed, and asset volatility tends to vary over time. This is also the case for freight derivatives. Kavussanos & Visvikis (2006a, p. 58) show that it is not only the average freight rate that is affected by the market conditions. The market cycle also causes changes in volatility levels, as seen in Section 2.3, discussing the supply and demand curves in the shipping industry. In their study they find that both a vessel's size and the length of the time-charter contract seem to affect the volatility e.g. the spot prices tend to have much higher volatility than the time-charter contracts. These conclusions verify the need to tackle time-varying volatility and covariance. This thesis will use the Exponentially Weighted Moving Average Model (EWMA), but first a simple form of time-varying volatility is introduced.

One way of including a time-varying estimate of volatility would be a rolling-window estimate. This method is based on standard BLUE estimation of variance, based on a sample (Window) of *M* most recent observations.

$$\hat{\sigma}_{t+1}^2 = \frac{1}{M-1} \sum_{i=t-M+1}^{t} (r_i - \overline{r_t})^2 \tag{26}$$

In Equation 26 r_i and $\overline{r_t}$ is the return and mean return at time *t*. This estimation method will incorporate the aspects of volatility changing over time. However, there exist more advanced methods which might give better estimates. One problem with the rolling-window method is known as the ghost-feature. This problem arises as the rolling-window either gives full weight to an observation within the window, or zero weight to the observations just outside the window. When an influential observation leaves the window a large jump in volatility might be observed, even though this has nothing to do with recent changes in volatility.

A more advanced method is through using Exponentially Weighted Moving Average (EWMA). This method can be described by Equation 27:

$$\hat{\sigma}_{t+1}^2 = (1-\lambda)\sum_{i=0}^{\infty} \lambda^i r_{t-i}^2 \tag{27}$$

This model introduces λ as a decay factor which is defined as a weight between zero and one. For simplicity it is assumed the mean weekly return to be zero, unless the formulation would have to incorporate the mean return of the time series[47]. By recursively substituting, Equation 28 might be written as (Hull Eq. 21.7):

$$\hat{\sigma}_{t+1}^2 = \lambda\sigma_t^2 + (1-\lambda)r_t^2 \tag{28}$$

Equation (28) shows that today's variance is a weighted average of yesterday's variance and yesterday's squared return. The first observation has to be specified by the model's user. The covariance may be estimated using a modified version of Equation (28) (See Hull (2009, p. 492)):

$$\widehat{cov}_{t+1}^2 = \lambda cov_t + (1-\lambda)x_t y_t \tag{29}$$

where *x* and *y* represent the first difference changes in the two data series. The covariance estimates have a similar interpretation as the variance, and they are therefore discussed as one in the discussion below.

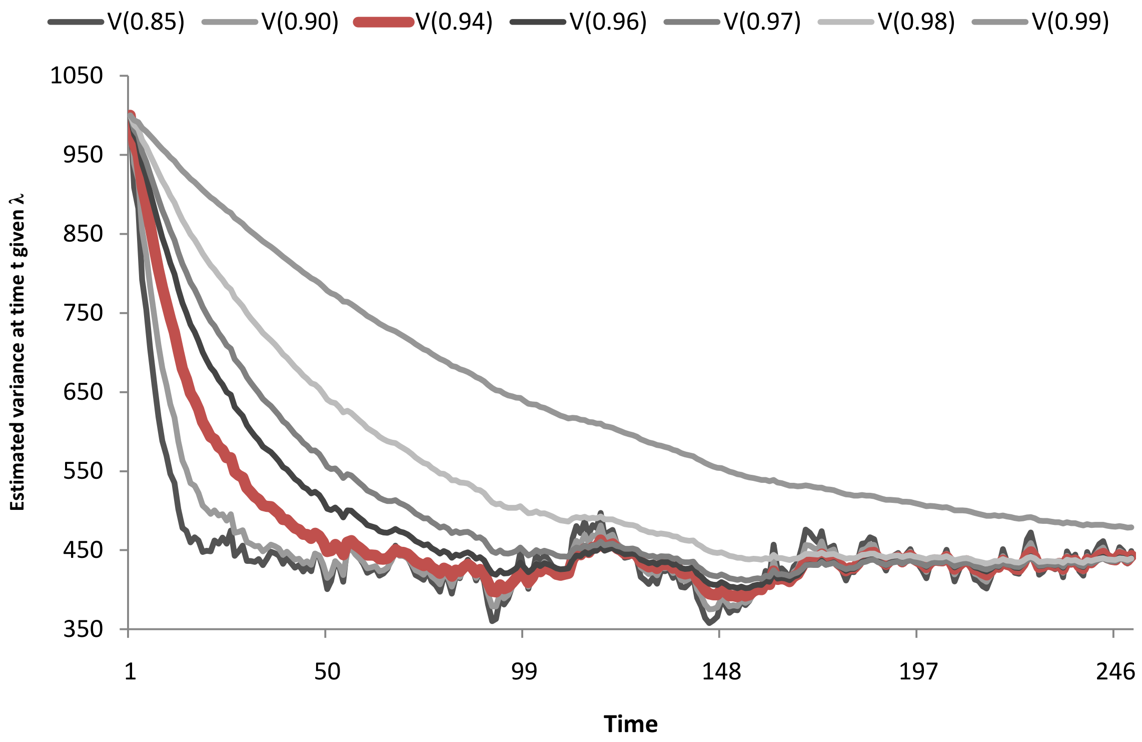
The choice of decay factor is analyzed by Jorion (2001). In the following a similar analysis is done using the statistical properties of the TD3 freight contract. When running a Monte Carlo simulation, a normal distribution with a zero-mean and a standard deviation equal to 20.8 is assumed. This is the corresponding statistical properties of the spot rates for the tanker route TD3[48]. Figure 10**Error! Reference source not found.** shows a Monte Carlo simulation of 50 variables expressed by 250 observations. To focus on the effects of the decay factor each curve shows the arithmetic average of the 50 variables *given* the decay factor. The initial shock is set to a variance of 1000. This is more than twice the constant variance estimated at 432.6, creating a large shock assumed to give a permanent effect on the variance. However, the weight on the shock will depend on the decay factor. The figure below illustrates how each decay factor responds to the initial shock.

---

[47] Equation (28) would have to be rewritten as $\hat{\sigma}_{t+1}^2 = (1-\lambda)\sum_{i=0}^{\infty} \lambda^i (r_{t-i}^2 - \bar{r}_{M,t-1})$

[48] The static variance estimate for TD3 is 432.6, which corresponds to a standard deviation of $\sqrt{432{,}6} = 20{,}8$. A mean of zero is just a simplifying assumption to stress the effects of changing the decay factor.

Figure 10 Different Decay Factors and Conditional Variance Using TD3 Weekly Observations



The graph shows weekly observations of the estimated time-varying volatility. The underlying spot prices are used. The spot prices are provided by Baltic Exchange.

Figure 10 shows the relationship between an initial shock and the choice of decay factor. When $\lambda \rightarrow 1$ the model will increase the weight on the historical volatility, hence it will take longer time before the estimates reach the static volatility approximation. Furthermore, when $\lambda \rightarrow 0$ historical observations become less important and the volatility estimates will converge towards the weekly change. One common approach to choose decay factor is to optimize an economical or statistical criterion Jorion (2001, p. 194). In practice it will be time consuming to optimize every time series separately. The decay factor might also fluctuate over time making the different time periods inconsistent. In practice RiskMetrics sets the decay factor equal to 0.94[49]. In the following analysis the authors use a decay factor equal to the RiskMetrics standard. According to the analysis above the first 50 observations should be treated with caution when analyzing the volatility estimates, because they might be affected by the assumption of the initial value. The best thing would be to remove them from the sample, but

[49] RiskMetrics is a computer software design to estimate risk and risk exposure. RiskMetrics uses a decay factor equal to 0.94 for daily data. RiskMetrics suggests a decay factor of 0.97 when using monthly data. Even though the sample used in the thesis consists of weekly data, the authors chose to use 0.94 for simplicity. This choice will affect the results from the time-varying hedging performance. See http://pascal.iseg.utl.pt/~aafonso/eif/rm/TD4ePt_2.pdf for more information about RiskMetrics.

this would also remove valuable information due to the small size of the sample. However, one way to correct this weakness would be to change the assumption of the base volatility. To minimize the gap between the short and long term volatility the base is set equal to the static volatility estimate of the complete observation period. This will be better than assuming a variance equal to zero for the first observation.

EWMA is used to estimate time-varying variance estimates for both the futures price and the price of the underlying asset. It is also used to estimate the time-varying covariances.

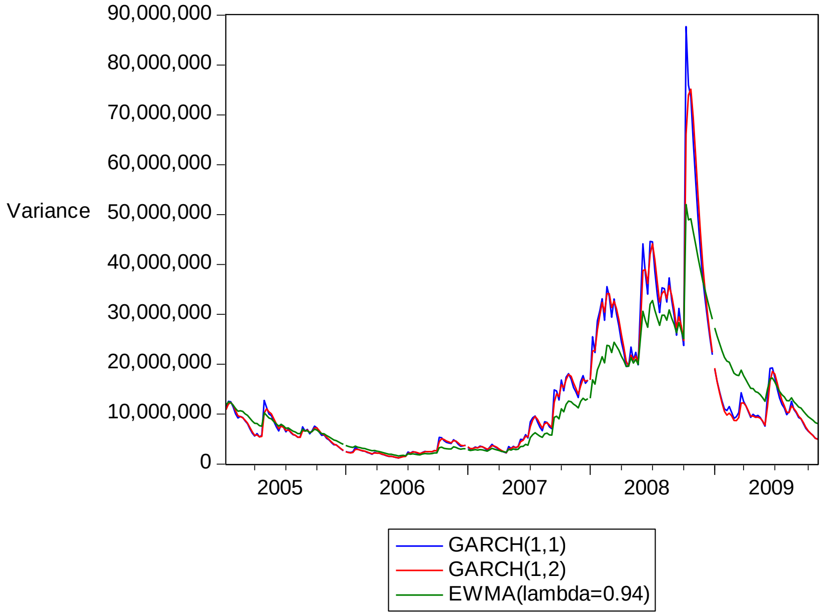
It should be mentioned that the rolling window and the EWMA-method are only two estimating methods for modeling changes in volatility over the time horizon. Many authors in the risk management literature choose the Generalized Autoregressive Conditional Heteroscedasticity Model (GARCH) and varieties of GARCH models. The GARCH model can be written as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \cdots + \alpha_p u_{t-p}^2 + \beta_1 \sigma_{t-1}^2 + \cdots + \beta_q \sigma_{t-q}^2 \tag{30}$$

Where: $u_t | \Omega_{t-1} \sim N(0, \sigma_t^2)$

In Equation 30 u_{t-1}^2 is the squared error from period *t-1*, α_0 is a constant and $\beta_i = (1,2,3 \ldots q)$. Figure 11 below shows the time-varying variance for PM4TC using EWMA (λ=0.94), GARCH(1,1) and GARCH(1,2). EWMA seems to give a lower estimate of the variance from 2007 to mid 2008. In mid 2008 the EWMA apparently shows a higher volatility compared to GARCH(1,1) and GARCH(1,2). This again is dependent on the decay factor used in the estimation of EWMA.

Figure 11 EWMA, GARCH(1,1) and GARCH(1,2) Compared



The graph shows the time-varying variance for the underlying spot price for PM4TC using different estimation methods. The spot prices are provided by Baltic Exchange.

It can be shown mathematically that EWMA is a GARCH(1,1) model where $\alpha_0 = 0$ and $\beta_1 = 1 - \alpha_1$. This thesis will use the EWMA method. Empirical research on time-varying hedge ratios shows that the differences between different estimation techniques are rather small[50].

It is important to note that the hedge ratios calculated from OLS will be termed *conventional* hedge ratios, while the hedge ratios calculated using EWMA will be termed *time-varying* hedge ratios. The hedge effectiveness of conventional and time-varying hedge ratios are compared with the hedge effectiveness of using a so-called "naïve" hedge ratio. This is a hedge ratio based on earlier misconceptions of movements in spot and futures markets, where it was believed that these would be the same in both direction and size, indicating an optimal hedge ratio always equal to -1. This naïve belief has been shown to be wrong, in some cases so much so that the naïve strategy may *increase* the risk of the hedger instead of decreasing it.

[50] See Rassmusen & Tversland's results on page 70. For example PM4TC proved a hedging effectiveness equal to 33.45% using a constant hedge ratio. The different time-varying models resulted in a hedging effectiveness of 33.45%, 33.44% and 34.26%. The differences between the constant and time-varying hedge ratio may be higher when using an out-of-sample test.

3.4.7 Literature Review

This section will provide information on earlier studies on subjects this thesis will look into, as well as expectations on what the studies will reveal.

Earlier studies on the hedge effectiveness of freight futures have provided bleak results for shipping agents. Thuong & Visscher (1990) looked into the hedge effectiveness of the futures contracts on 13 different routes composing the Baltic Freight Index. Through varying hedge periods and contract maturities, they reported hedge efficiencies ranging from 0.5% to 33.7%, using conventional hedge ratios in an in-sample study.

Kavussanos & Nomikos (2000) investigated the hedge performance of BIFFEX's futures contracts on freight (Route 1-10, Route 1A, Route 2A and Route 3A as well as the Panamax and Capesize contracts), and their findings were in line with the findings of Thoung & Visscher. Using naïve, conventional and time-varying hedge ratios (through VECM, VECM-GARCH and VECM-GARCH-X modeling), they reported maximum hedge effectiveness of 18.96% for in-sample studies, and 22.77% for out-of-sample studies. BIFFEX then altered the composition of the underlying index in order to attempt to improve hedge effectiveness, and Kavussanos & Nomikos (2000) reported variance reductions ranging from 18.46% to 39.95% for the altered contracts on Route 1-3, Route 1A-3A and Route 9 for in-sample studies using conventional hedge ratios.

Skjetne (2005) looked into the hedge effectiveness of Imarex's futures contracts for TD3, TD4, TD5, TD7, TD9, C4 and C7. He reported hedge effectiveness of between 37% and 70% for these contracts.

Rasmussen & Tversland (2007) also looked into the hedge effectiveness of futures contracts available through Imarex, though focusing on contracts on Panamax ships (P1A, P2A, P3A, P4 and PM4TC)[51]. Using naïve, conventional, LRM AR(p) and VAR(2) modeling for constant hedge ratio calculations, and VAR(2)-GARCH modeling for time-varying hedge ratios, they reported hedge effectiveness ranging from 29.5% to 34.26% for in-sample studies. Although concluding that time-varying hedge ratios outperformed constant hedge ratios for in-sample studies, they did not take into account the additional transaction costs of using time-varying hedge ratios.

[51] P1A and P4 are no longer traded on Imarex.

We expect the results to be in line with what Skjetne (2005) and Rasmussen & Tversland (2007) have found, with low hedge effectiveness for the Dry Bulk-contracts (30-40%), while a bit higher for tanker contracts (50-60%).

The only work the authors know of on hedge bunker price risks has been done by Alizadeh et al. (2004), who used different oil futures contracts to crosshedge the bunker price risks in Rotterdam, Singapore and Houston. Their results did not bode well for agents looking to hedge bunker price risks. In-sample results for the different contracts showed that the maximum variance reductions for the different contracts, using a conventional hedge ratio, was 24.79% for Rotterdam, 18.57% for Singapore and 8.70% for Houston. Combined with the poor results found by Kavussanos & Nomikos (2000) on freight rate risk hedge performance, Alizadeh et al. (2004) describe the situation for shipping agents the following way:

"- *a dismal picture is painted for the risk reduction prospects of 'agents' involved in the shipping industry".*

They then raise two possible reasons for why the hedge performances were so low. Firstly, they argue that bunker prices mainly reflect the balance of supply and demand for bunker fuel in each region, and may therefore deviate substantially from crude oil and petroleum contracts. Secondly, since the underlying commodities in the spot and futures markets are different, fluctuations in the spot and futures prices are not similar, which may again lead to poorer hedge performances.

A possible solution is found in their conclusion: "A possible (re)launch of a bunker futures contract may alleviate some of the issues raised above. Whether it will be used or not, though, depends on the volume of trading, which in turn would reflect partly the level of hedge effectiveness achieved by a specialized contract."

Since Imarex's derivatives are futures contracts where both the underlying and the hedging items are prices for bunker fuel in a specific region, it would be expected that the issues which were raised by Alizadeh et al. (2004) would be somewhat alleviated. A greater hedge effectiveness would therefore be expected. The hedge effectiveness of other futures contracts have been found to be much higher. Switzer & El-Khoury (2006) investigated NYMEX's crude oil futures contract, and found an out-of-sample hedge effectiveness, using a conventional hedge ratio, of 81%. Ripple & Moosa (2007) used the same contract, but studied the effects of using different differences and length of hedges for hedge effectiveness, reporting a hedge effectiveness for in-sample tests of 70-99%.

According to Alizadeh et al. (2004), the Singapore Exchange tried to launch a fuel oil futures market in 1988, but this closed in 1992. The International Petroleum Exchange tried as well in 1999, but these contracts were withdrawn just 6 months later. Both of the exchanges stopped trading of these contracts due to low liquidity. The fact that Imarex continues trading bunker futures contracts leads to expectations of hedge effectiveness should lie more in the line of what other studies in other futures markets have shown.

As a result of these findings (not cross-hedging and still trading), the authors of this thesis expect the hedge effectiveness of Imarex's bunker contracts to be significantly higher than the maximum hedge effectiveness found by Alizadeh et al. (2004), due to higher reported variance reductions of other futures contracts. A variance reduction of 70-80% would therefore seem like a logical expectation for these results.

4. Data

This chapter will describe the data material used and show how the futures data series of monthly contracts are constructed into one continuous series. The data material used in this thesis is provided by Imarex, Baltic Exchange and Platts and stretches from 2005 to 2009.

4.1 Description of the Time Series

Freight

The freight time series analyzed have two different lengths. The PM4TC data are from 05.04.2005 to 04.11.2009; while the other freight contracts have data are from 04.01.2005 to 04.11.2009. Spot prices were obtained from the Baltic Exchange, while the futures prices were obtained from Imarex. Table 10 provides summary statistics for the seven routes included in the analysis. The statistics are based on simple returns[52], which should be done with care as it does not necessarily suit well for futures contracts, since these have no initial outlay. It is, however, a method of normalizing the time series to easily compare them. Another problem is that, due to the splicing method chosen for the futures time series, the time series becomes negative at times, which leads to strange results when using simple returns. This is discussed below. Section 2.5 describes the more technical details of each contract.

[52] The simple return for each time series X_t is calculated as $\frac{X_t - X_{t-1}}{X_{t-1}}$.

Table 10 Descriptive Returns Statistics Freight Time Series

Baltic Exchange	PM4TC	P2A	P3A	C4	C7	TD3	T2C
# of observations	235	248	248	248	248	248	248
Median	0.012	0.010	0.004	0.000	0.069	-0.020	-0.010
Mean	0.007	0.006	0.014	-0.005	0.009	0.016	0.000
Maximum	0.584	0.403	1.011	0.502	0.523	1.409	0.352
Minimum	-0.561	-0.536	-0.582	-0.373	-0.403	-0.503	-0.358
Std. Deviation	0.126	0.100	0.176	2.124	2.241	0.207	0.104
Kurtosis[53]	4.820	4.342	7.529	4.702	6.262	10.480	1.812
Skewness[54]	0.315	-0.402	1.431	-0.594	-0.013	2.092	0.513
Imarex	**PM4TC**	**P2A**	**P3A**	**C4**	**C7**	**TD3**	**T2C**
# of observations	235	248	248	248	248	248	248
Median	0.000	-0.001	0.006	0.050	0.050	0.000	-0.015
Mean	-0.038	-0.241	0.027	0.033	0.067	0.962	0.031
Maximum	5.989	24.699	3.258	6.750	7.460	214.286	19.231
Minimum	-6.967	-64.146	-0.644	-9.250	-8.437	-8.421	-7.237
Std. Deviation	0.831	4.569	0.328	1.851	1.828	13.802	1.399
Kurtosis[53]	43.461	159.989	54.253	3.841	4.491	233.824	148.020
Skewness[54]	-0.492	-10.658	6.408	-0.618	-0.479	15.125	9.872

Table 10 presents the descriptive statistics of the freight time series. All calculations are based on simple returns on monthly contracts using weekly observations. It is important to note that the futures prices are spliced and should be interpreted with care. The futures prices are provided by Imarex and the spot prices comes from Baltic Exchange.

The thesis will use first difference estimates in the regression analyses, but the descriptive statistics are presented by using simple returns, in order to easier compare the different contracts. Due to the choice of splicing method, which is described later in this chapter, the futures time series becomes negative. Log-returns are therefore not possible to calculate for negative numbers and simple returns are therefore chosen instead. Please note that it is the futures series that is spliced and the time series for the underlying asset may therefore give a better indication of the nature of the shipping market.

The descriptive statistics in Table 10 shows that the average return is close to zero for all routes, although the futures contracts have a somewhat lower mean return. This may be due to negative values for the futures prices, since the splicing method allows for this. The standard deviation is very high for both the Baltic Exchange (spot) and Imarex (futures), which

[53] Kurtosis is defined as: $\left\{\frac{n(n+1)}{(n-1)(n-2)(n-3)}\sum\left(\frac{x_i-\bar{x}}{s}\right)^4\right\}-\frac{3(n-1)^2}{(n-2)(n-3)}$, as defined by Microsoft Excel

[54] Skewness is defined as: $\frac{n}{(n-1)(n-2)}\sum\left(\frac{x_i-\bar{x}}{s}\right)^3$, as defined by Microsoft Excel

confirms the shipping industry's reputation of high risk. A comparison between the spot and futures volatility reveals a rather colossal gap. The futures contracts seem to have a much higher volatility compared to the spot index, which may be due to the splicing method used. In Section 4.7 the settlement price of the Imarex futures contracts are discussed, and a table showing standard deviation and kurtosis using first differences is provided. The settlement price for the futures contract is based on the arithmetic average for the delivery period, which should imply a lower observed volatility in the futures series. This is discussed further in section 4.7, where the volatilities are compared using first difference, which should provide more correct volatility estimates. Table 10 also indicates a higher volatility for the larger vessels e.g. the volatility for the Capesize vessels are much higher than for Panamax vessels.

For the spot series, 4 out of 7 contracts, the exceptions being P2A, C4 and C7, exhibit a positive skewness, meaning that they have a longer right tail. The futures series exhibit the same signs for all the contracts, except that the PM4TC contract has now changed its sign from positive to negative skewness. It is interesting to note that all the absolute values of the skewness are much higher for the futures than the spot series, which is another result due to the splicing method used.

All the kurtosis measures are above the critical value of 3, except for the spot prices of TC2, which indicate that the distributions are very peaked. Again, the phenomenon of high results from the futures prices seem to indicate that the splicing method affects the results.

Bunker

Table 11 shows the descriptive simple returns statistics from the bunker time series. Due to the different age of the futures contracts from Imarex, there are different amounts of observations for the futures time series. All spot prices start on 07.12.2005 as is also the case for RMD35FO and SPO380FO futures prices. Futures prices for NWE10FO start on 04.01.2006, SPO180 start on 11.01.2006 and USG30FO start on 07.06.2006.

Table 11 Descriptive Returns Statistics on Bunker Time Series

Platts	RMD35FO	NWE10FO	SPO180FO	SPO380FO	USG30FO
# of observations	212	212	212	212	212
Median	0.007	0.008	0.007	0.008	0.009
Mean	0.005	0.004	0.004	0.004	0.005
Maximum	0.467	0.378	0.353	0.370	0.389
Minimum	-0.286	-0.196	-0.161	-0.164	-0.188
Standard deviation	0.068	0.062	0.056	0.058	0.061
Kurtosis[40]	10.908	6.584	7.405	7.777	7.481
Skewness[41]	0.947	0.756	0.797	0.879	0.708
Imarex	**RMD35FO**	**NWE10FO**	**SPO180FO**	**SPO380FO**	**USG30FO**
# of observations	212	208	207	212	186
Median	0.006	0.002	0.007	0.005	0.008
Mean	0.003	0.001	0.002	0.003	0.003
Maximum	0.488	0.364	0.333	0.373	0.483
Minimum	-0.204	-0.161	-0.193	-0.201	-0.183
Standard deviation	0.062	0.054	0.053	0.057	0.065
Kurtosis[40]	17.864	10.424	8.184	9.370	16.337
Skewness[41]	1.846	1.286	0.702	0.909	1.896

The calculations are based on simple weekly returns on monthly contracts. Spot prices are obtained from Platts, while futures prices are obtained from Imarex.

The descriptive statistics show that the differences between spot and futures time series is not as high for bunker as it was for freight. This is probably due to the fact that at no point in time did the spliced values fall below 0, i.e. no negative values[55]. As an example, the standard deviation from the spot and futures prices for PM4TC was 0.126 and 0.831 respectively, almost 7 times higher for the futures prices than the spot prices[56]. The difference between standard deviations for spot and futures for Rotterdam bunker fuel is only 0.006 (0.068 and 0.062 respectively).

The Rotterdam (RMD35FO) bunker contract seems to be the most volatile when it comes to spot prices, which is indicated by the highest weekly standard deviation, as well as the highest/lowest maximum/minimum values. The latter is also true for its futures prices, but here the USG30FO contract has a higher standard deviation. The spot and futures price volatilities seem very close.

[55] Remember that the simple return from -10 to +10 is $\frac{10}{-10} - 1 = -200\%$

[56] See discussion of the descriptive returns statistics for freight on the previous page.

All the time series exhibit a positive kurtosis (i.e. above 3), meaning that they all have fat tails and are peaked at the mean. In addition, they all have positive skewness, indicating longer right tails.

4.2 Implications of Non-Stationarity in the Time Series

Most financial time-series are non-stationary, which means that shocks to the system will not die away over time. This is a problem, as regressions performed on non-stationary time-series may lead to spurious results. However, most financial time-series who have unit roots (i.e. are non-stationary) have only one unit root, meaning that if they are differenced once, they will become stationary. A common notation of such a time series is that it is *I*(1). A time series is *I(n)* if it contains *n* unit roots. For further information on unit roots, please see Brooks (2002, p. 369).

To test whether or not the time series used contain unit roots, the Augmented Dickey-Fuller (ADF) test is used, which is an extension of the Dickey-Fuller test (Brooks, 2002, p. 380).

The Augmented Dickey-Fuller test is performed by running the regression

$$Y_t = \phi_0 + \phi_1 Y_{t-1} + \sum_{i=1}^{k} \psi_i Y_{t-1} \tag{31}$$

The null hypothesis is that the time series is non-stationary ($H_0\colon \phi_1 = 0$), which is rejected when the time series is stationary ($H_1\colon \phi_1 < 0$). The choice of amount of lags is here critical, as including too few lags will mean that the size of the test will be incorrect, while including too many will lead to a smaller sample, and thus lower the power of the tests. A rule of thumb method of choosing lags is to choose lags by considering the frequency of the data analyzed. Since the data used are weekly, using lags of 1,4,12 and 52 would seem logical, as it accounts for weekly, monthly, quarterly and yearly patterns. Another way of choosing lags is by using information criterions, such as Aikaike's Information Criterion, which measures how the addition of one more lag decrease the squares of the errors compared to the penalty for the loss of degrees of freedom. More on information criteria may be found in Brooks (2002, p. 257). The results of the tests may be found in Tables 12 and 13.

Table 12 Results from Augmented Dickey Fuller Tests on Freight Contracts

		Level				Differenced once			
	Lags	**1**	**4**	**12**	**52**	**1**	**4**	**12**	**52**
Spot	**PM4TC**	-1.313	-1.75	-1.804	-2.547	-7.305	-5.221	-3.629	-1.674
	TD3	-3.302	-2.682	-2.43	-2.794	-10.42	-7.795	-4.233	-2.188
	P2A	-1.397	-1.588	-2.016	-2.053	-7.524	-5.718	-3.194	-1.998
	P3A	-1.104	-1.71	-1.786	-2.594	-7.685	-5.457	-3.742	-1.561
	TC2	-2.596	-1.84	-1.655	-0.1569	-9.644	-7.756	-4.136	-2.953
	C4	-1.911	-2.221	-2.355	-2.056	-8.724	-6.213	-3.725	-1.894
	C7	-1.865	-2.426	-2.496	-1.693	-8.274	-5.682	-3.887	-2.142
Futures	**PM4TC**	-0.7052	-1.315	-1.941	-2.813	-6.477	-3.699	-2.795	-1.819
	TD3	-1.186	-1.556	-1.263	-1.344	-8.695	-5.118	-4.69	-1.594
	P2A	-1.305	-1.573	-2.262	-1.555	-6.415	-4.905	-3.135	-2.388
	P3A	-1.104	-1.71	-1.786	-2.594	-6.86	-4.549	-3.125	-1.706
	TC2	-1.619	-2.263	-3.106	-1.616	-8.412	-5.044	-3.392	-2.728
	C4	-1.129	-1.673	-1.921	-1.613	-7.749	-4.937	-3.512	-2.041
	C7	-1.308	-1.851	-2.11	-1.356	-6.99	-4.895	-3.657	-2.198

Table 12 shows the results of the ADF-tests on freight contracts. Numbers in red show where the null hypothesis of unit roots present in the time series is rejected on a 5% confidence level. The critical value for rejection on a 1% confidence level is -3.47 and -2.88 on a 5% confidence level.

Although the quarterly futures prices of TC2 and the weekly spot prices of TD3 seem stationary already before they are differenced, they are not so on a 1% confidence level. All the time series are however stationary when differenced once. As a consequence, only freight time series which have been differenced once will be used in the regression analyses performed in this thesis.

Table 13 Results from Augmented Dickey Fuller Tests on Bunker Contracts

		Level				Differenced once			
	Lags	**1**	**4**	**12**	**52**	**1**	**4**	**12**	**52**
Spot	**RMD35FO**	-1.558	-2.021	-2.745	-1.672	-8.666	-3.941	-3.463	-2.535
	NWE10FO	-1.479	-1.81	-2.833	-1.724	-8.956	-3.904	-2.776	-2.045
	SPO180FO	-1.477	-2.075	-2.755	-1.634	-8.283	-3.619	-3.358	-2.494
	SPO380FO	-1.508	-2.166	-2.744	-1.653	-8.428	-3.427	-3.466	-2.538
	USG30FO	-1.574	-1.86	-2.659	-1.516	-8.038	-3.861	-3.478	-2.669
Futures	**RMD35FO**	-1.399	-1.871	-2.779	-1.82	-8.8	-3.697	-3.184	-2.549
	NWE10FO	-1.369	-1.699	-2.931	-2.334	-9.29	-3.939	-2.743	-2.085
	SPO180FO	-1.558	-2.036	-2.743	-1.818	-8.373	-3.868	-3.099	-2.401
	SPO380FO	-1.563	-2.127	-2.772	-1.69	-8.637	-3.827	-3.216	-2.499
	USG30FO	-1.255	-1.793	-2.611	-1.832	-7.914	-3.315	-2.924	-2.275

Table 13 shows the results of the ADF-tests on bunker contracts. Numbers in red show where the null hypothesis of unit roots present in the time series is rejected on a 5% confidence level. The critical value for rejection on a 1% confidence level is -3.47 and -2.88 on a 5% confidence level.

The quarterly futures price time series of NWE10FO seems stationary before it is differenced, with a DF-value of -2.931, thus rejecting the null-hypothesis on a 5% confidence level. All the time series become stationary when differenced once, however, on a 1% confidence level. As a consequence, regressions will only be run on bunker time series which have been differenced once, to account for non-stationarity.

4.3 How to Splice the Data Series into one Continuous Series?

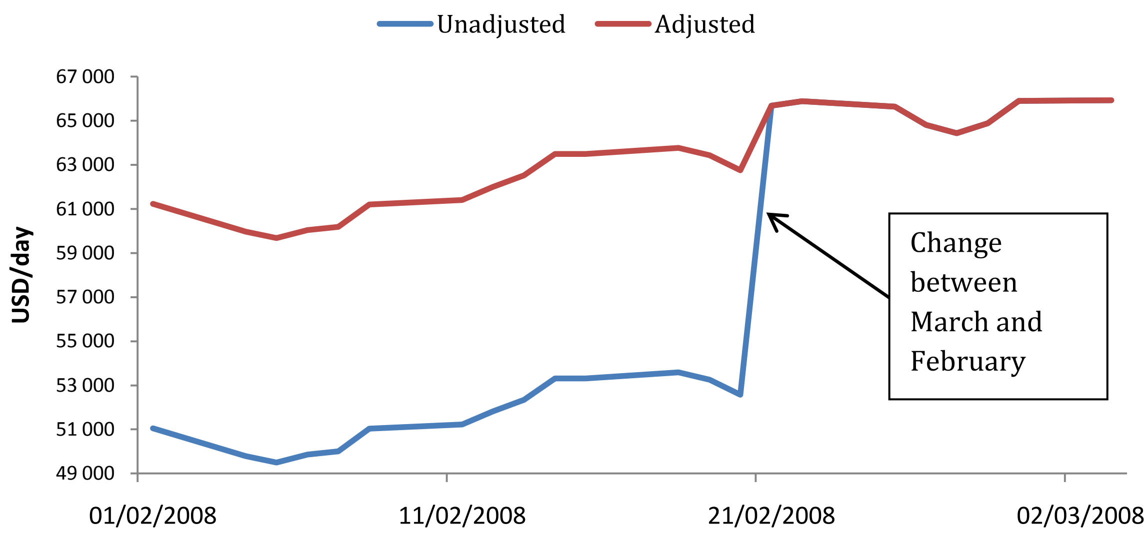
Futures markets consist of a number of different futures contracts, each with a given pre-determined maturity. This becomes problematic when looking at hedge effectiveness, since a large data sample is required. It therefore becomes necessary to use several contracts to obtain a continuous time-series, where the continuous time series reflects the actual cash flows of a trader rolling a contract forward.

There are different ways to create a continuous time series, and no correct way to do it[57]. The logical step would be to just use the next contract when one expires, which is called the spot-month continuous. This method is easy to implement, but with the move from one contract to another you might observe that the prices are not the same. The result could be that *jumps* could occur at the splice points, which creates irrational noise in the sample. This is shown graphically in Figure 12 below. There are several ways to tackle this problem. The methods

[57] Source and discussion on splicing futures time series, see http://www.premiumdata.net/support/futurescontinuous.php

described below for splicing the data use two different methods to adjust for the jumps, so that the time series becomes more meaningful.

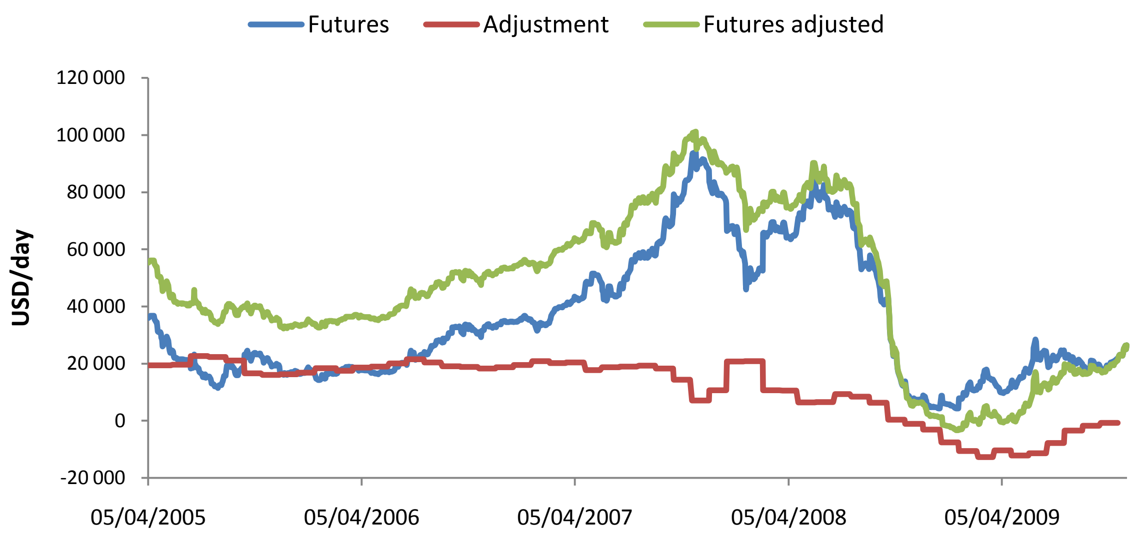
Figure 12 Illustration of Adjusted and Unadjusted Time Series for PM4TC Futures Prices



The figure shows how the unadjusted (spot-month continuous) time series jumps when the hedger changes from one contract to another. The adjusted time series is adjusted using the method described directly below. Since the method works backwards the jump in the series results in both the adjusted and unadjusted series being equal after the expiration of the February contract.

In previous studies of the Imarex futures market two different methods are used. Skjetne (2005) used a method were the time series were back-adjusted. When one contract reached maturity, the closing price of that contract is compared with the closing price of the sequential contract (Example: when the May contract has reached maturity, it is compared with the closing price of the June contract). The price of the matured contract is then subtracted from the price of the sequential contract. The difference between the two contracts is then applied to *all previous prices*. This method is then repeated, moving backwards, until it is applied to the entire data set for one contract type. A weakness of this method is that the jumps are accumulated, leaving a *permanent basis*. This could make the basis estimates significantly different from zero. Figure 13 also reveals that the cumulative jumps actually makes the futures series sometimes becomes *negative*. This might be caused by the market being in steep contango or backwardation, leaving a large gap when the contract is moved over. The consequence of a time series with negative numbers is that log and simple returns becomes unsuitable. Log is not defined for negative numbers and the simple returns will show extreme returns when the series goes from positive and negative and vice versa. Another problem is that the time series could become close or equal to 0, and returns could therefore become highly inflated or not defined.

Figure 13 Back Adjusted PM4TC (Monthly Contracts) Skjetne (2005) Method



The graph shows that the beginning of the time series only contained small jumps when the method moved from one monthly contract to another. After mid 2007 and 2008 the adjustment between the monthly contracts fluctuates more. Remember that the method works backwards, meaning that the adjusted and unadjusted series will meet in the end of the sample. It is also important to notice the significant gap between the adjusted and the unadjusted series in the beginning of the sample. If the unadjusted series at the beginning of the sample closely follows the price of the underlying asset, the adjusted series might show an artificially high basis.

Rasmussen & Tversland (2007) use a slightly different approach. In their method the contracts are rolled over on the on the Wednesday before the contract's last trading day. In order to cope with the problem of having two different futures prices at the moment when the hedge is rolled over, the futures price series are indexed such that the first observation is set to 100. This approach is maybe closer to the cash flow a trader will get in practice from rolling a hedge over to the next month.

Figure 14 Splice of Data Compared to Spot for PM4TC, 06.04.2005=100

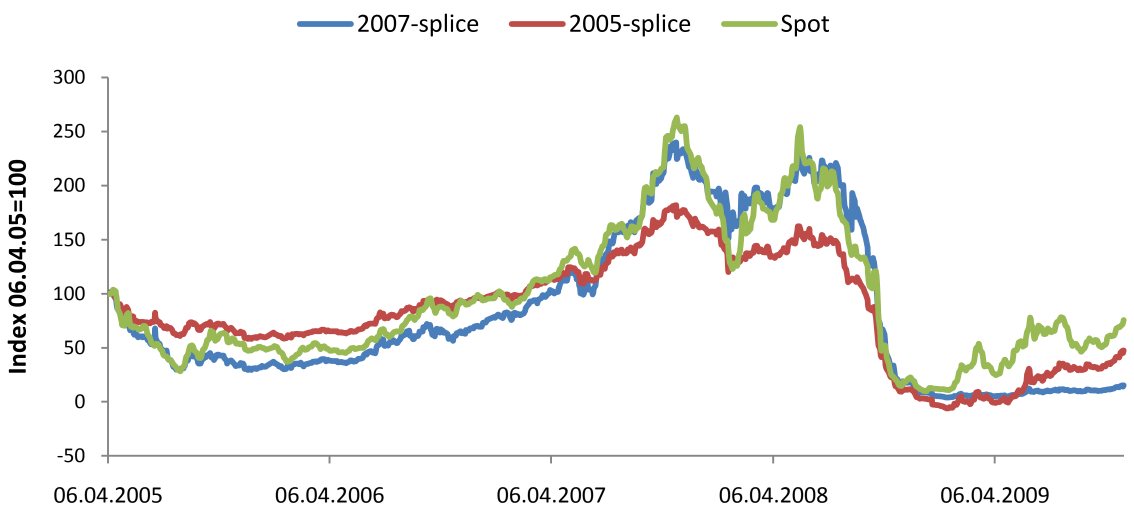


Figure 14 compares the different splicing methods. To easier compare the different methods, each series is indexed at 100 in the beginning of the sample daily observations are used.

Rasmussen and Tversland's method seems to track the underlying spot price quite well in 2007 and 2008, however, prior to and after that date it is harder to identify a "best" method. The table below presents a correlation matrix for the time series.

Table 14 Correlation Matrix for Different Splicing Methods

	Spot	2005-splice	2007-splice
Spot	1		
2005-splice	0.68	1	
2007-splice	0.63	0.87	1

The figures are calculated from weekly price changes (absolute) in each series for PM4TC. The analysis is based on the first difference of the indexed time series presented graphically above. The indexation explains the minor deviation from the results presented in Section 5.A.2.1.

Notice that each method has approximately the same correlation with the spot price. This analysis was only made on the PM4TC time series and a different result might occur if one of the other routes or the bunker data were used. Using the spot-month continuous method actually shows a higher correlation with the spot price in the case of PM4TC. This might be due to the large fluctuations in the adjustment factor in the end of the sample. The authors of this thesis chose to use the method used by Skjetne (2005). As indicated above there is no best way of making a continuous futures series. Choosing the 2005-method will however make it easier to compare the results with Skjetne (2005). Moreover, as seen in Table 14, the differences between the splicing methods seem to have a marginal effect on the results, and should therefore not be critical to the results.

4.4 Sampling Intervals

Stoll & Whaley (1993, p. 59) discuss the trade-off from choosing a long vs. a short sample interval. This is a common problem analysts are faced with when analyzing any type of financial data series. When the intervals are small, they capture relatively more information compared with a longer interval. On the other hand, a longer interval will remove more noise from the data, reducing uncertainty in the estimated values. Stoll & Whaley estimate hedge ratios using different samples intervals for the S&P 500. In the table below the same method is used to estimate the hedge ratio for PM4TC, using daily, weekly and biweekly data. The data used *only* contains observations from 2006.

Table 15 Hedge Ratio Using Different Sampling Intervals for PM4TC for 2006

Interval	n	β	σ_β	95% Lower	95% Upper	Range	R^2
Daily	248	0.2197	0.0407	0.1395	0.2999	0.1604	0.1058
Weekly	51	0.5899	0.1349	0.3188	0.8610	0.5422	0.2807
Biweekly	26	0.8584	0.1313	0.5868	1.1299	0.5431	0.6502

This table is calculated used simple returns for the PM4TC futures and the underlying asset price. The estimations are only based on 2006 and should therefore just be interpreted as an example of sampling intervals. The regression is based on the theoretical framework presented in Section 3.4.2.

The results from Table 15 are similar to what Stoll & Whaley find. The hedge ratio,β, seems to increase when the sampling interval gets larger. At the same time the hedge effectiveness also seems to rise. This is as expected since the biweekly and weekly observations remove much of the unexplainable noise observed in the daily observations. The difference between the standard deviation for weekly and biweekly observations is rather small. The same is observed from the calculation of the 95% confidence interval range. The results from the analysis of PM4TC and S&P 500 Stoll & Whaley (1993, p. 59) show a much higher difference between the estimated hedge ratios and hedge effectiveness. While the S&P 500 only increase hedge effectiveness from 0.9867 to 0.9928 when moving from weekly to biweekly observations, PM4TC jumps from 0.2807 to 0.6502. This jump is much higher, indicating the time series might contain a lot of noise. However, the estimates are based on one year only and therefore suffer from a short time series.

Moreover, due to low liquidity, not all contracts are traded on a daily basis. To address this, Imarex uses an algorithm to determine futures prices for contracts which have not been traded on a given day. They use the following algorithm for determining futures prices[58]:

The best bid if last price < best bid

The best offer if last price > best offer

Or else use last price.

This algorithm could possibly cause bid/ask price effects because the negotiations are done daily. To make the bid/ask effects smaller, and to make the thesis consistent and comparable with previous work, the authors of this thesis choose to use weekly observations. As can be seen from Table 15 above, this choice might underestimate the hedge performance presented in the results in Chapter 5.

4.5 Seasonality in the Shipping Markets

Kavussanos & Visvikis (2006b, p. 49) searched for seasonality effects in the shipping markets. They argue that seasonality effects exist in both dry-bulk and tank markets. Their results from the dry-bulk market are reported in the table below.

Table 16 Seasonality in the Dry-Bulk Market, Average Percentage Change in a Particular Season

	Voyage (Spot) Charter		1-year Time-Charter		3-Year Time-Charter	
	Capesize	Panamax	Capesize	Panamax	Capesize	Panamax
Spring	15.3%	8.6%	3.0%	2.4%	2.3%	2.1%
Summer	-26.0%	-21.3%	-8.4%	-9.7%	-4.2%	-4.3%
Autumn	-	14.4%	-	-	5.7%	-2.1%
Winter	-	-	-	-	-	-
R^2	0.11	0.15	0.07	0.11	0.08	0.09

The table is adapted from Kavussanos & Visvikis (2006b, p. 52). *The table is modified to only contain vessels included in this thesis. The figures indicate the average percentage change in freight rates in a given season.*

Their results show a seasonal cyclicality for larger vessels. This might be due to the fact that smaller vessels are more flexible, and can therefore better adjust to the market changes. As can be seen from the R^2 the explanation power from seasonality is rather small and is decreasing for longer contracts. Kavussanos & Visvikis also try to explain the causes of seasonality for the different vessels. Panamax ships are for example used for transporting coal

[58] The algorithm is downloaded from The Imarex Rule book - http://www.exchange.imarex.com/getfile.php/NOS%20Clearing%20ASA/Products%20and%20Services/Rulebook%20and%20agreements/Appendix_5_Product_Specification.pdf

and grain[59]. Transportation of seasonal commodities makes the demand curve dependent on the season of the year. This might explain the increase in spot prices from March to April by stock ups in Japanese inventories due to the end of the fiscal (tax) year. The presence of seasonality might also affect the underlying assumptions for the OLS. This is discussed in Section 5.A.1.

4.6 Choice of Contracts

Another important issue is which futures prices to use: Yearly, quarterly or monthly. Figure 15 shows the historical development for each contract length compared to the underlying spot price for PM4TC.

Figure 15 Monthly, Quarterly and Yearly Futures Contracts Compared to Spot for PM4TC

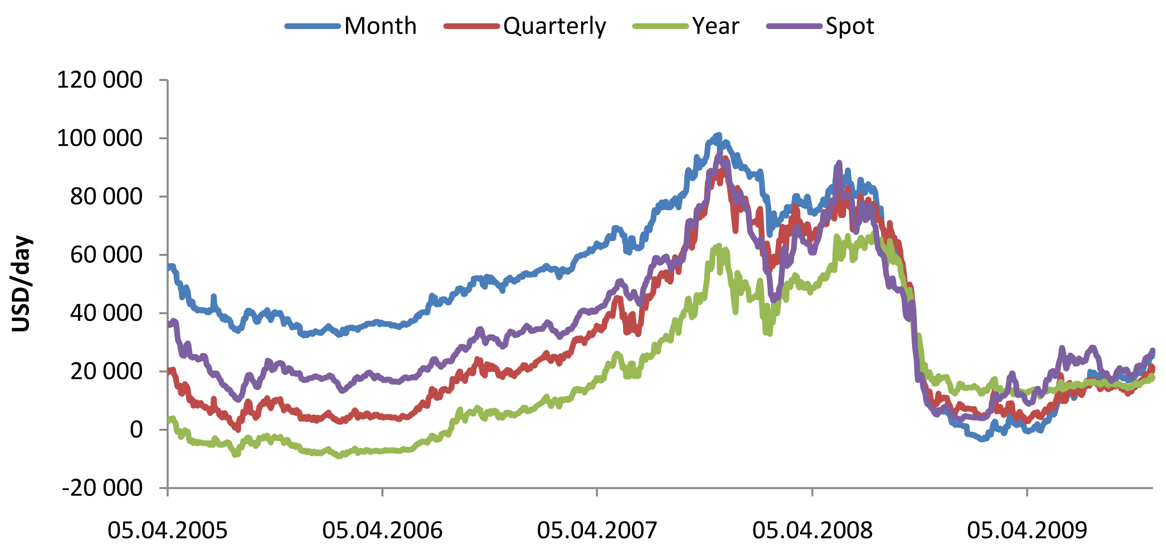


Figure 15 seems to imply that the quarterly contracts follow the spot prices most closely. However, there are several reasons for choosing monthly contracts. The Samuelson hypothesis states that futures prices show higher volatility closer to delivery (Duffie, 1989, p. 174). The current futures price reflects current information about the spot price and the delivery time. Available information concerning the spot price at time *T* ought to be rising. Therefore, a higher volatility is ought to be observed when a contract is closer to maturity Duffie (1989, p. 174). The Samuelson hypothesis could be used as an argument for choosing the contract with shortest time to delivery because it will reflect more information about the current market prospects[60]. Another argument for using the shortest contract is market

[59] See Chapter 3 for further detail of the shipping market.
[60] The Samuleson hypothesis is also important for the OLS assumptions. If the variance is increasing when the contact is approaching maturity the residuals might show heteroscedasticity.

participant's preference of rolling short-term contracts instead of using longer contracts. Table 17 below shows a correlation matrix for the four contract lengths.

Table 17 Correlation Matrix for Different Contracts Lengths

Correlation	Monthly	Quarterly	Yearly	Spot
Monthly	1			
Quarterly	0.784	1		
Yearly	0.716	0.887	1	
Spot	0.397	0.285	0.236	1

The correlation is calculated based on the first difference from each series. Daily observations are used.

The table clearly shows that correlation is declining with the length of the contract. Monthly contracts and spot receive a correlation coefficient of nearly 0.40 compared to only 0.24 for yearly contracts. All previous research on hedge performance that the authors of this thesis know of also chose to use the monthly contracts. Choosing monthly contracts would therefore make the results more comparable. For the reasons mentioned monthly contracts are used in this thesis.

4.7 Settlement as Arithmetic Averages

As stated in Section 2.5, Imarex uses the arithmetic average price in the delivery period as settlement price. The futures markets are characterized by a lower liquidity compared with other markets such as the stock market, and may therefore be subject to manipulations. When the settlement price is written on the arithmetic average it is harder for market agents to manipulate the price.

The arithmetic average for a contract may be expressed by the following equation:

$$\bar{S}_t = \frac{1}{T}\sum_{t=1}^{T} S_t \tag{32}$$

Where *{1,2…T}* are the days in the averaging period. For example, a monthly contract with maturity in May will have an averaging period from the 1st to the 31st of May[61]. The last trading day for the May-contract will be on the 31st of May. If the last trading day is a non-trading-day the last trading day will be the nearest trading day after the non-trading-day. When the contract is trading within the averaging period the rational market participant will

[61] Earlier on the averaging period were only set to the first 15 days of the delivery month. In practice the liquidity is relatively higher in the beginning of the averaging period compared with the last part. However, this change in averaging period might affect the results presented in chapter 5.

look both backwards and forward. The market participant will know the past values from time *{1,…t}*, however, the values from *{t..T}* are uncertain.

The market participants trading a May 2011 contract will therefore bet on the average of the delivery period for May 2011. This can be expressed modifying Equation (10).

$$B_t = S_t - F_t = S_T - \bar{S}_{t,T} \tag{33}$$

If the market participants are fully aware of this contract property, the Imarex futures contracts should not follow the underlying asset price perfectly. Expressed with the unbiased hypothesis the futures price should be an unbiased estimate of the arithmetic average price in the delivery period. For that reason the price-path of the futures contract is expected to be smoother than for the underlying asset. The effect should be an observed lower volatility in the futures prices, compared with the price of the underlying asset. Table 18 shows the standard deviation and kurtosis for PM4TC, TD3 and SPO380FO. A table including all the contracts used in this thesis is provided in appendix A3.

Table 18 Standard Deviation and Kurtosis for PM4TC, TD3 and SPO380FO (First Difference)

		PM4TC	TD3	SPO380FO
Std. Dev.	Futures	2852.0	14.3	22.9
	Spot	3429.5	20.8	22.1
Kurtosis	Futures	4.9	5.3	5.7
	Spot	6.9	5.6	3.5

The calculations are based on first difference estimates (not simple returns as in the descriptive statistics above). The reason for using first difference is due to the splicing method explained previous in this chapter. Please see Appendix A.3 for a complete table of all the contracts.

PM4TC and TD3 follow the hypothesis of a lower volatility and kurtosis for the futures price compared with the spot price. However, SPO380FO shows the opposite, higher volatility and kurtosis for the futures contract. Table 39 shows that the hypothesis of a higher volatility in futures prices hold for all the freight contracts and RMD380FO. The kurtosis is higher for all freight contracts except TC2. In the bunker market the kurtosis is higher for futures contracts compared with the price of the underlying asset. This might be due to lower liquidity in the bunker market or that the market participants in the freight market behave differently than those in the bunker market. The absolute difference between the standard deviation observed in the futures market compared with the spot market is much smaller in the bunker market. However these tests can not conclude that the market participants price the futures contracts according to their averaging properties.

5. Hedge Performance

This chapter will give an analysis of the hedge performance of the dry-bulk, tank and bunker markets. It is divided into sections A and B, with A analyzing freight futures and B analyzing bunker futures. The first part of the sections looks at the hedge performance of the futures contracts, presenting an analysis of the hedge efficiency using both constant and time-varying hedge ratios, performing both in-sample and out-of-sample studies, with short discussions on improvement potentials through multiple futures contracts. The performance of the futures contracts is then discussed through five criteria proposed by Carlton (1984), in addition to two criteria which the authors of this thesis theorize may affect their performances.

5.A Freight Futures

5.A.1 Testing Underlying Assumptions

As mentioned in Section 3.4.5, the results from the regressions are based upon five different assumptions. Three of these will be tested for in this section.

The first assumption to be tested for is homoscedasticity (assumption 2), i.e. that the errors have a constant and finite variance over all values of *t*. Breaks from this assumption may affect the standard errors of the regression coefficients, and therefore the strength of any hypothesis tests.

Tests for heteroscedasticity are performed by using White's test for heteroscedasticity (Brooks, 2002, p. 148). It is performed for all the regressions by using the following model:

$$u^2 = \delta_0 + \delta_1 \Delta F + \delta_2 \Delta F^2 + \varepsilon \tag{34}$$

The LM-statistic is then obtained by using the R^2 multiplied by the number of observations:

$$LM = nR^2 \tag{35}$$

The null hypothesis is that the errors are homoscedastic. Under the null, the LM-statistics are chi square distributed with two degrees for freedom, i.e. $LM \sim \chi_2^2$.

Example: The errors from TD3-regression for 2005-2007 are stored and squared. The futures time series is squared as well, and the squared errors are then regressed on the constant, changes in the futures price and changes in the futures price squared $((\Delta F)^2)$. This gave an R^2 of 0.012079. This is then multiplied by the number of observations:

$$0.012079 \times 124 = 1.498$$

Results from these tests are found in Table 19. The critical values are from tables of the chi square distribution with two degrees of freedom.

Table 19 Results White's Test for heteroscedasticity

	LM-statistics			Critical values	
	2005-2009	2005-2007	2007-2009	5% level	1% level
PM4TC	59.596	9.733	30.204	5.991	9.21
TD3	6.246	1.498	7.148	5.991	9.21
P2A	40.975	15.955	14.415	5.991	9.21
P3A	63.620	3.967	25.919	5.991	9.21
TC2	19.855	11.859	3.007	5.991	9.21
C4	6.555	5.948	0.982	5.991	9.21
C7	23.593	11.912	6.014	5.991	9.21

Table 19 shows the results from White's test for heteroscedasticity. Figures in red show where the null hypothesis of homoscedasticity is rejected on a 5% confidence level.

The results show that the null hypothesis of homoscedasticity is rejected for all the regressions performed, except for TD3, P3A and C4 in the period 2005-2007, as well as for C4 and TC2 in the period 2007-2009. Any tests performed using these regressions will therefore have to be done with care, as the presence of heteroscedasticity may affect the standard errors. The presence of heteroscedasticity will also make the use of EWMA more sensible. When the variance of the residuals is not constant, a time-varying hedge ratio should lead to higher hedge efficiency. However, this is based on the assumption that the EWMA model can correctly capture the heteroscedasticity present in the time series. The presence of heteroscedasticity is not surprising, due to the supply-demand curves observed in the shipping market, as discussed in Section 2.3. The variance of the price becomes greater during times of high utilization, as opposed to in times of low utilization. This could therefore lead to a change in the variance of the errors.

The third assumption is that of no serial correlation in the errors. To test for higher order serial correlation, the Breusch-Godfrey test (Brooks, 2002, p. 164) is performed by running the following regression on all errors:

$$u_t = \alpha + \beta \Delta F_t + \lambda_1 u_{t-1} + \lambda_2 u_{t-2} + \cdots + \lambda_p u_{t-p} \tag{36}$$

The choice of lags, p, should be done in reference to the frequency of data. Since the data used are weekly, testing for 1, 4, 12 and 52 lags would seem the most logical, as it would test for weekly, monthly, quarterly and yearly serial correlations.

The Lagrange Multiplier (LM) of the statistic is then calculated, using the R_p^2 computed from the regression from Equation 36.

$$LM = (n - p)R_p^2 \tag{37}$$

Some econometric programs, such as Eviews or OxMetrics/PcGive, add pre-sample errors which they set to 0, in order to account for lost observations, which is the reason for subtracting the amount of lags (p) when calculating the LM-statistic. The following calculations have not added pre-sample errors, and the LM-statistics are therefore calculated by subtracting the lags from the observations.

Under the null hypothesis, there is no serial correlation, and $LM \sim \chi_p^2$.

Example: The errors from the C4 regressions for 2007-2009 are stored and then regressed on a constant, the change in the futures price of C4 and 4 lags of itself. This gives an R_p^2 of 0.0144877. The amount of observations minus lags is 120. The LM-statistic is therefore:

$$0.0144877 \times 120 = 1.74$$

The results from the Breusch-Godfrey tests on residuals may be found in Table 20. The critical values are from chi square distribution tables with 1, 4, 12 and 52 degrees of freedom.

Table 20 Breusch Godfrey Tests on Residuals

	PM4TC	TD3	P2A	P3A	TC2	C4	C7	
				LM statistics				**Critical values**
				2005-2009				
-1 week	16.96	3.99	16.74	17.58	0.00	1.32	0.05	3.84
-4 weeks	17.36	4.80	20.54	18.64	3.77	4.55	4.66	9.49
-12 weeks	25.26	25.79	34.63	21.35	18.02	9.33	12.67	21.03
-52 weeks	60.38	50.84	70.80	52.28	34.16	42.35	56.15	69.83
				2005-2007				
-1 week	0.52	0.48	0.63	12.91	0.97	0.64	2.69	3.84
-4 weeks	5.18	1.30	5.18	13.79	4.41	3.80	3.74	9.49
-12 weeks	15.08	9.00	23.93	25.45	16.54	9.39	16.47	21.03
-52 weeks	52.28	51.21	51.20	51.42	39.40	51.19	46.77	69.83
				2007-2009				
-1 week	11.51	2.52	7.03	7.18	1.18	0.10	0.78	3.84
-4 weeks	11.39	5.55	9.77	9.77	3.78	1.74	3.66	9.49
-12 weeks	14.62	21.32	17.45	17.37	8.30	4.84	10.61	21.03
-52 weeks	50.05	55.50	55.06	55.02	48.12	34.15	50.33	69.83

Table 20 shows the results of the Breusch-Godfrey tests. The numbers in red show where the null-hypothesis of no serial correlation is rejected on a 5% confidence level.

If no serial correlation is present, then the tests should fail to reject the null hypothesis for all lags. All the contracts, except from TC2, C4 and C7 show serial correlation, and there is therefore reason to fear that the standard errors are significantly different from the ones obtained in the regression. In addition, the presence of serial correlation could lead to an inflated R^2 (Brooks, 2002, p. 166). This is very important, as R^2 measures the hedge effectiveness of the given contract.

As shown in Section 4.5, seasonality is present in freight rates. Brooks (2002, p. 173) argues that time series which include seasonality or cyclical patterns might lead to a positively auto correlated residual structure. This might explain some of the autocorrelation observed in the time series. He also argues that financial markets tend to overreact to any good or bad news, which could also explain some of the autocorrelation present.

The fifth assumption is that the errors should be normally distributed. If not, any joint or single hypothesis tests of the model parameters may be wrong. The Jarque-Bera test (Brooks, 2002, p. 179) is performed by calculating the JB-statistic from the errors of the regressions in the following manner:

$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}K^2\right) \tag{38}$$

Where S is skewness and K is kurtosis as defined in Section 4.1, the values of the JB-statistic may therefore vary based on the measures of skewness and kurtosis used. The null hypothesis is that the errors are normally distributed, with $JB \sim \chi_2^2$.

Example: The errors from the P2A regression from 2005-2009 are stored. Their skewness and kurtosis are calculated to be:

Skewness: -1.2415.

Kurtosis: 5.8787.

The JB-statistic is then calculated as:

$$\frac{248}{6}((-1.2415^2) + \frac{1}{4}(5.8787^2)) = 420.825$$

Table 21 Jarque Bera Test Results

Contract	2005-2009	2005-2007	2007-2009	Critical values
PM4TC	173.265	26.421	27.172	5.99
TD3	394.895	23.634	176.994	5.99
P2A	420.825	8.961	82.955	5.99
P3A	46.470	6.887	13.921	5.99
TC2	282.107	211.966	17.006	5.99
C4	101.454	20.786	28.782	5.99
C7	102.160	38.590	7.675	5.99

Table 21 shows the results from the Jarque-Bera tests. The numbers in red show where the null hypotheses of normally distributed errors are rejected on a 5% confidence level. The critical values are obtained from tables of chi square distributions with 2 degrees of freedom.

The results show that the errors are not normally distributed for all of the contracts for all of the periods. There is therefore a chance that wrong conclusions are made when testing hypotheses based on these regressions. High JB-statistics could be a result of the presence of extreme events in the time series, which could possibly have large effects on hedge ratios and hedge efficiencies. This is discussed in Section 5.A.2.1.

5.A.2 Results Freight

5.A.2.1 In-Sample Results

To analyze changes in hedge performance over time, two sub-periods are analyzed for hedge performance using freight derivatives. Period 1 stretches from 12.01.2005 to 30.05.2007 and period 2 is defined from 30.05.2007 to 04.11.2009. It is important to note that the regressions for only period 1 and 2 are based on just above 120 observations, and may therefore suffer from a smaller dataset compared to the ones based on the complete sample (period 1 and 2). The variance reductions for using naïve hedges (1:1 relationship) are included for comparison purposes. For the theory underlying the calculations, please see sections 3.4.1 and 3.4.2 for the conventional hedge strategy and 3.4.6 for the time-varying hedge strategy.

Table 22 In-Sample Results on Freight Contracts

Variance reductions							
2005-2009							
	PM4TC	**P2A**	**P3A**	**TD3**	**TC2**	**C4**	**C7**
Conventional hedge ratio	0.756	0.977	0.991	0.986	0.904	0.951	1.070
Conventional hedge eff.	0.385	0.699	0.711	0.459	0.426	0.684	0.761
Naive hedge eff.	0.345	0.698	0.711	0.459	0.421	0.682	0.758
Time-varying hedge eff.	0.307	0.581	0.690	0.402	0.377	0.697	0.746
2005-2007							
Conventional hedge ratio	0.612	0.697	0.760	0.964	0.859	0.620	0.821
Conventional hedge eff.	0.365	0.565	0.558	0.588	0.450	0.458	0.655
Naive hedge eff.	0.218	0.457	0.503	0.587	0.439	0.205	0.611
2007-2009							
Conventional hedge ratio	0.791	1.046	1.065	1.012	1.014	1.056	1.112
Conventional hedge eff.	0.393	0.736	0.755	0.378	0.392	0.753	0.782
Naive hedge eff.	0.366	0.735	0.752	0.378	0.391	0.752	0.774

Table 22 shows the variance reductions from using naïve, conventional and the time-varying hedge ratios, except the first row which show the conventional hedge ratios used during that period. Numbers highlighted in red show the highest hedge effectiveness for that contract and period studied.

Using a naïve hedge ratio was almost as good as the conventional hedge ratio. This is especially true when one includes the period from after the 30th of May 2007. This is evidenced by the variance reduction on the TD3 from using a naïve hedge ratio, which gave an almost identical variance reduction compared to using a conventional or a time-varying hedge ratio. This is due to the fact that all the hedge ratios go from less than 1 to 1 when including the second period.

Figure 16 Comparing Time-Varying and Conventional Hedge Ratios on the TD3

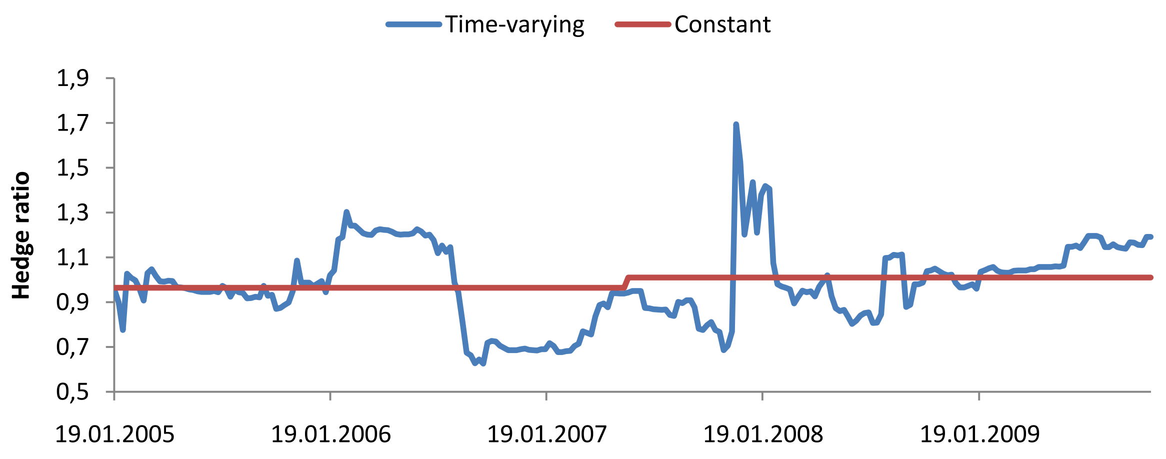


Figure 16 shows how the time-varying hedge-ratios changes over time on the TD3, compared with the hedge ratios from period 1 and period 2.

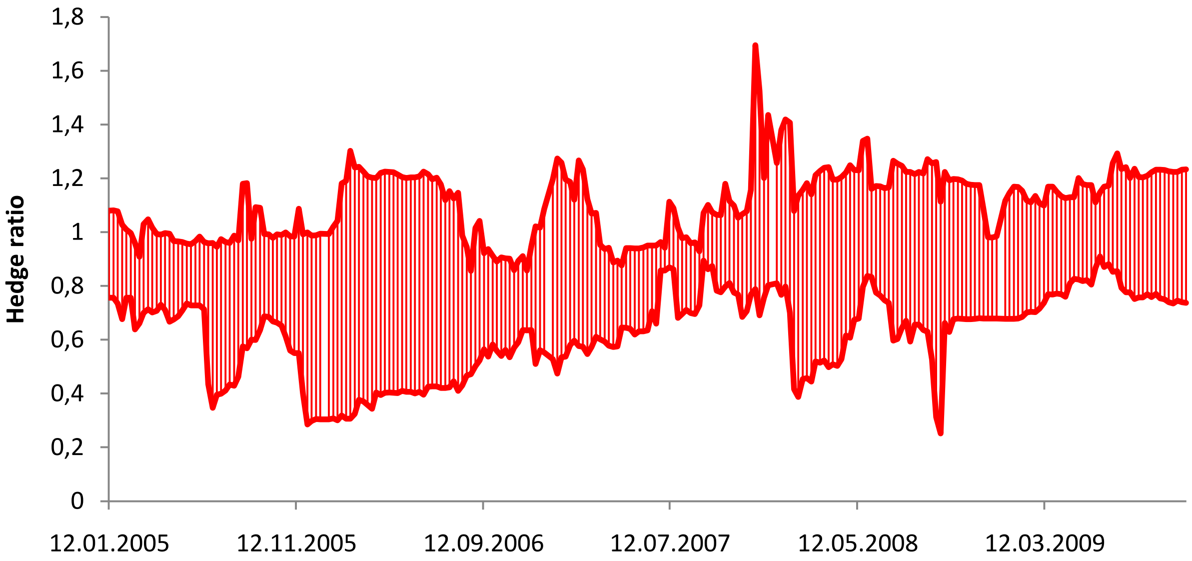
Using time-varying hedge ratios underperform even naïve hedge ratios for all the contracts, except on the C4 contract, where it is even better than using conventional hedge ratios. This is surprising, as it would be expected that EWMA would outperform conventional when hedging time series with heteroscedasticity. The reason could be that the EWMA model is not able to take into account the correct set of information necessary to outperform the conventional hedge ratios. The conventional hedge ratios proved to be the superior hedging strategy for all the contracts and periods, except C4 for period 1 and 2. It is natural that this strategy should outperform naïve hedge ratios, as if the optimal static hedge-ratio strategy was the 1:1 relationship, then the conventional hedge ratio would be 1.

The basis of the regressions were calculated, but none of them were found to be significantly different from series. These results may be found in Appendix A.4.

The results are none the less similar to what has been found by earlier studies into the hedge performances of IMAREX derivatives. Rasmussen & Tversland (2007) found that the hedge performance of the PM4TC futures contract, with a conventional hedge ratio, was 0.335, similar to the findings presented above. Skjetne (2005) looked into the hedge effectiveness of TD3, C4 and C7 as well, reporting hedge effectiveness of the respective contracts to 0.520 for the TD3, 0.467 for C4 and 0.697 for C7.

The time-varying hedge ratio seems to fluctuate quite a lot over the time horizon analyzed in the thesis. The figure below shows the maximum and minimum hedge ratio among all freight futures contracts at a given point in time.

Figure 17 Minimum and Maximum Hedge Ratio Intervals for Freight Futures



The maximum and minimum hedge ratio is calculated at each point in time comparing all the hedge ratios calculated using a time-varying hedge ratio among all freight contacts. The highest and lowest hedge ratio among all the contracts for a given week is presented in the figure.

Figure 17 seems to indicate that the gap between maximum and minimum hedge ratio is quite high and fluctuating to a large degree. This is supported by Figure 16, indicating that the time-varying hedge ratio for TD3 is fluctuating from 0.63 to 1.69. To put Figure 17 in perspective, please consider Figure 21 in the bunker analysis, showing a much more stable time-varying hedge ratio.

An interesting finding here is that although the optimal hedge ratio has increased for both the dry bulk and the tanker contracts, the change in hedge effectiveness is different. The tanker contracts, TD3 and TC2, have seen an increase in the optimal hedge ratio, but a decrease in hedge effectiveness. The dry-bulk contracts, PM4TC, P2A, P3A, C4 and C7 have seen an increase in both hedge ratio and hedge effectiveness.

Why have the hedge ratios increased? Recall Equation 16 for calculating optimal hedge ratios:

$$h^* = \frac{\sigma_{\Delta S,\Delta F}}{\sigma_{\Delta F}^2}$$

This can be rewritten as

$$h^* = \rho_{\Delta S,\Delta F}\frac{\sigma_{\Delta S}}{\sigma_{\Delta F}}$$

Table 23 below shows the correlation coefficients and standard deviations for all the different contracts for all the periods.

Table 23 Analysis of Changes in Standard Deviations and Correlation Coefficients

		P2A			P3A	
	Period 1	**Period 2**	**Period 1 & 2**	**Period 1**	**Period 2**	**Period 1 & 2**
Standard deviations						
-Spot	1961.64	5163.45	3911.74	2366.85	5101.08	3979.51
-Futures	2118.88	4215.97	3338.30	2325.12	4175.01	3382.67
Correlation coeff.	0.75	0.86	0.84	0.75	0.87	0.84
		TC2			**C4**	
	Period 1	**Period 2**	**Period 1 & 2**	**Period 1**	**Period 2**	**Period 1 & 2**
Standard deviations						
-Spot	27.82	22.10	25.07	1.16	2.78	2.12
-Futures	21.69	13.70	18.10	1.26	2.29	1.85
Correlation coeff.	0,67	0.63	0.65	0.68	0.87	0.83
		PM4TC			**TD3**	
	Period 1	**Period 2**	**Period 1 & 2**	**Period 1**	**Period 2**	**Period 1 & 2**
Standard deviations						
-Spot	1835.48	4452.59	3476.79	18.94	22.55	20.80
-Futures	1815.01	3521.78	2852.04	14.94	13.57	14.29
Correlation coeff.	0.61	0.63	0.62	0.77	0.62	0.68
		C7				
	Period 1	**Period 2**	**Period 1 & 2**			
Standard deviations						
-Spot	1.00	3.00	2.24			
-Futures	0.98	2.38	1.83			
Correlation coeff.	0.81	0.88	0.87			

Table 23 shows standard deviations and correlation coefficients from all the different time series used in the regression analyses.

According to Table 23 the correlation coefficient increased for all dry-bulk routes from period 1 to period 2. In the tank market the opposite is observed. The coefficient fell from 0.77 to 0.62 for each respective period for TD3 and from 0.67 to 0.63 for TC2. For all the dry-bulk routes the volatility for both futures and spot prices increase from period 1 to 2 and the spot volatility increased relatively more than futures volatility. However, the tank market did not show the same trend. Volatility for TC2 actually decreased in period 2 and the same is observed for volatility in futures prices for TD3. In the dry-bulk market a combination of both higher correlation and increased volatility in the spot market compared to the futures market led to a higher optimal hedge ratio. The tank market suffered from lower correlation, but the effect of higher volatility in the spot market compared to the futures market made the hedge ratio increase a bit.

Recall Section 5.A.1, where the results of the tests for normality were shown in Table 21. The JB-statistic for P2A was shown to be 420.83 for all 248 observations, a fair amount above its 95% critical value of 5.99. As an experiment, the 10 most extreme positive and negative changes in the spot price of the time series for P2A for period 1 and 2 were removed, along with its corresponding change in futures price for that week. Running regressions on this altered time series now presents the following results:

Conventional hedge ratio (old values in parenthesis): 0.725 (0.979), conventional hedge eff.: 0.615 (0.699), new JB-statistic: 10.31 (420.83).

The presence of these twenty extreme observations contributed greatly to the high JB-statistic of 420.83, indicating that these were much of the reason why the errors were not normally distributed. Another interesting find is that the hedge ratio fell from 0.979 to 0.725, while the hedge efficiency fell from 0.699 to 0.615. The drop in hedge ratio indicates that, for 228 of the 248 observations, there would be an overexposure in the futures market, or in other words: 61.5% of the variance could be explained by a 26% lower hedge ratio. This illustrates the sensitivity of the measures computed. However, since it would be expected that most hedgers are more afraid of extreme events than the day-to-day changes, this procedure of eliminating extreme observations could disregard one of the most important reasons for hedging: Reducing exposure to the greatest drops/jumps. How hedging with freight contracts would affect a hedgers portfolio in a worst-case scenario would therefore be interesting to look into. This will be the subject for the section.

5.A.2.2 Hedging the Worst-Case Scenario

On a week-to-week basis the hedge effectiveness presented in Table 22 is not the constant prevention from an increase/fall in rates. This implies that the actual loss prevention at a given point in time might deviate from the hedge effectiveness observed for the period as whole. A ship owner could be especially interested in hedging the most significant drops in the freight rates. It could therefore be interesting to see what would happen if the spot prices were hedged with a ratio equal to the calculated conventional ratios (see Table 22) from in-sample studies during these events. For illustration purposes, the ten most negative changes in the spot price are used to analyze the effect of using futures contracts for hedging freight risk. It is important to note that this analysis only looks at the implications for a hedger a given week.

Table 24 Loss Reduction for the Ten Worst Cases in Freight (Conventional Hedge Ratio)

	PM4TC	P2A	P3A	TD3	TC2	C4	C7
1	46 %	49 %	66 %	23 %	42 %	84 %	81 %
2	26 %	135 %	64 %	30 %	10 %	45 %	58 %
3	20 %	37 %	107 %	48 %	-75 %	51 %	91 %
4	1 %	146 %	114 %	-26 %	101 %	82 %	42 %
5	70 %	77 %	108 %	8 %	3 %	98 %	131 %
6	12 %	102 %	82 %	45 %	23 %	99 %	50 %
7	50 %	127 %	72 %	50 %	56 %	88 %	137 %
8	84 %	125 %	49 %	-10 %	40 %	-23 %	65 %
9	36 %	117 %	68 %	-5 %	47 %	33 %	7 %
10	55 %	96 %	62 %	-6 %	50 %	86 %	19 %
Averages	**40 %**	**101 %**	**79 %**	**16 %**	**30 %**	**64 %**	**68 %**

The calculations are based on first difference weekly estimates. The hedged portfolio is calculated given the conventional optimal hedge ratio. Red indicates a situation where the observed loss reduction is lower then what's found using the conventional hedge ratio in Table 22.

Table 24 presents the loss reductions observed for the ten worst cases in the spot prices. The calculations are done by sorting the weekly first difference estimates in the spot price from smallest to largest. Using only the ten worst weeks, a hedge portfolio is constructed using the optimal conventional hedge ratios presented earlier in this chapter (Table 22). The figures presented in the table are the percentage loss reduction compared with the unhedged portfolio[62].

For example: On 01.10.2008 the PM4TC spot price dropped 21 760.50 USD/day since last week. The futures contract dropped 13 138 USD/day in the same period. The optimal hedge ratio from Table 22 is 0.756, which means that the hedged portfolio would have had a drop equal to 11 828 USD/day. The use of a futures contract in this example reduced the loss by 46%. The time-varying hedge ratio on that specific date was 0.51. Using this ratio instead of the conventional ratio would only lead to a loss reduction of 31%.

The results in Table 24 clearly show that the dry-bulk contracts help reduce these risks quite well. The Panamax contracts actually remove more variance in the worst ten cases compared with the average from the whole period. P2A is by far the best contract for hedging the worst ten events. On average, the contract removes 101% of the risk observed in the spot price (meaning that the hedged portfolio would make money on such events). On the other hand, the tanker contracts seem to reduce only 16% and 30% on average for the worst ten weeks. For TD3, only three weeks gave a higher variance reduction than what was expected by the

[62] For comparison with a time-varying hedge ratio please see Appendix A.7.

overall hedge efficiency. Even more surprising is it that, in four out of ten weeks, the use of futures contracts actually increased the loss. This was worst for the TC2 contract, where in one case the use of futures contract actually increased the loss by 75%.

This analysis emphasizes the point that the variance reductions due to futures contracts are not necessary stable. Hence, using futures contracts might help in the long-run, but from a week-to-week basis the results might deviate.

5.A.2.3 Out-of-Sample Study

To compare the various hedging strategies better, an out-of-sample study has been performed on the freight data. Using the earliest available data up till the 31st of December 2008 to calculate conventional hedge ratios and EWMA hedge ratios, the hedge efficiency of the various strategies are compared for data from 4th of January 2009 to the 4th of November 2009. Results may be found in Table 25[63]. For the background for the out-of-sample strategies, please see Appendix A.6.

Table 25 Results Out-of-Sample Study on Freight Contracts

	PM4TC	P2A	P3A	TD3	TC2	C4	C7
Conventional hedge ratio	0.730	0.968	0.974	0.979	0.894	0.917	1.029
Conventional hedge eff.	0.431	0.718	0.822	0.565	0.300	0.727	0.699
Naive hedge eff.	0.479	0.723	0.829	0.570	0.319	0.755	0.691
Time-varying hedge eff.	0.446	0.659	0.836	0.572	0.316	0.774	0.716

Table 25 shows the results from out-of-sample studies for 2009. Numbers highlighted in red show which strategy gave the best hedge efficiency.

Using time-varying hedge ratios outperformed the conventional hedge ratios for all the contracts, except for P2A. This is as expected, since time-varying hedge ratios are able to take into account new information. However, it is surprising to see that a naïve hedge ratio was the best strategy for PM4TC, P2A and TC2, and was even better than conventional hedge ratios for all the contracts except C7. The comparatively low hedge efficiency is still present, ranging from 0.319, for TC2 using a naïve hedge, to 0.836 for P3A using time varying hedge ratios.

Based on the results found in these studies, it would appear time-varying hedge ratios would be the optimal hedge strategy, since it would be naïve to think that naïve hedge ratios would

[63] Please note that this is not the same time period as indicated by period one and two in the section above. The in-sample calculations used for estimating the hedge ratios is provided in Appendix A.6.

continue to be as good as it was in 2009. It is, however, important to consider the transaction costs of constant re-positioning in the futures markets.

5.A.2.4 Analyzing the Hedge Performance of the Freight Futures

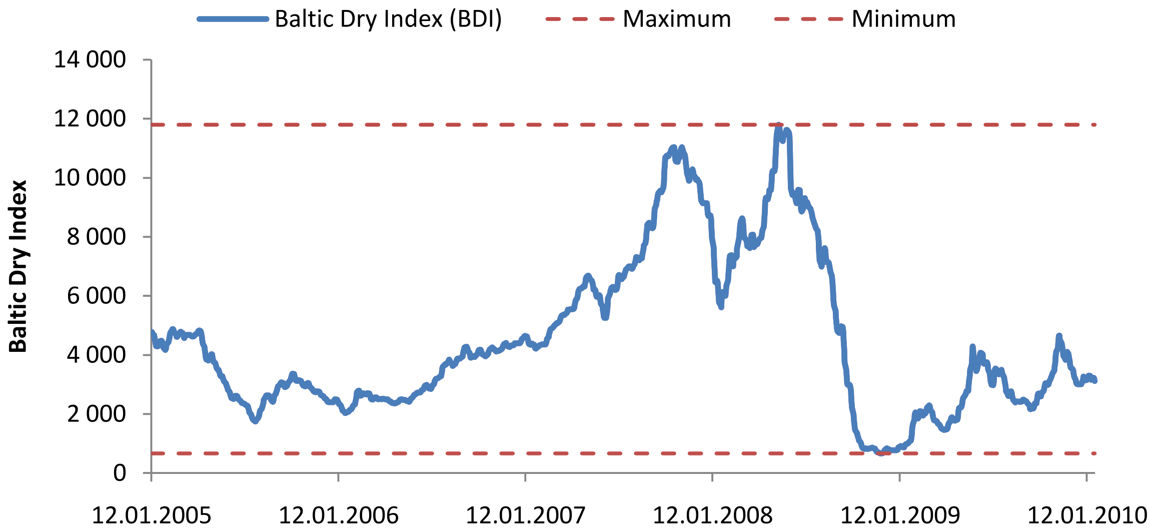
Despite the increased hedge effectiveness over the last five years, the hedge effectiveness for freight futures is still lower than what's observed in other futures markets. Black (1986) concludes that the futures contracts offering the highest reduction in risk were the ones attracting the highest trading volume and attention. Brorsen & Fofana (2001) define a successful futures market as a market which maintains a consistently high trading volume and a high volume of open interest over time, i.e. the amount of futures contracts which are not closed on a given day. Based on Black (1986) and Carlton (1984, p. 242) among others Brorsen & Fofana investigate the success and failure of agricultural futures contracts. To investigate the phenomenon of comparable lower hedge efficiency further, a specification of factors for success in futures market is appropriate. Carlton (1984, p 242-245) presents five key characteristics of commodities traded on futures markets, which will be presented below. Supplementing these factors with the empirical evidence from Brorsen & Fofana (2001), this can be used as a framework to explain why or why not freight is suitable as an underlying for financial futures. The authors of this thesis also add two more characteristics as a base-line for discussing the suitability of the futures contracts.

1. **Uncertainty**

The price of the underlying has to be fluctuating to some degree. If the price is rather stable, market agents will have no need to hedge the underlying price. Figure 18 below shows the recent history for the Baltic Dry Index (BDI)[64].

[64] The Baltic Dry Index (BDI) in an index based on the average of the Baltic Supramax, Panamax, Capesize and Handysize indices. The index is used as a benchmark for the dry-bulk freight market and economists also use it as a leading indicator of the world economy.

Figure 18 High Fluctuations in Freight Rates Measured by Baltic Dry Index (BDI)



Source: Baltic Exchange

The BDI reached a high of 11 793 on the 20th of May 2008, before falling down to only 663 on the 5th of December the same year, which equals a drop in the price of freight rates of 94.4%. This dramatic drop in freight rates were a ship owner's nightmare and it could hardly have been predictable. Hence, it should be no doubt that, as mentioned multiple times earlier, the shipping market is volatile and uncertain. This criterion should therefore not be able to explain the comparatively low hedge effectiveness of the freight futures contracts.

2. Price correlations across slightly different products

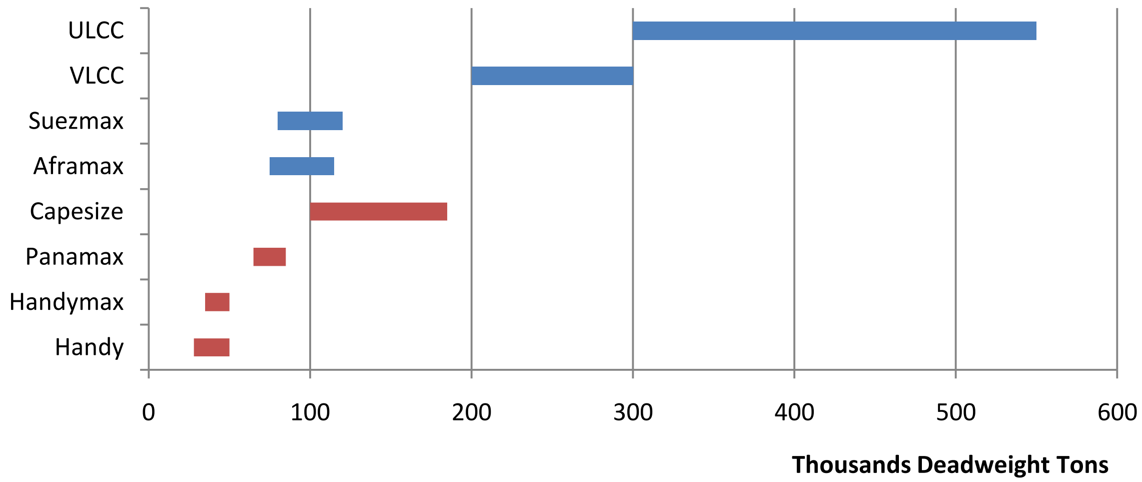
Carlton (1984, p. 242) : *"[a] futures contract is for a commodity standardized in grade and location, while the physical products traded can differ in specification and location. A futures market is most valuable when the prices across different specifications and locations are highly correlated."*

If prices across specifications and locations are not highly correlated, this would reduce the value of the futures contracts, as cross-hedging would become less effective. The issue of low correlations between different specifications and locations is an issue in freight markets. The correlations between different vessel sizes are hard to estimate, but even small deviations in size might lead to lower observed hedge effectiveness. Even though the P3A is defined for Panamax vessels of the size of 74,000 dwt, the Panamax segment is defined from 65,000 – 80,000dwt[65]. The variety of vessels size creates a problem in the futures market where the

[65] See http://www.lr.org/Images/30%20ship%20sizes_tcm155-173543.pdf.

market might be dominated by Panamax ship owners with larger or smaller vessel than what the futures is defined for. This problem is also observed in all the freight futures contracts discussed in this thesis. Figure 19 below shows the size heterogeneity of different vessel sizes.

Figure 19 Ship Size Definitions for the Dry-Bulk and Tank Segment, Measured by dwt



Source: Lloyd's Register (http://www.lr.org/Images/30%20ship%20sizes_tcm155-173543.pdf). The red bars indicates that the ship is in the dry-bulk segment. The blue bars are vessels in the tank segment.

The figure clearly shows that regardless of the general name of the vessel category, the heterogeneity among a specific vessel type can vary quite a lot. This problem is addressed by Kavussanos & Nomikos (2000, p. 54), who look at the BIFFEX contract. They state that the introduction of a new index which only tracks the price of Panamax ships increased the hedge effectiveness. The hedge effectiveness found for Imarex futures are higher than what studies finds for the BIFFEX contract. However, the fact that the ships to some extent are still heterogeneous cannot be excluded as one of the factors why the freight futures show a lower hedge effectiveness.

Moreover, the route a given ship transports goods might also differ from the routes traced by the futures contracts. The correlation between the freight rates of different routes should be high. If, say, a Panamax ship owner observes higher profitability on another route than where he is currently transporting goods, he will switch to this market. This should neutralize large deviation between the different routes in the long-term. However, if the market participants use the futures contract to systematically cross-hedge another route, this might affect the futures price if the trade volume is significant.

In Appendix A.2 the correlation matrix between different spot prices may be found, across different routes and vessel sizes. It is interesting to note that the correlation between the Panamax routes is comparatively high, as opposed to between for example TD3 and TC2, which appear to be negatively correlated. This seems to indicate that routes are less important than vessel sizes. The correlations between Capesize and Panamax are also comparatively high compared with the tanker contracts TD3 and TC2, which might also be a consequence of the goods the vessels are transporting[66].

Differences in other factors such as age or technology may also affect the viability of futures markets, but these are difficult to measure. To sum up, the factors mentioned above may contribute to the low hedge effectiveness.

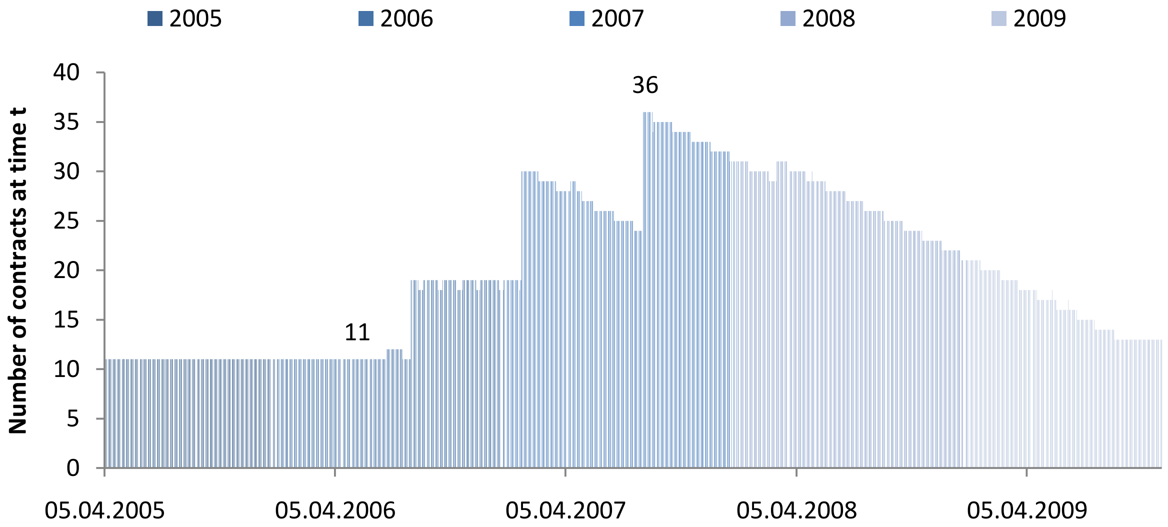
3. Large potential number of interested participants and industrial structure

There has to be a large number of market agents to make sure that the *liquidity* of the futures and underlying stays at a comfortable level. The tremendous boom in the dry-bulk market until the fall 2008 financial crisis, described in point one above, attracted many speculators. Brokers at Imarex claim that approximately 70% of the trades made on Imarex are for speculation purposes, which is also claimed by Kavussanos & Visvikis (2006b, p. 192). The true amount of hedgers is hard to specify. The speculators helped the liquidity on Imarex increase during the boom. After the collapse of Lehman Brothers (15th of September 2008) the number of transactions fell back to 2007 levels[67]. The trading volume measured by 1000 tons per day did not fall much compared with the fall in trading value. The latter is due to both lower prices on futures contracts and the fact that many of the speculators were ship owners, now struggling to pay their next debt payment and therefore left the market. In the beginning of 2009 the market rallied somewhat, and both trading volume and value has increased. Compared with earlier studies of the Imarex futures market, by Skjetne (2005) and Rasmussen & Tversland (2007), the liquidity is now much higher. This might explain the increase in hedge effectiveness observed over the horizon. However, it is hard to define a certain level where one can define a market as liquid. Moreover, market participants in other markets (such as the stock market) have increased their focus on liquidity dramatically since earlier studies.

[66] See Chapter 2.3.1 for further information.
[67] See Appendix A.5 for a graphical representation of the liquidity of the futures contracts on Imarex.

Skjetne (2005) states that over the duration of one year Imarex will trade in 525 different freight futures contracts. This amount has changed over time, as Imarex has adjusted the amount of contracts available for any given route. The figure below shows how many futures contracts were available for PM4TC at a given point in time.

Figure 20 Number of Available Contracts for PM4TC at a Given Point in Time



From 2006 to 2007 the number of available contracts for PM4TC increased from 11 to 36 contracts. This was mainly due to the introduction of several monthly contracts, making it possible to hedge freight risk for more time intervals than earlier. An increase in available contracts will increase the possibilities for hedging. However, each contract will need some amount of liquidity to be efficient. After mid 2007 the number of available contracts decreased, due to low trading volumes in some of the contracts offered. This should therefore lead to a higher liquidity for the remaining contracts.

Although the amount of contracts has subsided, it is still high, and may thus affect the effectiveness of the futures markets.

4. Large value of transactions

Fluctuations in prices must have a high economical impact on the market agent. If the economical consequences of the fluctuations are low, the market agent might want to take the risk of fluctuations. The fluctuations in the freight rates have tremendous impact on the profitability for the ship owners and charterers. For that reason it would be safe to assume that this criterion is fulfilled.

5. Prices freely determined and absence of regulation

If the equilibrium prices are influenced by government regulations, or controlled by one large firm, this may affect the demand for a futures market. Regulations could lead to set prices, whereas monopolists could manipulate spot prices in order to take advantage of their futures positions, both of which could lead hedgers to be reluctant in entering into such a futures market. This is not the case in the freight market, which is characterized as highly competitive and global. In addition, as discussed in Section 4.7, the futures prices are based on averages from a delivery period, and are therefore less likely to be influenced by single market participants.

In addition to Carlton's list of five factors, two additional factors may be added to discuss the success of a futures market.

6. Freight futures prices are not linked to the underlying spot prices by a cost-of-carry arbitrage relationship

Since freight is characterized as a non-storable good, the cost-of-carry relationship breaks down, as discussed in Section 3.2.3. Recent research shows that the unbiasedness hypothesis does not hold for freight futures traded on Imarex. This might make the futures market inefficient because arbitrageurs cannot do cost-of-carry arbitrage.

Furthermore, research from other markets of non-storable goods, such as the electricity market, shows an even lower hedge effectiveness. Byström (2003) investigates the hedge performance of six futures contracts on the Nord Pool futures market for electricity. The results of the out-of-sample test shows that the hedge effectiveness stretches from -0.0164 to 0.2927 for a variety of estimation methods. Madaleno & Pinho (2008) also looked into the hedge effectiveness of electricity futures on Nord Pool, as well as EEX and Powernext, with similar results. The hedge efficiencies ranged from 0.021 to 0.234 for a variety of estimation methods. These results are significantly lower than what is observed in markets where the cost-of-carry relationship is valid. This might indicate that the futures market is dependent on arbitrageurs to make the market place efficient.

7. The own-hedge contract should be more effective reducing risk than the existing cross-hedge contract

Brorsen & Fofana (2001) argue that it would be expected that any given futures contract would have explained more of the variance in its underlying spot market than any other futures contract, i.e. no futures contract explains more of the variance for C4 than the futures contract on C4. Table 26 shows the hedge efficiencies for period 1 & 2, using a conventional hedge ratio for all futures contracts on each individual spot price.

Table 26 Cross-Hedging with Imarex's Futures Contracts, Hedge Efficiency (R^2)

	Spot						
Futures	**PM4TC**	**TD3**	**P2A**	**P3A**	**TC2**	**C4**	**C7**
PM4TC	0.385	0.010	0.356	0.306	0.003	0.079	0.091
TD3	0.000	0.459	0.001	0.001	0.014	0.006	0.013
P2A	0.609	0.006	0.699	0.372	0.000	0.036	0.065
P3A	0.622	0.000	0.392	0.711	0.002	0.092	0.090
TC2	0.000	0.002	0.001	0.000	0.426	0.004	0.018
C4	0.079	0.000	0.044	0.106	0.012	0.684	0.494
C7	0.064	0.005	0.045	0.094	0.016	0.664	0.761

This table shows the hedge efficiencies for using Imarex's futures contracts for hedging a number of spot prices. Numbers highlighted in red show the maximum hedge efficiency for any given spot price.

The results are as expected, except for the optimal contract to use to hedge exposure to PM4TC spot prices. While the futures contract traded on PM4TC only explained 38.5% of the variance in the spot prices of PM4TC, both P2A and P3A explained more than 60%. This is a surprising finding. As observed for the capesize contracts, where C4 futures explained 49.4% of the variance of C7 spots, and C7 futures explained 66.4% of the futures of C4 spots, it would be expected that P2A and P3A explained some of the variance of PM4TC spots, especially since PM4TC is an average of, among others, both P2A and P3A. This is, however, clearly a break from the criterion mentioned by Brorsen & Fofana, which might contribute to the low hedge effectiveness.

Kavussanos & Visvikis (2006b, p. 192) mention that 70% of trading on Imarex is for speculation purposes. Since PM4TC is the only futures contract which is a portfolio of an average of other contracts, it could be that it is even less likely that it is used for hedging purposes than the other futures contracts. This could, partly, explain why the hedge efficiency of the PM4TC futures contract is so low.

Stoll and Whaley (1993, p. 57) suggest that it might be optimal to use a portfolio of contracts to hedge exposure in the price of the underlying asset. The portfolio of contracts can then be calculated using a multiple regression analysis. Using the equation presented in Stoll and Whaley (1993, p. 57), Equation 19 can be written as:

$$\Delta S_t = \alpha_0 + \beta_1 \Delta F_{t,T}^1 + \beta_2 \Delta F_{t,T}^2 + \cdots + \beta_n \Delta F_{t,T}^n + u_t \qquad (39)$$

Where ΔS_t is the (first difference) change in the underlying spot price at time t , α_0 is the constant (basis) and β_n is the hedge ratio for futures contract n with $\Delta F_{t,T}^n$ indicating the first difference change in the futures prices of contract *n*. The results from the multiple regression using PM4TC as the underlying spot price is presented in Table 27.

Table 27 Results from using multiple contracts for hedging PM4TC spot prices

	Unstandardized Coefficients	Standardized Coefficients	Sig.	Collinearity Statistics	
	Beta	Beta		Tolerance	VIF
(Constant)	-116.441		.299		
PM4TC	-.226	-.185	.002	.302	3.314
TD3	-31.291	-.113	.001	.944	1.060
P2A	.628	.608	.000	.271	3.687
P3A	.580	.568	.000	.361	2.767
TC2	.557	.003	.929	.983	1.017
C4	-384.358	-.209	.002	.233	4.298
C7	170.338	.091	.181	.223	4.492

Results from multiple regression with PM4TC as the underlying. Numbers highlighted in red indicates that the variable is not significant on a 5% confidence level.

The hedge effectiveness for the calculated portfolio is 0.769, which is higher than using just P3A (0.622) or PM4TC (0.385). The unstandardized beta coefficients can be interpreted as the hedge ratio for each contract relative to the underlying spot price. However, the beta coefficients for TC2 and C7 are not significant, meaning that these contracts might not be used in the portfolio for hedging PM4TC.

One important issue when dealing with a multiple regression analysis is *multicollinearity*. When two regressors, such as C7 and C4, are correlated, it is hard to separate their effects on the dependent variable (PM4TC). According to Brooks (2002, p. 191-192) multicollinearity can cause each coefficient to have a high standard error, making an individual contract not significant. Table 27 shows that C7 and TC2 were not statistical significant. Appendix A.2 indicates that the correlation between C7 and PM4TC is quite high, whereas TC2 is much less correlated with PM4TC. Appendix A.2 also shows a correlation coefficient for C7 and C4 close to 0.843. This might indicate the presence of multicollinearity in the regression, which made C7 not significant. Multicollinearity might also make the model sensitive to small changes such as adding or removing an explanatory factor. Tests for multicollinearity may be performed through *VIF-tests* (Variance Inflation Factor-tests). VIF-statistics of above 10 (or a tolerance coefficient of below 0.1) (Seiler, 2004, p. 146) indicate a problem with multicollinearity. The VIF-statistics in Table 27 indicate that this so with the freight contracts.

Due to limitations in time and size, this thesis will not look further into hedging freight with multiple contracts, but the above analysis shows that it might be possible to achieve greater hedge efficiency in freight through multiple futures contracts, and could therefore prove to be an interesting subject for future studies on Imarex's futures contracts.

5.B Bunker

The following section will look into the hedge effectiveness of the bunker futures contracts on Imarex. The structure will be the same as for the freight contracts, except that there is no multiple-period analysis in the in-sample study. This is due to the fact that there are no new comparable studies for bunker, as was the case with freight. Comparisons with earlier studies on cross-hedging bunker prices will nonetheless be made.

5.B.1 Testing Underlying Assumptions

The results of the tests of the underlying assumptions for OLS are presented here. For more information on the tests, please see Section 5.A.1.

Table 28 Results from White's Test for Heteroscedasticity

	LM-statistics	Critical values	
	2005-2009	5% level	1% level
RMD35FO	3.134	5.991	9.21
NWE10FO	9.827	5.991	9.21
SPO180FO	0.203	5.991	9.21
SPO380FO	2.071	5.991	9.21
USG30FO	10.427	5.991	9.21

Table 28 shows the results from White's test for heteroscedasticity. Figures in red show where the null hypothesis of homoscedasticity is rejected. Critical values are obtained from tables of the χ^2 *distribution with two degrees of freedom. Sources for data: Platts and Imarex.*

The results from White's test for heteroscedasticity, which are found in Table 28, show that the null hypothesis is rejected for the regressions performed on NWE10FO and USG30FO. Any tests performed using results from these regressions will therefore have to be done with care, as the presence of heteroscedasticity may affect the standard errors. This will have the same implications for the studies as discussed in Section 5.A.1.

Results from Breusch-Godfrey tests on residuals may be found in Table 29.

Table 29 Results from Breusch-Godfrey Tests on Residuals

	LM-statistics					
	RMD35FO	NWE10FO	SPO180FO	SPO380FO	USG30FO	Critical values
1 week	16.061	14.474	34.374	32.205	12.100	3.84
4 weeks	31.095	33.667	37.542	37.728	26.121	9.49
12 weeks	35.695	43.107	45.708	46.499	28.442	21.03
52 weeks	61.618	74.815	63.158	64.520	57.375	69.83

Table 29 shows the results from Breusch-Godfrey tests on the residuals. The numbers in red show where the null-hypothesis of no serial correlation is rejected on a 5% confidence level. The critical values are obtained from table of the χ^2 *distribution with p (number of lags, 1,4,12 and 52) degrees of freedom. Sources for data: Platts and Imarex.*

If no serial correlation is present, then the tests should fail to reject the null hypothesis for all lags. Regressions on all the bunker contracts show serial correlation. There is therefore reason to fear that the standard errors are significantly different from the reported ones, in addition to the presence of inflated R^2s. It would be expected that bunker prices follow the same seasonality as freight prices, and therefore the presence of seasonality and overreactions in financial markets could explain the serial correlation.

The results of the Jarque-Bera tests may be found in Table 30.

Table 30 Results of the Jarque-Bera Tests on Bunker Futures Contracts

Contract	JB-statistic	Critical value
RMD35FO	28.959	5.99
NWE10FO	12.405	5.99
SPO180FO	52.309	5.99
SPO380FO	31.944	5.99
USG30FO	14.012	5.99

Table 30 shows the results from the Jarque-Bera tests. The numbers in red show where the null hypotheses of normally distributed errors are rejected. The critical values are obtained from tables of χ^2 *distributions with 2 degrees of freedom. Sources for data: Platts and Imarex.*

The results in Table 30 show that the errors from all the regressions performed on bunker contracts are not normally distributed. There is therefore a chance that wrong conclusions are made when testing hypotheses based on these regressions.

5.B.2 Results

5.B.2.1 In-Sample Study

Hedging through three different strategies is compared for the five different futures contracts provided by Imarex. Using a naïve hedge ratio, the conventional hedge ratio and a time-varying hedge ratio through EWMA, comparisons are done for the in-sample analysis on data from early 2006 to 2009 for all the contracts. The results may be found in Table 31.

Table 31 In-Sample Results for Bunker Futures Contracts.

	NWE10FO	RMD35FO	SPO380FO	USG30FO	SPO180FO
Conv. hedge ratio	0.921	1.017	0.891	0.891	0.894
Conv. hedge effectiveness	0.866	0.913	0.849	0.743	0.851
Naïve hedge effectiveness	0.859	0.913	0.836	0.733	0.839
Time-varying hedge eff.	0.861	0.911	0.845	0.731	0.844

Table 31 shows the hedge effectiveness for the different hedging strategies, except row 1, which shows the conventional hedging ratios. Sources for data: Platts and Imarex.

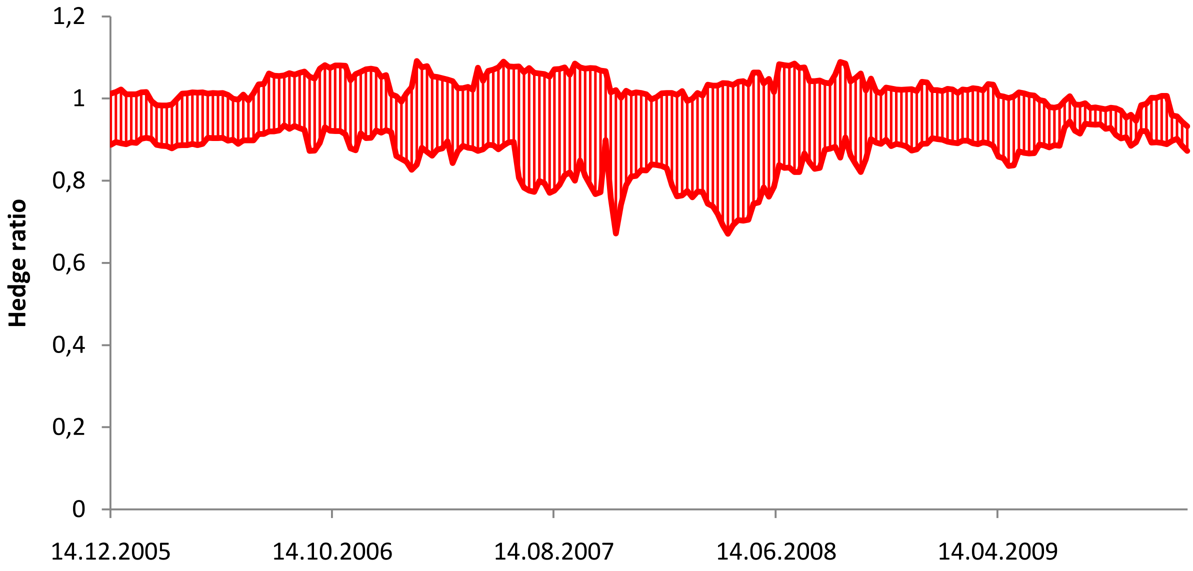
The results shown in Table 31 exceed the expected values for hedge effectiveness. The conventional hedge ratios show a hedge effectiveness of 91.3% on the Rotterdam contract, whereas the North West Europe and the Singapore 380 and 180 contracts show hedge effectiveness of 86.6%, 84.9% and 85.1% respectively. The Houston contract has the worst result, showing a hedge ratio of 74.3%.

Even more so than in the freight rate tests, the hedge ratios are close to one. This explains why following a naïve strategy for hedging would have given almost as high a hedge effectiveness as when using a conventional hedge ratio. This would seem to indicate that changes in prices are similar both in size and direction in the spot and futures markets.

The following time-varying hedge ratios computed through EWMAs for variances and covariances would not out-perform the conventional hedge ratios for any of the contracts. In addition, continuously changing weights in the futures contracts would lead to higher transaction costs, and this should also be taken into account when considering a time-varying versus a conventional hedge ratio. It is beyond the scope of this thesis to look into the transaction costs of time-varying hedge ratios, but an example of how this could be taken into account may be found in Kavussanos & Visvikis (2008).

The figure below gives a similar analysis as Figure 17 in the freight analysis. It shows the maximum and minimum hedge ratio at a given point in time.

Figure 21 Minimum and Maximum Hedge Ratio Intervals for Bunker Futures



The maximum and minimum hedge ratio is calculated at each point in time comparing all the hedge ratios calculated using a time-varying hedge ratio among all bunker contracts. The highest and lowest hedge ratio among all the contracts is presented in the figure. Sources for data: Platts and Imarex.

The figure shows a much more stable hedge ratio than what's found for freight futures. This indicates that the investor would be less exposed to basis risk when trading in bunker futures compared to freight futures.

The Houston contract shows the lowest hedge effectiveness for all the hedging strategies, but its hedge effectiveness is still within the expected values mentioned in Section 3.4.7. Its relatively weak effectiveness may be explained by the fact that it is younger than the others: The Houston futures contract on Imarex was launched on the 2nd of June 2006, while all the others were launched on the 5th of January 2006 or earlier. Alizadeh et al. (2004) argue that the inferior hedge effectiveness of the Houston contract, when using cross-hedges through petroleum futures, may have been due to the Houston market being "..a much smaller – regional – market in terms of volume exchanged compared to the other two markets…". This may also be why the hedge effectiveness of the Houston contract is lower than the others.

In Section 3.4.7, the reasons Alizadeh et al. (2004) used to explain the low cross-hedging efficiency of bunker spot prices were mentioned, such as differences in supply and demand for bunker and other oil products, as well as cross-hedge problems due to different underlying products in the spot and futures markets. Since the results presented above exceed the expectations, this may indicate that these problems have been remedied by Imarex's futures contracts.

5.B.2.2 The Dark Side of the Hedge

The analysis of the worst ten cases for freight focused on the reduction in income due to lower rates, and how hedging could prevent this. This section is meant to target the downside of hedging with futures contracts. Lower fuel prices will normally mean lower costs for a ship owner. However, if the ship owner hedges his exposure to this fuel price with a futures contract, he will miss out on the decrease in bunker costs implied in such a decrease in bunker prices[68]. Table 32 is calculated using the same framework as presented in Section 5.A.2.2.

Table 32 Prevented cost decreases for the ten best cases in bunker (conventional hedge ratio)

	NWE10FO	RMD35FO	SPO380FO	USG30FO	SPO180FO
1	108 %	111 %	113 %	90 %	114 %
2	127 %	107 %	94 %	55 %	93 %
3	85 %	103 %	109 %	70 %	110 %
4	125 %	68 %	106 %	44 %	110 %
5	48 %	95 %	73 %	116 %	54 %
6	73 %	73 %	50 %	58 %	54 %
7	56 %	70 %	59 %	51 %	70 %
8	85 %	134 %	71 %	108 %	75 %
9	73 %	66 %	17 %	50 %	19 %
10	94 %	104 %	111 %	152 %	65 %
Average	**87 %**	**93 %**	**80 %**	**79 %**	**76 %**

The calculations are based on first difference weekly estimates. The hedged portfolio is calculated given the conventional optimal hedge ratio. Red indicates a situation where the observed prevention in cost decrease is lower than what would be expected from the hedge effectiveness in Table 31. Sources for data: Platts and Imarex.

Table 32 shows how using futures contracts will affect the bunker costs for a hedged portfolio. The greatest drops in bunker prices should lead to a lower bunker cost, but a hedger will not be able to take advantage of this. Example: The "best" week for NWE10FO saw a decrease in bunker spot prices of 77.25 dollars per metric ton. The decrease in futures price for NWE10FO that week was 90.5. Using the optimal conventional hedge ratio of 0.921 would mean that the change in the portfolio would be:

$$-77.25 - 90.5 \times 0.921 = 6.1\text{USD per metric ton}$$

In other words, instead of a decrease in bunker price of 77.25, the hedged portfolio would instead have increased its bunker cost by 6.1USD per metric ton. Compared with the price drop, this would imply a prevented cost decrease of:

[68] This is of course an argument for why ship owners often use options instead. The option gives the ship owner the possibility of hedging only downside risk by paying the option premium.

$$-(6.1 — 77.25) = 83.35\text{USD per metric ton}$$

In percentage terms, compared with the drop in bunker spot price:

$$\frac{83.35}{77.25} \times 100\% = 108\%$$

In other words, instead of being able to see a decrease in bunker costs of 77.25USD per metric ton, the hedger would see an increase in bunker costs of 6.01USD per metric ton, 108% more than what a non-hedger would have. Using time-varying hedge ratios would have led to a 107% cost decrease.[69] The corresponding percentages for all the bunker contracts for their ten largest drops in spot prices are found in Table 32.

The results are, on average, about what one would expect when considering the hedge effectiveness from in-sample analysis in Section 5.B.2.1. All the contracts have at least 3 weeks where there is an increase in the portfolio compared with the decrease in spot prices (prevented cost decrease above 100%). Hull (2009 p. 49) states that hedging could become troublesome if a CEO or equivalent does not understand that hedging is about decreasing risks, and is presented with an increase in prices due to hedging, despite a decrease in spot prices. Causing one's company to lose money when it could have been saving money is a tough responsibility, and all parties should be aware of this phenomenon before using futures contracts to hedge with.

5.B.2.3 Out-of-Sample Study

An out-of-sample study has been performed on the bunker data as well. The procedure has been the same as it was in the out-of-sample study on freight: The earliest available data up till the 31st of December 2008 are used to calculate conventional hedge ratios and EWMA hedge ratios, and these are then used to compare the hedge efficiencies for the different strategies for 2009. Results may be found in Table 33. For the background for the out-of-sample strategies, please see Appendix A.6.

[69] Complete table for time-varying hedge ratios may be found in Appendix A.7.

Table 33 Results from Out-of-Sample Studies on Bunker Futures Contracts.

	NWE10FO	RDM35FO	SPO380FO	USG30FO	SPO180FO
Conv. hedge ratio	0.935	1.039	0.879	0.894	0.881
Conv. hedge eff.	0.785	0.826	0.820	0.720	0.828
Naive hedge eff.	0.772	0.832	0.822	0.709	0.831
Time-varying hedge eff.	0.782	0.830	0.820	0.715	0.827

Table 33 shows the results from out-of-sample studies performed on the bunker contracts. The out-of-sample data are from 2009. The numbers are all hedge efficiencies, except those in the first row, which show the conventional hedge ratios used in the out-of-sample study. Sources for data: Platts and Imarex.

It would be expected that EWMA would outperform the conventional or naïve hedge ratios, since it is able to take into account new information as time proceeds. Although true for freight contracts, this is not so for the bunker contracts. The optimal strategy would have been to use naïve hedges for RDM35FO, SPO380FO and SPO180FO, giving hedge efficiencies of 0.832, 0.822 and 0.831, while conventional hedge ratios would have been optimal for NWE10FO and USG30FO, giving hedge efficiencies of 0.785 and 0.720 respectively. EWMA was only better than conventional hedge ratios for the NWE10FO contract. It is interesting to note that the statistical differences in hedge effectiveness between strategies are very small, both in the in-sample and out-of-sample study. It is however important to note that, especially considering transaction costs when using time-varying hedge ratios, the economic differences between the strategies could become significant.

Since the hedge ratios through EWMA were time-varying, why did they not outperform all the other strategies? Two possible reasons for this may be that either the EWMA-calculations do not take into account the correct set of information, or that it loses efficiency due to its complicated calculations. A possible remedy for these issues may be to use GARCH-modeling to try to capture the auto-regressive and heteroscedastic artifacts in the time series.

5.B.2.4 Analyzing the Hedge Performance of the Bunker Futures

The five key characteristics presented by Carlton (1984) could also explain why the hedge effectiveness is higher for the bunker futures contracts compared to the freight futures contracts.

1. **Uncertainty**

As mentioned in Section 2.2.3, 50-60% of the costs to a ship-owner consist of bunker fuel costs. It is well established that bunker fuel prices are closely linked to highly volatile oil prices, and subject to local supply and demand conditions. These factors combined could therefore lead to much uncertainty in bunker prices. Recalling the discussion in Section 3.1 on why firms hedge, this could lead to less predictable firms with higher probabilities of incurring bankruptcy costs. The uncertainty in bunker costs should therefore count positively towards the hedge effectiveness of the futures bunker contracts.

2. Price correlations across slightly different products

Since futures markets are most valuable when prices across locations and specifications are highly correlated, a look into the correlation coefficients of the different futures prices could prove interesting, as the high hedge efficiency would seem to indicate that high correlations between different futures prices could be expected. The results may be found in Table 34.

Table 34 Correlation Coefficients Between the Different Changes in Spot Prices

	NWE10FO	RMD35FO	SPO380FO	USG30FO	SPO180FO
NWE10FO	1.00				
RMD35FO	0.91	1.00			
SPO380FO	0.83	0.91	1.00		
USG30FO	0.78	0.84	0.85	1.00	
SPO180FO	0.83	0.91	0.99	0.85	1.00

Correlation coefficients between spot prices. Source for data: Platts.

The results found in Table 34 show what would be expected. The correlation coefficients between the different locations are all above 0.78, indicating strong positive correlations between all the routes. The correlations are however not perfect, due to local supply and demand differences and quality differences in the fuel[70]. It is, however, much higher than the correlation coefficients found in the freight rate futures markets, and could be one of the reasons why the hedge efficiency is so much higher for bunker futures contracts.

3. Large potential number of interested participants and industrial structure

Anders Nordahl, an employee at Imarex, describes the evolution of the liquidity of the bunker futures in the following manner[71]: *"There was some liquidity, then it all but disappeared, but is now increasing somewhat again. The volumes traded are very small, and there are large gaps in time between each trade, at least compared with other futures markets."*

[70] See section 2.2.3 for more information on how the fuel contracts differ.
[71] This is a response from an e-mail to Imarex where the authors inquired about the development of the liquidity in the bunker contracts.

The apparent lack of liquidity of Imarex's bunker futures contract could lead to a lower hedge effectiveness. However, as the hedge effectiveness reported above is seemingly high, the lack of liquidity does not seem to have a very large effect.

4. **Large value of transactions**

The large sums involved in any ship-owners bunker costs should make them ideal candidates for hedging. This should therefore count positively towards the success of the bunker futures contracts.

5. **Price freely determined and absence of regulation**

One may assume that the prices in the spot bunker markets are freely determined, as they tend to be competitive, especially the Rotterdam prices, which Kavussanos & Visvikis (2006b) claim to be "… extremely competitive". However, as the bunker prices are closely linked to oil prices, they will be indirectly subject to the regulations on oil prices (such as through OPEC). This does not seem to have affected the oil futures in any degree, however, as both Ripple & Moosa (2007) and Switzer & El-Khoury (2006) report hedge effectiveness in the ranges of 80-99%.

It may be that yet another factor could explain why the hedge effectiveness is higher for the bunker contracts than the freight contracts, namely:

6. **Bunker futures contracts are linked to the underlying through a cost-of-carry arbitrage relationship**

Bunker fuel is a storable commodity, and arbitrageurs may therefore use the cost-of-carry relationship to exploit any deviations from this relationship. This could increase the liquidity of the bunker futures contracts, and may therefore contribute positively to the hedge effectiveness of the bunker contracts compared to the freight contracts. This criterion might be considered one of the most important reasons why the bunker futures market exhibits higher hedge effectiveness than non-storable futures markets.

7. **The own-hedge contract should be more effective reducing risk than the existing cross-hedge contract**

As in Section 5.A.2.4, it would be expected that the optimal contract to use for hedging any spot price would be the futures contract with that spot price as underlying. For curiosity's sake, the hedge performance of using conventional hedge ratios are compared for all spot prices on all futures contracts.

Table 35 Cross-Hedging Using Imarex's Futures Contracts on Bunker

	Spot				
Futures	**NWE10FO**	**RMD35FO**	**SPO380FO**	**USG30FO**	**SPO180FO**
NWE10FO	0.810	0.810	0.777	0.610	0.776
RMD35FO	0.774	0.913	0.865	0.709	0.859
SPO380FO	0.704	0.811	0.849	0.643	0.839
USG30FO	0.782	0.898	0.853	0.744	0.848
SPO180FO	0.708	0.815	0.848	0.652	0.851

This table shows the hedge efficiencies for using Imarex's futures contracts for hedging a number of bunker spot prices using conventional hedge ratios. Numbers highlighted in red show the maximum hedge efficiency for any given spot price.

The results in Table 35 are surprising. Changes in the futures price of the Rotterdam contract seem to explain more of the variance in changes of the spot prices of both the Singapore contracts than their respective futures contracts. It is important to note that the differences here are very small, and no tests for the underlying assumptions for these contracts have been done. In the case of heteroscedasticity, these measures could be inflated. Moreover, the results from Table 30 show that the residuals from the original regressions are not normally distributed. How this may affect the optimal hedge ratio and hedge efficiency may be seen in Section 5.A.2.1. That the Rotterdam contracts should continue to explain more of the variance of the Singapore prices is therefore a conclusion one should do with care.

Since the Houston-contract has lower hedge efficiency than the other, it might be possible to see if it could be possible to increase the variance reduction of Houston spot prices with several futures contracts. The results may be found in Table 36.

Table 36 Results from using multiple futures contracts to hedge Houston spot prices

	Unstandardized Coefficients	Standardized Coefficients	Sig.	Collinearity Statistics	
	Beta	Beta		Tolerance	VIF
(Constant)	.058		.668		
NWE10FO	-.035	-.228	.046	.107	9.385
RMD35FO	.025	.156	.490	.027	37.035
SPO380FO	-.056	-.372	.305	.010	95.551
USG30FO	.852	.824	.000	.036	27.484
SPO180FO	.072	.479	.184	.011	94.152

Results from multiple regression on Houston spot prices. Numbers highlighted in red indicate that the coefficient is not significant on a 5% confidence level.

Using multiple futures contracts, with hedge ratios equal to the unstandardized coefficients in Table 36, gave a hedge efficiency of 0.752. The hedge efficiency of using only the Houston futures contract gave a hedge efficiency of 0.744, which indicates that there is little to gain by using multiple futures contracts to reduce the variance of Houston spot prices. The VIF-statistics are also very high, ranging from 9.385 to 95.551, which indicate that the multiple regression may be affected by multicollinearity.

It could be that the increase in hedge efficiency could be higher for the other bunker spot prices, but due to limitations in time and size, this will not be focused on further in this thesis. It could provide an interesting subject for further studies on Imarex's futures contracts.

The high correlations between Imarex's bunker contracts indicate that it is not necessary with such a wide range of futures contracts for bunker prices. The authors of this thesis would suggest that it might be optimal to create an index of all bunker prices in the world, which could maintain high hedge efficiency while increasing the liquidity through a smaller number of available contracts (see criterion number 3 in Section 5.B.2.4.). The weighting of the different spot prices in such a contract could provide an interesting subject for further studies on Imarex's futures contracts.

5.B.2.5 Cross-hedging Bunker Risks

Alizadeh et al. (2004) tested the cross-hedging performances of oil futures contracts traded on IPE and NYMEX on bunker price fluctuations, as these were actively traded and assumed correlated with bunker prices. These facts made them candidates for cross-hedging, but their effectiveness was poor, reporting in-sample variance reductions ranging from 4.49% to 28.25%, which was surprisingly low, especially since it would be expected that bunker prices are correlated with oil prices, in light of the criteria discussed in the Section 5.B.2.4. It could therefore be interesting to investigate if these futures contracts would still prove poor cross-hedging vehicles for bunker price risks.

Using the same contracts as Alizadeh et al. (2004), regressions were performed on the different bunker prices on all the 5 different futures contracts, giving 25 different hedge efficiencies. The results may be found in Table 37:

Table 37 Results Cross-Hedging Using Oil Futures Contracts

Futures\Spots	RMD35FO	USG30FO	SPO180FO	SPO380FO	NWE10FO
IPECO	0.538	0.649	0.374	0.369	0.668
IPEGO	0.628	0.536	0.532	0.536	0.566
IPEHO	0.559	0.642	0.435	0.438	0.589
NYMHO	0.533	0.600	0.482	0.423	0.561
NYMCO	0.646	0.776	0.468	0.469	0.646

Table 37 shows the different hedge efficiencies for the different contracts, using data from the December 2005 to December 2009. The hedge effectiveness of the contracts were obtained through using conventional hedge ratios. Numbers in red indicate which futures contracts proved the best hedging vehicle for a given bunker price series and its variance reduction.

The results in Table 37 shows that the futures contracts which were studied by Alizadeh et al now prove much better hedging vehicles than they did before. The NYMCO contract provided the best hedging vehicle for Rotterdam and the US Gulf Coast, reducing 64-6% and 77.6% percent of the variance, respectively. The NYMCO contract actually explains more of the variance of USG30FO spots than Imarex's futures contract on these bunker prices (even more so than a portfolio of all of Imarex's futures contracts, as discussed in section 5.B.2.3). The IPEGO contract seems the best hedging vehicle for the Singapore contracts, with variance reductions of 53.2% and 53.6%. IPECO was the best for North West Europe, reducing 66.8% of the variance.

The results differ not only in the variance reductions, but also in the optimal contract to use for hedging. Alizadeh et al. (2004) reported that the IPEGO contract was the best hedging vehicle for all the contracts in the in-sample studies, which is now only true for the Singapore contracts.

Although not on par with hedge performances through futures contracts such as reported by Ripple & Moosa (2007), the results provide good news for agents in shipping who are interested in hedging bunker prices through other means than Imarex's bunker futures contracts.

5. C Suggestions for Further Studies

Although studies on the hedge performance has been done on Imarex's futures contracts, little or no studies have been done on the effect of maturity (monthly, quarterly or yearly) and frequency (daily, weekly or monthly) of data on hedge effectiveness. Earlier studies on other futures markets have shown that these may have significant effects on results (See Thuong & Visscher (1990)). In addition, when comparing time-varying versus constant hedge ratios, transaction costs should be considered. How these affect the hedge performance of Imarex's futures contracts, through different strategies, could provide interesting studies.

An interesting study on the bunker contracts would be to test the unbiasedness hypothesis, i.e. if their futures prices are unbiased predictors on future spot prices. Moreover, the authors of this thesis suggest that Imarex's bunker contracts liquidity may become greater if it is reduced to one contract. The feasibility and composition of such a contract could provide interesting subjects for further studies.

The futures contracts on bunker seem to suffer from low liquidity, which may be due to several reasons. Imarex seems to have been successful in launching options on freight, so it could be interesting to investigate whether agents in the shipping industry would be more interested in options on bunker instead of futures contracts, or if there are other futures contracts which follow the development of bunker spot prices so closely that they make Imarex's bunker futures redundant.

6. Conclusion

This thesis analyzed the hedge performance observed in the freight and bunker futures markets, starting with a brief introduction to the shipping market and an introduction to fundamental theories on futures markets and pricing. This is then followed by a discussion on the use of sampling intervals, seasonality in shipping and evaluating different methods of splicing the futures data series.

Freight

The in-sample analysis reveals increased hedge performance for dry-bulk over the two periods with hedge efficiency ranging from 38.5% to 76.1% over the entire period studies. The tanker market shows a negative development in hedge performance, indicating a 42.6% and 45.9% variance reduction for the entire period. Comparing dry-bulk and tank shows a higher hedge efficiency in dry-bulk, diverging from previous studies indicating the opposite relationship. Nevertheless, the conclusions should be interpreted with care due to the violation of some of the underlying assumptions for the OLS calculations, as the tests disclose both autocorrelation and heteroscedasticity. Moreover, the time-varying hedge ratio fails to beat the conventional hedge ratios. In the out-of-sample test the time-varying hedge ratio slightly outperforms conventional ones in 4 out of 7 cases. Analyzing how well the futures contracts work during extreme events show that using futures contracts to hedge may increase losses in the short run.

An interesting finding is made trough an internal Imarex cross-hedge between the different futures markets and the underlying asset, indicating that PM4TC-futures is not the best choice for hedging PM4TC spot prices, as other Panamax contracts (P2A and P3A) show a higher hedge effectiveness. The overall hedge performance in the freight market is somewhat lower than what is found in other futures markets. The thesis presents a possible explanation for this to be found in the heterogeneity of vessels sizes, low liquidity in the futures market and the non-existence of the cost-of-carry relationship.

Bunker

The in-sample tests show higher hedge efficiency compared to freight futures. Only marginal deviations are observed from using different estimations techniques. In the out-of-sample test the time-varying hedge ratio beats the *conventional* hedge for 2 out of 5 contracts. The time-varying hedge ratios seem to be much more stable in the bunker market compared to the freight market. An analysis of internal Imarex cross-hedges shows that the Singapore contracts are maybe not the optimal contracts for hedging exposure in the Singaporean market, although this should be considered with care due to possible breaks from underlying assumptions. A cross-hedge using other oil-futures concludes that using NYMCO futures contracts gives a higher risk reduction if USG30FO is the underlying asset.

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8. Appendix

A.1 World scale and calculation of contract value

World scale was developed by the British Government under the Second World War. It shows the cost of transporting a cargo of *oil* on each of the main routes using a standard sized vessel. Before the Second World War dollars or pounds expressed the rates. When charters needed loading or discharging of cargo it was necessary to agree multiple rates of freight. When the World Scale was established only one rate was necessary to agree upon. The World scale Association discusses the definition of the standard size and update the scale each year.

Calculation of the contract value[72]

$$contracts\ value = number\ of lots \times lot\ size \times Worldscale\ Flat\ Rate \times \frac{Worldscale\ Points}{100}$$

A.2 Correlation matrix between spot prices for freight

Table 38 Correlation Matrix Between Spot Prices for Freight

Correlations

		PM4TC	TD3	P2A	P3A	TC2	C4	C7
PM4TC	Pearson Correlation	1	.031	.924**	.906**	.069	.550**	.564**
	Sig. (2-tailed)		.622	.000	.000	.281	.000	.000
	N	248	248	248	248	248	248	248
TD3	Pearson Correlation	.031	1	.044	-.004	-.143*	.034	.126*
	Sig. (2-tailed)	.622		.493	.945	.025	.598	.048
	N	248	248	248	248	248	248	248
P2A	Pearson Correlation	.924**	.044	1	.696**	.043	.539**	.590**
	Sig. (2-tailed)	.000	.493		.000	.496	.000	.000
	N	248	248	248	248	248	248	248
P3A	Pearson Correlation	.906**	-.004	.696**	1	.083	.493**	.437**
	Sig. (2-tailed)	.000	.945	.000		.192	.000	.000
	N	248	248	248	248	248	248	248
TC2	Pearson Correlation	.069	-.143*	.043	.083	1	-.053	-.029
	Sig. (2-tailed)	.281	.025	.496	.192		.406	.654
	N	248	248	248	248	248	248	248
C4	Pearson Correlation	.550**	.034	.539**	.493**	-.053	1	.843**
	Sig. (2-tailed)	.000	.598	.000	.000	.406		.000
	N	248	248	248	248	248	248	248
C7	Pearson Correlation	.564**	.126*	.590**	.437**	-.029	.843**	1
	Sig. (2-tailed)	.000	.048	.000	.000	.654	.000	
	N	248	248	248	248	248	248	248

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

[72] The equation is interpreted from the information given in The Imarex Rule book - http://www.exchange.imarex.com/getfile.php/NOS%20Clearing%20ASA/Products%20and%20Services/Rulebook%20and%20agreements/Appendix_5_Product_Specification.pdf

A.3 Standard Deviation and Kurtosis Using First Difference Calculations

Table 39 Standard Deviation and Kurtosis Using First Difference Calculations

	Std. Dev			Kurtosis		
	Futures	Spot	S>F	Futures	Spot	S>F
PM4TC	2852.04	3429.47	Yes	4.95	6.89	Yes
P2A	3338.30	3911.74	Yes	3.04	8.64	Yes
P3A	3382.67	3979.51	Yes	2.50	5.67	Yes
TD3	14.29	20.80	Yes	5.31	5.58	Yes
TC2	18.10	25.07	Yes	4.51	2.72	No
C4	1.85	2.24	Yes	3.84	6.26	Yes
C7	1.83	2.12	Yes	4.49	4.70	Yes
NWE10FO	22.86	22.47	No	4.84	2.72	No
RMD35FO	21.68	23.07	Yes	4.86	3.54	No
SPO380FO	22.89	22.15	No	5.68	3.50	No
USG30FO	3.51	3.44	No	3.53	2.21	No
SPO180FO	23.04	22.16	No	5.84	3.61	No

This table is meant to discover the differences in standard deviation and kurtosis between spot and futures prices. Because of the Asian properties of the futures traded on Imarex it is expected that the standard deviation for spot prices exceeds the one for futures contracts.

A.4 Basis

Below are the tables for basis, their standard error and their t-statistics.

Table 40 Basis from Regressions Run on Freight Futures

		2005-2009	2005-2007	2007-2009
PM4TC	Basis	56.263	51.989	67.463
	Std. Error	178.400	140.100	310.800
	T-values	0.315	0.371	0.217
TD3	Basis	-0.091	1.312	-1.531
	Std. Error	0.973	1.106	1.591
	T-values	-0.094	1.186	-0.962
P2A	Basis	-146.710	69.414	-338.725
	Std. Error	136.800	117.300	236.500
	T-values	-1.072	0.592	-1.432
P3A	Basis	59.895	7.848	109.310
	Std. Error	136.200	142.500	226.400
	T-values	0.440	0.055	0.483
TC2	Basis	-1.000	-0.900	-0.896
	Std. error	1.208	1.870	1.540
	T-values	-0.828	-0.481	-0.582
C4	Basis	-0.039	-0.018	-0.025
	Std. error	0.076	0.077	0.122
	T-values	-0.512	-0.230	-0.206
C7	Basis	-0.064	-0.030	-0.064
	Std. error	0.070	0.053	0.124
	T-values	-0.924	-0.558	-0.516

This table shows the basis from the regressions run on freight futures.

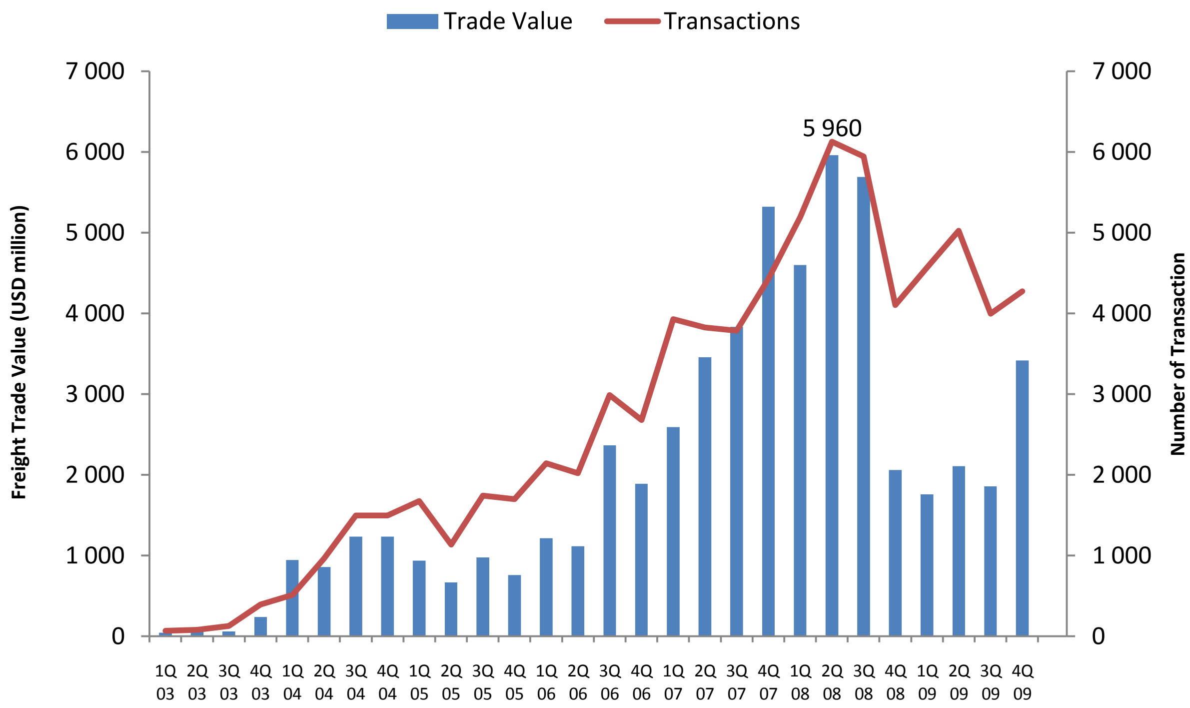
Table 41 Basis from Regressions on Bunker Futures

Contract	NWE	RDAM	SPO380	USGC	SPO180
Basis	0.853	0.323	0.388	0.061	0.544
Std.error	0.573	0.468	0.593	0.135	0.600
T-value	1.488	0.691	0.655	0.453	0.907

This table shows the basis from regression run on bunker futures from 2005-2009.

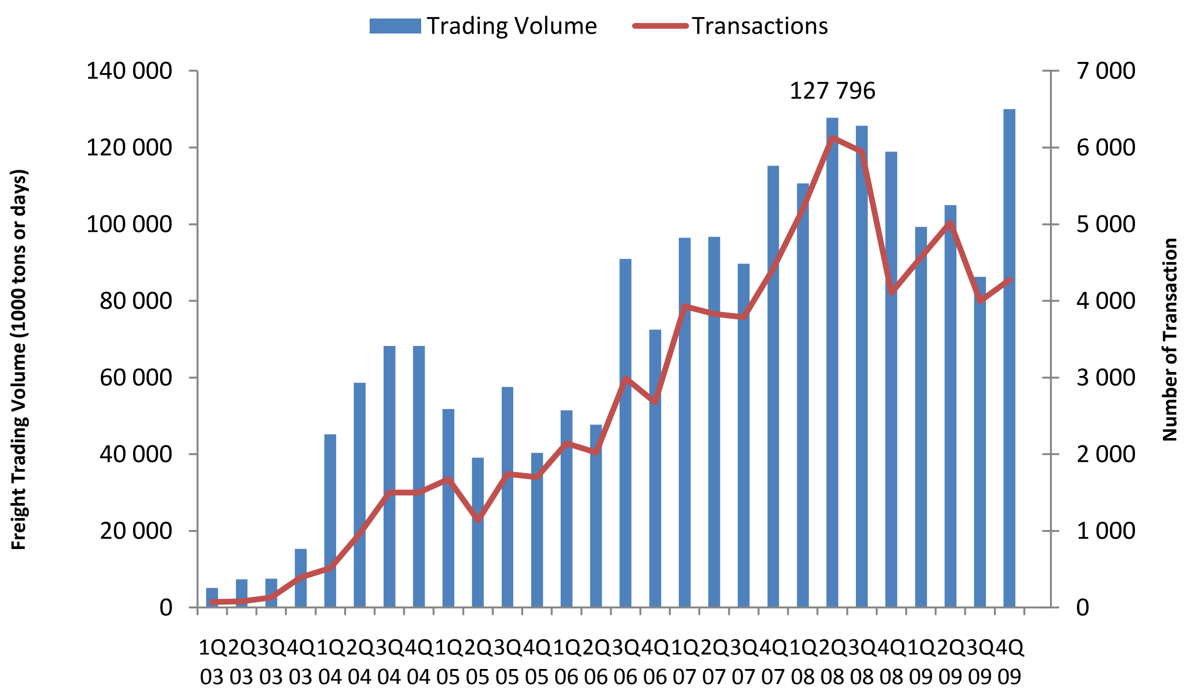
A.5 Figures for Trading Volume at Imarex

Figure 22 Liquidity on Imarex Expressed with Trading Value (Number of transaction showed on the secondary axis)



Source: http://www.imarex.com/analytical-download/category118.html

Figure 23 Liquidity on Imarex Expressed with Trading Volume (Number of Transaction Showed on the Secondary Axis)



Source: http://www.imarex.com/analytical-download/category118.html

A.6 Background for Out-of-Sample Studies

When performing out-of-sample studies, a background for the strategies needs to be used (i.e. conventional hedge ratios and a sample for previous variances and covariances for EWMA to use). Tables 42 and 43 show the hedge performances (and conventional hedge ratio) of various strategies for data from the start of the data set to the 31st of December 2008.

Table 42 Out-of-sample Background for Freight Contracts

	PM4TC	TD3	P2A	P3A	TC2	C4	C7
Conv. hedge ratio	0.730	0.979	0.968	0.974	0.894	0.917	1.029
Conv. hedge eff.	0.374	0.456	0.694	0.698	0.435	0.676	0.777
Naïve hedge eff.	0.323	0.456	0.693	0.698	0.429	0.671	0.777
Time-varying hedge eff.	0.283	0.395	0.564	0.674	0.377	0.686	0.756

This table shows the hedge performances, and conventional hedge ratio, for the sample which the out-of-sample strategies are based on for freight contracts. Numbers highlighted in red show the optimal hedge performance.

Table 43 Out-of-Sample Background for Bunker Contracts

	NWE10FO	RMD35FO	SPO180FO	SPO380FO	USG30FO
Conv. hedge ratio	0.935	1.039	0.881	0.879	0.894
Conv. hedge eff.	0.785	0.826	0.828	0.820	0.720
Naive hedge eff.	0.772	0.832	0.831	0.822	0.709
Time-varying hedge eff.	0.782	0.830	0.827	0.820	0.715

This table shows the hedge performances, and conventional hedge ratio, for the sample which the out-of-sample strategies are based on for bunker contracts. Numbers highlighted in red show the optimal hedge performance.

A.7 Loss Reduction for Worst Ten Cases Using Time-Varying Hedge Ratios

Table 44 Loss Reduction for the Ten Worst Cases in Freight (Time-Varying Hedge Ratio)

	PM4TC	P2A	P3A	TD3	TC2	C4	C7
1	31 %	17 %	52 %	20 %	37 %	82 %	76 %
2	27 %	197 %	68 %	37 %	11 %	53 %	64 %
3	20 %	50 %	117 %	44 %	-91 %	59 %	88 %
4	1 %	61 %	119 %	-37 %	83 %	84 %	50 %
5	70 %	52 %	120 %	6 %	3 %	111 %	149 %
6	11 %	55 %	84 %	55 %	22 %	113 %	57 %
7	56 %	94 %	55 %	70 %	68 %	98 %	163 %
8	75 %	86 %	52 %	-9 %	47 %	-28 %	60 %
9	-1 %	118 %	73 %	-7 %	62 %	35 %	8 %
10	58 %	106 %	65 %	-7 %	47 %	84 %	17 %
Average	**35 %**	**84 %**	**80 %**	**17 %**	**29 %**	**69 %**	**73 %**

The calculations are based on first difference weekly estimates. The hedged portfolio is calculated given the time-varying optimal hedge ratio at a given point in time. Red indicates a situation where the observed loss reduction is lower then what's found using the time-varying hedge ratio in Table 22.

Table 45 Loss Reduction for the Ten Worst Cases in Bunker (Time-Varying Hedge Ratio)

	NWE10FO	RMD35FO	SPO380FO	USG30FO	SPO180FO
1	107 %	116 %	117 %	83 %	119 %
2	132 %	114 %	95 %	52 %	94 %
3	87 %	109 %	106 %	73 %	111 %
4	130 %	68 %	107 %	44 %	111 %
5	47 %	102 %	68 %	115 %	52 %
6	70 %	73 %	48 %	54 %	54 %
7	54 %	70 %	59 %	51 %	66 %
8	86 %	138 %	71 %	110 %	74 %
9	74 %	69 %	17 %	49 %	20 %
10	94 %	105 %	95 %	170 %	68 %
Average	**88 %**	**97 %**	**78 %**	**80 %**	**77 %**

The calculations are based on first difference weekly estimates. The hedged portfolio is calculated given the time-varying optimal hedge ratio at a given point in time. Red indicates a situation where the observed loss reduction is lower then what's found using the time-varying hedge ratio in Table 31.