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Applied Financial Risk Management for the Shipping Industry Using IMAREX Derivatives

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Abstract

Risk Management in shipping has taken a great leap with the introduction of IMAREX, trading in cleared freight futures contracts. This thesis evaluates the derivatives introduced by IMAREX as financial instruments for risk management in the volatile industry of international shipping. The main focus is on evaluating the IMAREX Freight Futures, assessing its observed performance, and providing guidelines for optimal usage. I introduce relevant measures of hedge effectiveness, and the hedging performance of the products are evaluated according to these. The thesis furthermore describes the products in detail, and raises issues and present recommendations for effective risk management using the IMAREX derivatives from the eyes of prospective users. In this respect, section five will contain the essence of the analysis, the latter part of which will illustrate by examples a lot of the issues that could arise in an actual hedging scenario. The IMAREX Freight Options are evaluated from a more theoretical angle, where we will introduce pricing models for these options.

Acknowledgements

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1. INTRODUCTION

1.1 General notes

The business of shipping and ocean going freight dates far back. With the development of larger vessels, economies of scale, and the trends of globalization, in particular over the last century, the business of ocean going freight has grown considerably. The business, however, has been characterized as highly risky, and many investors have classified the industry as one of high-risk and low-return. Many shipowners have met a sad demise in the low points of the volatile business cycles, but the industry has also made countless millionaires.

Shipping is an industry with many sources of uncertainty. The revenues are tied to the freight rates, which in almost every segment of the business fluctuate heavily. The costs are tied to the price of bunker fuel, which is tied to the petroleum business. Assets, or the value of the fleet of a shipowner, also fluctuate according to the business cycle of the shipping industry, making asset play[1] a significant source of revenue or costs. Newbuilding prices for ships depend on factors such as steel prices and conversely scrapping costs, being a labour intensive activity depending on both steel prices and wage rates.

In addition to the risks above come the risks associated with unforeseen maintenance of vessels, accidents, and situations of liability. Furthermore, being a business operating internationally, one is also exposed to risks of foreign exchange, interest rates, and political circumstances. The risks associated with shipping will be further elaborated on later.

1.2 Objective

Having indicated the uncertain environment a shipowner operates in, the need for risk management tools is established. Earlier contractual specifications were able to

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[1] The activity of speculating on the prices of vessels and buying/selling these for a profit

transfer certain risks between charterer and shipowner, and insurance for ocean going freight has existed for a long time. During the last twenty years, however, financial risk management tools have been introduced. The BIFFEX contract, being the first exchange traded futures contract on freight rates, was traded from 1985 until 1995. Since 1992 bilaterally negotiated instruments such as forward freight agreements are becoming increasingly popular.

The latest development in shipping risk management is the Norwegian authorized marketplace for freight rate derivatives, IMAREX. This marketplace is the only regulated marketplace for such derivatives and has seen a strong growth over the few years since its introduction. The products provided by IMAREX will be the scope of this thesis. The thesis will first address and evaluate the IMAREX freight futures from a descriptive point of view, measuring their performance as hedging tools. Guidelines for optimal usage will also be presented. Secondly, I will analyze the newly introduced IMAREX freight options from an a priori perspective, giving recommendations for how such options should be priced correctly, given the complex nature of the underlying assets. The paper will move in the borderline between the shipping industry and traditional finance, addressing how the hedger can employ the IMAREX contracts to reduce risk.

1.3 IMAREX Freight Futures

The principal users of derivative contracts are the hedgers. These are users that aim to reduce the risks of the physical exposures they have in the business, and originally these were the users forming such forward markets. Hand in hand with the hedgers are the speculators who do not necessarily have any physical exposure, but use the forward markets as a means to profit from speculating on price movements. The third group, the arbitrageurs, are present in nearly all financial markets, and their objectives are to make riskless profit from any wrongful pricing possibly prevailing in the market. To attract hedgers to a newly established forward market, there needs to be significant risk reduction potential, termed hedge effectiveness. The BIFFEX contract had an overall low hedge effectiveness compared to other commodity futures due to a

very high basis[2]. I will look at these properties for the case of IMAREX from the eyes of the industrial users, establishing the appropriateness and effectiveness of the risk reduction potential. I will show that by employing linear regressions on the futures prices versus the spot prices we will obtain estimates on hedge effectiveness, basis, and optimal hedge ratios. Given the wide array of available historical data, this will be the more empirical part of the paper.

A perfect hedge is one that can hedge an industrial participant's endowments in the physical market perfectly. That means that all risk may be eliminated completely. This is seldom the case, since futures contracts have to be standardized in order to achieve necessary liquidity. The consequence is that the futures prices may not co-move exactly with the prices of the endowments being hedged. Another problem with the standardization is that the futures contracts have established maturities, often quarterly, such that the contract may reach maturity before or after the exposure in the physical market.

Many of these issues can be resolved if we know more about how basis risk arises, and we will return to this in section 3.2. Strategies adopted by hedgers are numerous, and through so-called financial engineering one can improve risk management. Cross hedging is another notion which will be addressed, where the hedger uses a contract specified for another asset than his exposure, but where the correlations between the two are positive. I will be showing how one can use regressions of the futures prices against the spot rates and estimate basis, hedge ratios and hedge effectiveness based on these regressions.

1.4 IMAREX Freight Options

For the second part of the paper, I will provide a rather pragmatic analysis of the newly introduced IMAREX freight options. Time and scope limitations of such a thesis combined with the fact that virtually no empirical data is available at the time of writing will limit the analysis of these options to be one of ex ante and highly generalized considerations. The analysis will address the rather complex nature of

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[2] I will return to these definitions in section 3.

such options, and give recommendations for how such options should be correctly priced by market participants. This is an issue that arose on the suspicion that many market participants were using an inappropriate pricing model and improper parameter estimates. I will begin in one end of the scale, trying to establish the most accurate model for pricing of such options, and secondly try to substantiate the claim that the market is using the wrong model in many cases. The second part will be a challenge, given that the IMAREX freight options were introduced less than a month ago, and over the counter data are generally hard to come by in a business that has traditionally been highly secretive.

1.5 Risks in International Trade

A more comprehensive analysis of the sources of risk stemming from the activity of international trade is in order. The following figure shows the parties relevant in an international transaction, with the ship-owner in the center. According to agreements between seller and buyer of goods, they bilaterally agree who is to bear the costs incurred in transporting the goods. Different contractual agreements can be reached such as free-on-board (FOB) contracts, which state that the goods are to be delivered to the nearest port or pick-up point and the buyer covers freight. The other end of the scale is so-called "cost, insurance, freight" (CIF) contracts, in which the seller covers all expenses up until delivery to the buyer.

Figure 1.1: Contractual Specifications
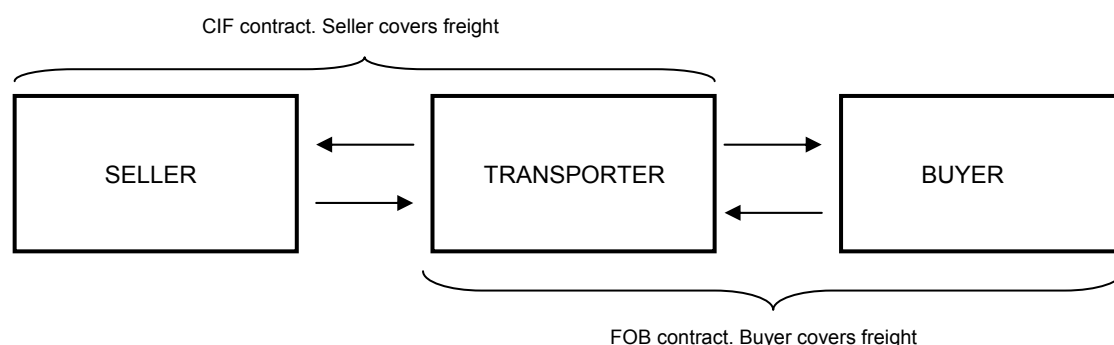
The party who has to bear the transport costs then makes a contract with the transporter. These contracts can be so-called contracts of affreightment (CoA), which specifies volume of transportation, while another type of contract is the so-called time

charter contract, specifying that an entire vessel is chartered for a certain amount of time. From figure 1.1 we can infer that the price of freight equals the CIF price less the FOB price of the goods shipped.

For the party who agrees to ship the goods, freight rate risks are not the only risk stemming from such a transaction. For trade between countries, a foreign exchange risk also arises. If a buyer is based in the Euro-area and agrees to purchase goods from Japan denominated in Yen, the buyer is also exposed to changes in the relative rates between Euro / JPY in the time between contracting and delivery. A risk associated with the price of the goods purchased is a further source of risk. If the buyer buys 200.000 ton of iron ore from Brazil and the international price of iron ore depreciates from the time of the contract fixture until delivery, commodity price risk is also introduced. The two parties are careful to state who are to bear these risks if the time of delivery is in the future, but more often than not, one of these parties are stuck with risks far exceeding the risks associated with the fair price of freight alone.

If we consider the situation as perceived by a shipowner, there are only two parties. The shipowner provides a product, which is freight, and the customers are all who require freight (no distinction between the buyer and the seller of the goods shipped).

Contrary to the party that requires transportation of goods, the shipowner is exposed to different risks. The shipowner is similar to the charterer exposed to freight rate risk, but the price of the underlying good is not an issue for the shipowner[3]. Furthermore, freight rates are in most cases denoted in US dollars, and the shipowner often has both his revenues and costs denoted in this currency. Hence, the shipowner bears less foreign exchange risk. The shipowner is, however, exposed to risks on his cost side in terms of bunker costs. Contractual specifications can rid the shipowner of risks associated with bunker costs. By entering a time-charter (T/C) contract the risks surrounding the voyage specific costs are shifted, as in such a contract the charterer bears voyage costs such as bunkers, port charges, and canal dues. One objective of this exercise is to establish that there is an asymmetry between the riskiness of the charterer's and the shipowner's sources of risk.

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[3] Not considering any correlation there may be between freight rates and the underlying good.

As we know, trading in futures requires both buyers and sellers. If there is a mismatch between these two parties, the liquidity of the contract may be reduced. To draw an analogy, over the recent years the salmon farmers have been opting for a futures market for farmed salmon. Even if the salmon farmers will be on the short side[4] of such futures contracts, there will be a lack of long positions, since, by nature, buyers of salmon are smaller and scattered and do not to the same extent consider hedging their positions.

1.6 Involved Parties

IMAREX:

Being classified by Kredittilsynet (the Financial Supervisory Authority of Norway) as an authorised market place, IMAREX is the only regulated exchange for freight derivatives in the world. The company was established in 2000 with objectives to become the largest international marketplace for freight derivatives and other risk management tools for the shipping industry.

By getting the stamp of approval from Kredittilsynet, IMAREX became the first regulated marketplace for such derivatives. Through its cooperation with and later through partial ownership of NOS (Norsk Oppgjørssentral), the traded derivatives are now cleared through a central clearing house.

IMAREX went public on April 4, 2005, when it was listed on the Oslo Stock Exchange. On June 1, 2005, the IMAREX Freight Options was launched; initially with the Baltic route TD3[5] as the underlying commodity.

NOS:

Short for Norges Oppgjørssentral (The Norwegian Futures and Options Clearinghouse), NOS is the clearing central[6] for all IMAREX freight futures. At the time of writing, IMAREX has a strategic ownership-position in NOS of around 16.7%.

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[4] Securing the fair value they will receive for the salmon by holding the physical salmon and selling futures contracts on it.

[5] VLCC, 250000mt. From Arabian Gulf to Japan

[6] We will return to the functions of a clearing central in section 3.1.2.2.

NOS is also clearing the IMAREX Freight Options and also certain bilateral Forward Freight Agreements as negotiated with IMAREX assistance.

Kredittilsynet:

The Financial Supervisory Authority of Norway, Kredittilsynet, is the supervising body of the Norwegian financial corporations. In their Annual Report of 2004, they state that their primary objectives are to ensure:

- Financial Stability – Solid Financial Institutions
- Well functioning finance and securities markets

Kredittilsynet classifies IMAREX for their supervisory purposes as an authorised marketplace. The authorised marketplace is regulated by Norwegian law, with a mandate of organizing or managing a market for financial instruments, where trade is facilitated through regular and public quoting of financial instruments. In contrast to that of authorised *exchanges*, the instruments quoted there, such as a company's stock, have to fulfil stricter requirements for authorised *exchanges*. This is the responsibility of the exchange to monitor. Authorised marketplaces also have more relaxed requirements of quotation than the authorised exchanges[7].

1.7 Outline

The thesis will in **section two** first turn to the traditional shipping industry and review how freight rates are determined. This will be a brief presentation of two alternate starting points, one looking at microeconomic determinants of freight rate modeling, the second being an illustration of a more analytic modeling of time series.

Sections three to five will present and analyse the IMAREX Freight Futures. **Section three** will provide a minimum of theoretical foundation, as well as some preliminary notes on risk management in the shipping industry. Readers familiar with the theory of futures contracts can skip this chapter. **Section four** will deal with technicalities regarding the IMAREX contract specification and the manner in which the data is handled and the analyses are conducted. I attempt to clarify how the IMAREX Freight Futures are different from the base case futures I have presented in section, and pose

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[7] Definitions in the Norwegian Stock Exchange Act (Børsloven) §1-3 and §5-6.

some words of caution regarding both the futures contract specification and how the data material is handled. **Section five** will by far be the most important part, as here the summaries of the analyses are presented, and two different, tentative applications are reviewed. Table 5.1 will present the summaries of the analyses conducted and the estimates for hedge effectiveness and optimal hedge ratios for seven different routes/contracts. Diagnostic tests on the estimates will be made, particularly for violations of the OLS assumptions, and limitations will be presented. Furthermore, I will provide two hypothetical and strictly tentative examples, using historical data to highlight practical aspects of the use of IMAREX derivatives. These examples will also highlight some issues that we are not able to include in the standard analysis, but that nonetheless are likely to be of interest in a real life hedging situation.

Section six will address the IMAREX Freight Options, where the analysis will review the pricing of options under the current circumstances. This analysis will be strictly theoretical and from an ex ante perspective.

2. NOTES ON FORMATION OF FREIGHT RATES

Before I proceed to evaluate how derivatives on freight rates work, an analysis of freight rate formation is in order. This presentation is a basic need to know for anyone considering using the IMAREX derivatives for any purpose. First we present a microeconomic approach to explaining how freight rates are formed, before we proceed to showing how freight rates can be modelled as stochastic processes. The example I will use in the latter part will be a so-called Ornstein-Uhlenbeck mean reverting process.

2.1 An Economic Approach to Freight Rate Determination

By considering the market forces working on the freight rates, one can partly explain the fluctuations of these rates from an economic viewpoint. Four shipping markets work together. In addition, exogenous factors such as oil and steel prices put pressure on the markets from the outside. I will now briefly review the determinants of freight rate formation.

2.1.1 The Four Shipping Markets

Stopford (1997) divides the market related to ocean going freight into four different markets, which to a large extent are interconnected:

- The market for newbuilding
- The market for freight
- The sale and purchase market
- The market for demolitions

How these markets work together I will return to shortly, but briefly I can say that the first and the last market helps regulate the long-term fleet size, and hence the supply of ton-miles in the industry. For shorter time-horizons this supply is regulated from the freight-rate mechanism. Higher output means that the whole fleet will be utilized

at a higher than normal speed, while at a certain low level, ship-owners will start laying up their vessels. The sale and purchase market is simply a rebalancing of assets within the industry, so that the total fleet size will not be affected, but can be a significant source of revenues for individual participants.

2.1.2 The Supply and Demand for Freight

The Demand for Freight:

This question has to be answered for each cargo segment separately, as the demand for freight within a specific segment is determined from the world demand for the goods shipped. The common denominator for all these markets is of course the world economy. If we are at a peak of an economic cycle, the need for transportation rises. For the shipowners dealing with crude oil, the OECD world oil demand index may be a more useful indicator. The length of the transportation, measured by the average haul, is another determinant for demand. This is a measure of the average length (distance) of each contract of affreightment. To illustrate this: If the US starts importing relatively more of their oil from Venezuela than from the Arabian Gulf, the average haul will decrease, as this distance is shorter.

Other factors important to world demand for freight include political circumstances, political events, and transport costs. An example of political circumstances that may affect the industry may be regulations by the EU in working towards downsizing the fleet of single hull vessels, the effects of which would be increased scrapping and newbuilding.

The Supply of Freight:

If we can treat factors influencing demand as largely exogenous, we cannot do the same with the supply side. The supply side depends on the current world fleet and its productivity, as well as the newbuilding less the amount of scrapping of vessels. The current world fleet can adjust itself in the short run, although slowly, through the so-called fleet productivity. This consist of average speed, loaded days at sea (as opposed

to ballast and port time), load factor etc. Higher speed means on average more output, so does more loaded days at sea. A higher average load factor (or deadweight utilization) means that each ship on average carries more cargo. Low demand can in the short run be met by lay-ups. In this case, the shipowner can eliminate all voyage related costs if the revenues are not large enough to cover variable costs. In the longer run, supply is adjusted through newbuilding and scrapping.

2.1.3 The Freight Rate Mechanism

The supply and demand schedules come together through the freight rate mechanism. This is portrayed in figure 2.1. We see that the first section of the supply schedule is completely inelastic in terms of freight rates. If the market clears in this section, this is due to the fact that the highest cost shipowners will start laying up their vessels. If the market clears at a point to the right of this section, all vessels will be utilized, and the fleet productivity will be increased to meet the increased demand.

Figure 2.1: Supply and Demand for Freight
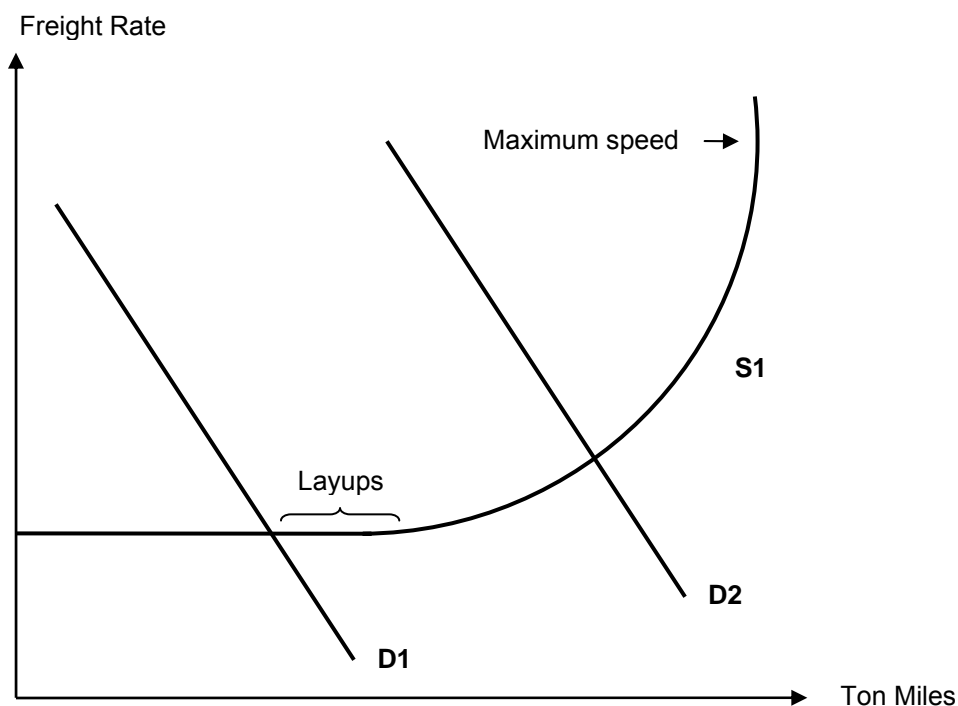
Source: Stopford (1997) and Strandenes (2004)

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Given the nature of supply and demand in the industry, some of the fluctuations in freight rates can be ascribed to lags. Demand on the one hand is very volatile where the world demand changes from day to day. The supply side is however hindered by inertia. Adjusting supply takes time, which means that supply is constantly trying to catch up with the volatile demand, while simultaneously over - and undershooting in the medium run. Supply being measured by ton miles can also be somewhat misleading. As the output of ton miles is provided by vessels traveling large distances, supply takes on a bulky form. From day to day, supply of ton miles is not independent of the past day. If 100 vessels are fixed on a day at high rates, these vessels will be sailing for maybe two months on average. During this period, the freight rates can be expected to remain high. Demand on the other hand can be high one day and low another day depending on a large number of factors and market clearing in a large and diversified number of commodity markets.

Based on the above it is clear that freight rates are determined through a very large amount of factors, and is therefore very complex in nature. Given the volatility and the inability of market participants to predict freight rates, risk management tools are greatly needed. I will now review a different approach to explaining freight rates.

2.2 An Analytic Approach to Freight Rate Determination

Attempts have been made to uncover relationships about the future freight rates based on their past values. In attempts to do so, it is important to distinguish between spot rates and TC-rates. Since TC-contracts are offered for different lengths of time, the implied forward TC-rates can be found from their term structure.

Spot rates are often assumed to be mean-reverting. As opposed to the so-called random walk, mean-reverting rates tend to fluctuate, but more so around a long term mean or trend. While the increments of random walk processes are independent of the past values, a mean-reverting process assigns higher probabilities for an up movement the next period given that there were down movements in the preceding periods and vice versa.

2.2.1 The Ornstein-Uhlenbeck Process

As an illustration, Bjerksund & Ekern (1995), analyze shipping derivatives assuming that the spot freight rates follow a so-called Ornstein-Uhlenbeck mean-reverting arithmetic process:

$$dX(t) = k[\alpha_X - X(t)]dt + \sigma_X dZ(t) \tag{2.1}$$

In the above expression X(t) is the spot rate per period, α_X is its long term natural mean, σ_x is the volatility per period and Z(t) is the increment for a standard Brownian motion. The term k > 0 indicates that the process is mean-reverting, and its numerical value is a measure for the speed of adjustment. A greater k will move the process towards the long term mean more swiftly. This is what is referred to as an arithmetic model in that this is the *amount* of instantaneous change and added to the current level, rather than being a change *rate* multiplied with the current level. Tvedt (2003) attempts to bridge the gap between traditional theories of market clearing in shipping markets and shows that the model (2.1) above may be a realistic process to describe freight rates. He ascribes the mean reversion to rigidities in total supply, such as the lead time in the building of new vessels.

The value of the stochastic freight rate process at time T, dependent on X(0) can be written as a stochastic integral. The first two terms in equation 2.2 is the weighted average of the process, while the last term is the random term.

$$X(T) = e^{-kT}X(0) + (1 - e^{-kT})\alpha + \sigma_x e^{-kT}\int e^{kT}dZ(t) \tag{2.2}$$

From equation (2.2), it can be shown that X(t) is normally distributed with:

$$E_0[X(T)] = e^{-kT}X(0) + (1 - e^{-kT})\alpha$$
$$Var_0[X(T)] = \frac{\sigma^2}{2k}(1 - e^{-2kT}) \tag{2.3}$$

3. IMAREX FREIGHT FUTURES

Theory and Preliminary Notes

3.1 Introduction to Forward Markets

3.1.1 Introduction

Many real as well as financial markets are highly volatile. The prices of goods and financial securities have stochastic properties and the actual spot price in the future may be difficult to foretell. Players in these markets are therefore exposed to a risk concerning the price they will be able to receive (or have to pay) for the goods they sell (require) in the future. Their exposure may be due to requirements in terms of factors of production or the revenue from their output. Consider a shipowner that knows he will have a vessel available for trading in 5 months. The spot freight rates are good today, but the shipowner is concerned that the freight rates will decrease in 5 months. If no time charter is available for negotiation today at a favourable rate, the shipowner's revenues are at a risk. This is where forward markets come in.

A forward contract in its simplest form is an agreement between a buyer and a seller of a certain good, where delivery takes place in the future, but the price is agreed on today. An agreement such as this is referred to as an over-the-counter (OTC) derivative: Over-the-counter because it is a bilateral agreement between two parties, and derivative because the value of this agreement is derived from the price-structure of the underlying asset (in our case: freight).

3.1.2 Futures

Futures markets are believed to date back to India around 2000 B.C., but the modern day futures markets were introduced with the Chicago Board of Trade commodity derivatives in the mid 1800s. Trade volumes did not skyrocket, however, until the introduction of financial futures in the 1970s.[8] The significance of futures contracts

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[8] History lesson provided by Duffie (1989).

have continued to grow with an increasing sophistication from industry and financial players combined with the introduction of exchange traded, standardized derivatives such as futures, options and swaps of different specifications. While a bilateral contract can include a lot of detailed specifications regarding the delivery, quality, quantity and maturity of the underlying asset, a standardized contract can not. If a contract is to be traded at an exchange it needs to be traded on a large scale to become efficiently priced. A standardization of such forward agreements with the purpose of trading at exchanges establishes the basis for the future contract. For a future, terms of quality, quantity, and time and terms of delivery are pre-established, and established with the purpose of being the common denominator among all the needs of the market participant in terms of correlation with their physical exposure. The only thing that needs to be determined in the market place is the price.

3.1.2.1 Types of futures

Today, futures contracts are traded on a variety of different underlying products. We can broadly make the distinction between consumption assets and financial assets, as I will elaborate on in 3.1.4.2. Financial assets on which futures contracts are written include stocks and stock indices, currencies, and interest rates. Consumption assets include agricultural and life-stock products, commodities such as petroleum products, minerals, coal, electric energy, and metals. Precious metals such as gold fall in between the two categories. Freight rates, the scope of this thesis, are similar to commodities that are not easily classifiable into these categories. It is clearly a consumption asset, but some of its properties are like those of financial assets. We will elaborate on this in later sections.

3.1.2.2 The Clearing Function

Another property of futures contracts compared to OTC forwards is the clearing function. For exchange traded futures, a clearinghouse acts as counterparty between the two positions involved in a trade, and so the clearinghouse acts as a buyer vis-à-vis the seller of the future. The clearinghouse is the buyer's seller and the seller's buyer. This effectively eliminates all credit risk for the parties, in case one of the

parties were to default on their obligation. Also forward contracts and options can be cleared, but settlement of these is performed on maturity or time of exercise.

3.1.2.3 Marking to Market

Marking to market is another property of exchange traded futures contracts. It involves a daily settlement of gains/losses between the parties, based on the difference between the fixed future-price and the prevailing spot price. Daily marking-to-market is performed such that the parties involved in the trade deposit a margin with the clearinghouse, and this is debited/credited every day according to daily gains/losses. If the margin account falls below a certain level, its owner is, through a so-called margin call, prompted to deposit more into the account.

3.1.3 The Forward Market Functions

3.1.3.1 The Risk Management Function of Forward Markets

Section 1.5 introduced the risks involved in the shipping industry. How can futures markets help offset some of this risk? In any transaction there has to be a buyer and a seller, a long and a short position. In the physical market the seller runs the risk of prices decreasing from now until the time of the transaction, and the buyer conversely runs the risk of a corresponding price increase. The risk decreasing properties of the futures markets comes through participants taking futures positions opposite of their physical exposures. If the shipowner in section 3.1.1 will have his VLCC off-hire in the Arabian Gulf, putting him in a long physical position, he takes the opposite position in the futures market and sells (shorts) a contract for freight of 250000mt of crude oil to Japan. Upon maturity he buys back the futures position and fixes the vessel spot. Any gain (loss) he has in the spot market will be offset by a loss (gain) in the futures market[9].

3.1.3.2 The Price Discovery Function of Forward Markets

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[9] Provided that there is no difference between the product underlying the future and the physical product. This is a component of what is termed basis risk, which we will return to in section 3.2.1.

In theory, futures prices should show the future spot prices of the underlying asset. Therefore, futures prices are valuable tools for all industry participants, whether they are invested in futures or not. This is the price discovery function of forward and futures market. I will not elaborate more on this, but I will refer interested readers to Kavusannos and Nomikos (2003), who examines the causality and price discovery function in shipping futures markets applied on the BIFFEX contract.

3.1.4 Pricing of Futures Contracts

3.1.4.2 Investment Assets vs. Consumption Assets

Pricing of futures contracts is driven by market expectations. The distinction between investment assets and consumption assets is crucial, as the pricing foundation of the two differs significantly. Investment assets are assets held for investment purposes like stocks and bonds, while consumption assets are assets held for consumption or as factors in production. Investment assets are relatively easy to price correctly through use of arbitrage arguments and stringent assumptions regarding market efficiency. Given that all players can both borrow and lend at a uniform risk-free rate, the following pricing formula must hold (also assuming no dividends or convenience yield[10]) (see Hull: Eq 3.5)

$$F_{0,T} = S_0 e^{rT} \qquad\qquad (3.1)$$

If the future prices are greater or smaller than the right hand side of this equation, arbitrage is possible through a combination of a risk-free position, a position in the underlying, and a futures position[11].

For consumption assets the picture is more complicated. Since consumption assets are physical in nature, compared to the non-physical investment assets, we have to include storage costs for these assets. If you are holding 50'000 ton of wheat, it is not

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[10] The term convenience yield will be discussed later in this section.
[11] See Hull (2003) chapter 3.5 for a presentation of forward and futures pricing with arbitrage arguments.

possible to neglect the costs associated with storing these. We have to include these costs into our formula: (Hull: Eq 3.15)

$$F_0 = (S_0 + U)e^{rT} \qquad (3.2)$$

This is the case where the storage costs (U) are a lump sum displayed as the present value of storage costs incurred during the period. If the storage costs are directly proportional to each unit of stored commodity, the same costs can be shown as follows: (Hull: Eq 3.16)

$$F_0 = S_0 e^{(r+u)T} \qquad (3.3)$$

In 3.3, u is the continuous rate of storage costs. Since consumption assets are used as factors of production, and therefore have a different value for each individual producer, implementing arbitrage arguments for convergence of prices does not work for these kinds of assets. Since the assets are held for consumption rather than for investment, arbitrage does not hold. There will therefore most likely be an inequality rather than equality in the formula above (Hull: Eq 3.20)

$$F_0 \leq S_0 e^{(r+u)T} \qquad (3.4)$$

Since it is of more value to hold the physical assets than holding a forward position for producers with the underlying as a factor of production, the futures prices are normally less than the value of the underlying plus the storage costs. This difference is defined as convenience yield. Put another way, the convenience yield is defined as anything accruing to the owners of the underlying asset, but not to the owners of a futures contract on the underlying asset. The correct equation then will be: (Hull: Eq 3.21)

$$F_0 = S_0 e^{(r+u-y)T} \qquad (3.5)$$

Convenience yield differs from time to time and from market to market. If the market participants have high inventories of the commodity, the convenience yield is normally lower, and conversely, in a time of shortage and low inventories the convenience yield tends to be higher. The factor r + u is for commodity futures often referred to as cost of carry, or c. The final pricing equation I will present will therefore be: (Hull Eq 3.23)

$$F_0 = S_0 e^{(c-y)T}$$
(3.6)

3.1.4.2 Futures vs. Forwards

Future and forward prices are often used interchangeably, and so I will do here. The contracts forms are identical in all respects, except for the fact that a holder of a futures contract will realize his gains or losses every day. This means that the future holder can reinvest the proceeds, something a holder of a forward cannot. Stoll and Whaley (1993) points out that the futures and forward prices are identical if the interest rate over the period is known. I refer interested readers to appendix 3.2 of Stoll and Whaley (1993) or Appendix 3A in Hull (2003) for a formal proof. I will however treat the terms futures and forwards as synonymous, thereby implying constant interest rates. A word of caution is however not to make futures trades on a large scale without investigating this relationship further.

3.1.4.3 Returns in Futures Markets

Whilst hedgers are in the market to reduce their risk, speculators take on extra risk in order to profit from their futures transactions. This implies that in order for speculators to get attracted to the market, there has to be an average and positive risk premium. Keynes (1930) and Hicks (1939)[12] therefore argued that if speculators tend to be on the long end while hedgers are at the short end, the expected future spot price should be above the futures price. If this is the case, this is referred to as *normal backwardation*, while if the expected future spot price is below the futures price, this is known as *contango*. We will not elaborate much on returns in futures markets, as

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[12] As presented by Hull (2003), chapter 3. See also Bodie, Kane and Marcus (2005), section 22.5

this thesis addresses the market as seen from the eyes of the hedgers. One must, however, have an understanding on how prices are formed in such markets.

3.2 Hedging with Forward Markets

3.2.1 The Basis

In this section I will elaborate on the concept of basis and basis risk. In the context of hedging, the basis is defined as the difference between the spot price of the asset that is being hedged and the futures price of the contract[13] (Hull: Ch 4.3)

$$b_{t,T} = S_t - F_{t,T} \tag{3.7}$$

Over the life of the contract the basis changes, and the variance of the basis is called the basis risk. Since hedgers want as close a correlation as possible between their physical exposure and the contract used for hedging it, basis risk is generally considered undesirable to hedgers.

Basis risk is usually a problem that is haunting index-futures. If hedging a portfolio by employing a future on an index such as the S&P 500, there is no guarantee that the index will co-move exactly along with the portfolio (unless exactly replicating the index itself)

Considering two times during the life of the contract, t = 1 and t = 2. An industrial player considers hedging the future price he will get for his goods, and takes a short position. The price he will receive for his goods is S_2, while the profit he receives from his futures position is $F_{1,T} - F_{2,T}$. The effective price on the hedged position is therefore (Hull: Ch 4.3)

$$S_{2,T} + F_{1,T} - F_{2,T} = F_{1,T} + b_{2,T} \tag{3.8}$$

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[13] This definition is presented by Hull (2003). Stoll and Whaley (1993) switches the terms around, so that the basis is b = F – S. So does Bodie, Kane and Marcus (2005), who comment that "usage of the word basis is somewhat loose." The variance of the basis is independent of the definition, whereas the sign of covariance and correlation terms depend on which definition is used.

The situation is reverse for the opposite party. We see that if b_2 is known at time zero, there could be a perfect hedge. However, b is stochastic, and its variance is the so-called basis risk.

Stoll and Whaley (1993) splits basis into two components which they call time basis and space and grade basis. In equation 3.8 the first term is the time basis while the second is the space and grade basis. Note the opposite sign convention in (3.9). (Stoll,Whaley Eq. 3.1).

$$F_t - S_{it} = (F_t - S_t) + (S_t - S_{it}) \qquad\qquad (3.9)$$

Actual hedging strategies deal with the problems of basis risk. Firstly, there is a careful choice of futures contracts. Secondly, the maturity of the contract is also an important issue that must be resolved. According to Hull (2003), hedgers tend to use contracts with maturities longer than the maturity of their physical commitments, and then close out their positions as they close out the position in the physical market. I will elaborate on relevant hedging strategies later in the analysis of the IMAREX Freight Futures.

We can distinguish between hedging with zero basis, and hedging with random basis. If both the space and grade basis as well as the time basis are zero, we call this hedging with zero basis. Hedging with random basis, such as is the case in nearly all real life applications, means that a risk reduction may very well be possible, but the hedge cannot be perfect. In this case the basis changes over the life of the hedge.

3.2.2 Hedge Ratios

Given a wide array of definitions of what hedging actually is, I will utilize the definition that hedging is taking a position in a hedging instrument to reduce the overall variability, measured by the variance, of a otherwise unhedged portfolio. When using futures contracts, a hedger is therefore only concerned with reducing the variance of his unhedged portfolio. By decreasing the basis risk, the hedge is also

improved. A hedge ratio is a measure of how much of the physical endowment that is being hedged by futures, i.e., the ratio of hedging instruments to the underlying. This ratio is denoted as h. A hedger that is long one unit in the physical asset and short in h units of futures will have future cash flows characterized as shown in table 3.1. Hedgers want to offset the variability of their portfolio, and so the most relevant measures will be the changes of the values rather than the levels. And the most relevant measures of variability will be the variance of the changes of these values. Note that in this table Δ indicates the total lifespan of the desired hedge.

Table 3.1: Values and Variances (levels and changes) of Hedged vs. Unhedged Portfolios

Value of unhedged portfolio: $$CF_{S,t} = S_t$$ Change in value of unhedged portfolio: $$\Delta CF_{S,t} = \Delta S_t$$	Value of hedged portfolio: $$CF_{C,t} = S_t - hF_t$$ Change in value of hedged portfolio: $$\Delta CF_{C,t} = \Delta S_t - h\Delta F_t$$
Variance of unhedged portfolio: $$\sigma_{S,t}^2 = \sigma_{S,t}^2$$ Variance of change in the unhedged portfolio: $$\sigma_{\Delta S,t}^2 = \sigma_{\Delta S,t}^2$$	Variance of hedged portfolio: $$\sigma_{C,t}^2 = \sigma_{S,t}^2 + h^2\sigma_{F,t}^2 - 2h\rho_{S,F}\sigma_{S,t}\sigma_{F,t}$$ Variance of change in the hedged portfolio $$\sigma_{\Delta C,t}^2 = \sigma_{\Delta S,t}^2 + h^2\sigma_{\Delta F,t}^2 - 2h\rho_{\Delta S,\Delta F}\sigma_{\Delta S,t}\sigma_{\Delta F,t}$$

CF hence denotes cash flows if the portfolio value is realized at time t. The optimal hedge ratio must therefore, to the hedger, be the ratio that minimizes the variance of the hedged portfolio. Finding the hedge ratio that can achieve the greatest risk reduction is given with the following equation. The optimal hedge ratio h* is the ratio that minimizes the variance of the change in the value of the hedger's position[14] over the life span of the hedge, Δ:(Hull: Eq 4.1)

$$h^* = \rho\frac{\sigma_S}{\sigma_F} = \beta \tag{3.10}$$

where (using a slightly more simplified notation than above):

ρ is the correlation coefficient between ΔS and ΔF

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[14] For a formal proof, see for example Hull (2003), Appendix 4A

σ_S is the standard deviation of ΔS

σ_F is the standard deviation of ΔF

The beta in equation 3.9 is included to show the similarity with the beta used in factor models such as the capital asset pricing model (CAPM), and which shows the systematic component of variability between an asset and a benchmark portfolio/index. In this case the beta measures the systematic variability of the change in spot prices versus the change of futures prices.

3.2.3 Hedge Effectiveness

Hedge effectiveness is a measure of the appropriateness of the hedging instrument employed on the physical position. There are several approaches to determining this[15]. I will briefly review the most important. Hedging Instrument Effectiveness (HIE)[16] is defined as (Charnes, Koch: Eq. 4)

$$HIE = 1 - (\sigma^2_{C*} / \sigma^2_S) = (\sigma^2_S - \sigma^2_{C*}) / \sigma^2_S \qquad (3.11)$$

The last term in (3.10) shows the hedge *in*effectiveness. That is the ratio of the variance of the optimally hedged position to that of the unhedged position. The greater this term, the more inefficient is the hedge. Subtracted from one this is transformed into a measure of hedge effectiveness, the HIE. In section 3.2.4 I will review how this measure can be obtained from using regressions.

Hull shows that this relationship is equivalent to the ρ^2 from expression 3.10.

$$\rho^2 = \frac{h^{*2}\,\sigma_F^2}{\sigma_S^2} \qquad (3.12)$$

---

[15] Popularized presentation by Charnes and Koch (2003).
[16] Originally proposed by Ederington (1979)

It is important to note the arguments of Duffie (1989), chapter 4, that for any mean/variance utility maximizer[17] with risk aversion, the optimal total position in the futures market can be shown to contain one pure hedging position, and one purely speculative position.

This optimal position is given by (note that Duffie (1989) uses the same definition of h* as Hull (2003), but with opposite signs. The h* in 3.13 is therefore the same as in 3.12):

$$y = z + h = \frac{E[F_1] - F_0}{2r \operatorname{var}(F_1)} - h*$$
(3.13)

where subscript 0 denotes "now" and 1 denotes maturity of the physical endowment. It is important to note that the HIE I have defined in this section is only part of the optimal position proposed by Duffie (1989). However, he also states that the hedging position should be of the main concern to the hedger. I will from here on neglect the speculative portion of the optimal position, and assume that h* *is* the optimal hedge ratio.

Overall Hedge Effectiveness (OHE)

While HIE gives a measure of the *potential* risk reduction that is possible by optimally utilizing an instrument, OHE does account for the risk reduction actually attained after the hedger is invested in the hedging instruments. (Charnes, Koch: Eq 5)

$$OHE \equiv \frac{\sigma_C^2}{\sigma_S^2}$$
(3.14)

This is the measure of the variance *that remains* after an arbitrary and possibly non-optimal hedge ratio, h has been set and the hedger is invested in the hedged portfolio.

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[17] Duffie (1989) page 91 proposes the "mean-variance" utility function: $U(x) = E(x) - r * \operatorname{Var}(x)$, where r is a risk aversion coefficient greater than zero, indicating risk aversion and penalizing variability. This is a variation of the "rule of thumb" preference indicator: $U(r) = E[r] - \frac{1}{2} A \operatorname{Var}(r)$, as presented in Bodie, Kane and Marcus equation 6.1 page 157.

The volatility reduction measure is another measure but is only a transformation of the OHE to account for standard deviations rather than variances, and I will therefore not elaborate on this[18].

The link between HIE and OHE is the HRE. The Hedge Ratio Effectiveness is linked to the above through 1 - OHE = HIE * HRE. While HIE measures the potential hedge effectiveness when the optimal hedge ratio is used, HRE measures the ratio of risk reduction between a position with the actual hedge ratio h employed and a position with the optimal hedge ratio h*.(Charnes, Koch: Eq 7).

$$HRE = \frac{\sigma_S^2 - \sigma_C^2}{\sigma_S^2 - \sigma_{C*}^2}$$
(3.15)

3.2.4 Hedge Effectiveness Using Regressions

It can be shown that the adjusted R^2-measure from the OLS regression below corresponds to HIE. By employing this method we hold ΔS as the dependent variable and ΔF as the independent variable, the regressor.

$$\Delta S_t = b_0 + b_1 \Delta F_t + u_t$$
(3.16)

The variables are defined on the first difference: ΔS_t is defined as $S_t - S_{t-1}$ .u_t is a random disturbance term and gives the residuals stemming from the regression. The estimation technique used in classical linear regression is the so called OLS (Ordinary Least Squares)[19], in which minimizing the sum of u_t^2 , or the *residual sum of squares,* is the optimization problem.

For OLS to be a valid technique and in order to conduct meaningful hypothesis testing on the estimates, we have to impose five assumptions on the model

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[18] Originally introduced by A.Kalotay and Leslie Abreo. Discussed in Charnes and Koch (2003),
[19] We assume that standard OLS estimation is known, but for a easy presentation see Brooks (2002)

1. $E(u_t) = 0$ *(3.17)*
2. $var(u_t) = \sigma^2 < \infty$ *(3.18)*
3. $cov(u_i, u_j) = 0$ *(3.19)*
4. $cov(u_t, x_t) = 0$ *(3.20)*
5. $u_t \sim N(0, \sigma^2)$ [20]:   *(3.21)*

Heteroscedasticity

For changes in futures prices regressed on changes in spot prices, assumption 2 is likely to be violated. This is the assumption of homoscedasticity. The Samuelson hypothesis, as proposed by Paul Samuelson, suggests that futures prices tend to have an increasing variance as the contract nears maturity. For meaningful modeling of time-series this has to be accounted for in order for regressions to be meaningful. We can distinguish between conditional and unconditional heteroscedasticity. Unconditional heteroscedasticity assumes that changes in variance are non-systematic, that the variance changes does not depend on time On the other hand, conditional heteroscedasticity incorporates time dynamics. This means that the variance at time = 1 depends to some extent on the variance at time = t – 1. This is a frequent phenomenon in financial time series, and is termed GARCH-effects.

Hedging Measures from Regression Coefficients

When regressing changes of spot prices on changes on futures prices, we have what Duffie (1989) refers to as a "natural coincidence". The slope measure b_2 is the optimal hedge ratio h*.

In the context of regressions, the R^2 is a measure for the ability of the regression to explain variability in the dependent variable with the independent variables. In the OLS framework we have:

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[20] Expressions (3.17)-(3.21) taken from Brooks (2002), chapter 3. Assumption 1 states that the expected value of the error term is unbiased and equal to zero. Assumption 2 states that the variance of the error terms is fixed over the period (homoscedastic). Assumption 3 assumes no autocorrelation between the error terms, while assumption 4 states that no variability of the dependent variables are left in the error term. Assumption 5 states that the error term is normally distributed. In sum, assumptions 1-5 is what is referred to as white noise.

$$R^2 = \frac{ESS}{TSS} = \frac{TSS - RSS}{TSS} = 1 - \frac{RSS}{TSS} \qquad (3.22)$$

$$\bar{R}^2 = 1 - \left[\frac{T-1}{T-k}(1-R^2) \right] \qquad (3.23)$$

The first expression shows the R^2 while the latter shows the adjusted R^2. TSS is the total sum of squares from the OLS procedure, ESS is the estimated sum of squares, the sum of squares incorporated by the model, while the RSS is the residual sum of squares.

Another manifestation of this "natural coincidence" is that the adjusted R^2 from the regression happens to be the hedging instrument effectiveness (HIE) explained above. An R^2 of 1,0 is then what is called a perfect hedge, with no risk attached to the basis. *(Hull: Chapter 4.4)*. From expression 3.12, we then have:

$$R^2 = \rho^2 = \frac{h^{*2}\sigma_F^2}{\sigma_S^2} \qquad (3.24)$$

3.3 Trends in Risk Management for the Shipping Industry

3.3.1 The Life and Death of BIFFEX

The BIFFEX (Baltic International Freight Future Exchange) contract I have mentioned, but so far not explained, was the first exchange traded future contract on futures. The contract was structured like an index future, where the underlying product was the Baltic Freight Index (BFI), a index composed of a number of routes in dry-bulk shipping. The index was later replaced by the Baltic Panamax Index, but many minor changes were also made to its composition as the patterns of world trade changed. The BIFFEX contract started trading in May 1985 on the London International Financial Futures Exchange (LIFFE), and ceased trading in April 2002 due to low trading volume.

What is there to learn from the short life of BIFFEX? For one, index futures have the general problem of high basis risks. Although the market for risk management tools in the shipping industry was clearly present, when the contract does not co-move with the physical exposures of the potential users, the contract loses some of its value. Kavussanos and Nomikos[21] found the hedge effectiveness[22] of the BIFFEX to vary between 19.2% and 4.0% across the routes constituting the underlying index[23]. Secondly, Haigh and Holt (2002) analyzed the BIFFEX contract in the time after the decision to close down its trading, and their conclusion was in support of LIFFE's decision to terminate trading. They conducted a study where they assessed the entire spectre of risks a charterer may have: commodity, foreign exchange and freight rate. They were able to isolate the contribution of the BIFFEX contract to the total risk reduction[24]. The case they analyzed was the case of a European buyer covering all three sources of risk in a purchase of grains from the US Gulf and transporting the goods back to Europe. The result they obtained showed that from a risk reduction of the hedged portfolio compared to the unhedged portfolio of 74,6%, the BIFFEX position contributed only 6,3%. This experience serves as a caution to exchanges introducing futures on freight rates, in particular IMAREX, which I am addressing in this thesis.

3.3.2 Forward Freight Agreements

Forward Freight Agreements probably account for a large fraction of the freight derivatives used in the market today. However, I cannot provide any statistics of the extent to which such over the counter forward contracts are used. A point to note about such contracts, however, is that they are bilaterally negotiated, and normally not cleared with a central clearing house. This means that firstly, the contracts are highly inflexible, in that if any detail of the contract needs to be altered, the two parties have to meet and often renegotiate the whole contract. Secondly, there is a significant source of credit risk as there is no institutional third party who can guarantee that the

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[21] As presented by Nomikos and Alizadeh, chapter 31 in Grammenos (2002)
[22] Hedge Effectiveness computed both for in-sample and out-of-sample using a VECM-GARCH-X model proposed by Engle, Bollerslev and Lee.
[23] Be adviced that these measures of hedge effectiveness are not directly comparable to the estimates I will present in section 5.
[24] The study was conducted using an M-GARCH model proposed by Engle (1982) and Bollerslev (1986).

commitment will not be defaulted. As a secondary product, IMAREX, can step in and assist in the negotiation of such forward contract, and in certain cases, NOS can also clear such forwards.

4. IMAREX FREIGHT FUTURES
Product Description, Data, and Need-To-Knows

4.1 Section Outline

As section five presents the findings for the IMAREX futures, this section will deal with many of the technicalities that need to be addressed in the case of these futures. I will in this section review the product structure of the IMAREX Freight Futures. I will examine the contract specifications and the market for freight and freight futures. The IMAREX freight futures will be placed in a larger setting and how these futures are different from standard stock or commodity futures will be examined.

How the choice of hedging strategies affect how the data should be prepared for the next section will be also be reviewed. As hedging involves a lot of subjective choices that has to be made with respects to hedging strategies, a discussion of how these decisions affect the final outcome will also be made. An example of such choices is the selection of which maturity contracts to use when hedging your portfolio.

4.2 Baltic Spot Quotes

The Baltic Exchange is the world leading provider of freight data. The routes used for analysis are drawn both from the Baltic Exchange Capesize Index and the Baltic International Tanker Routes. The Baltic Tanker routes are divided into the Baltic Dirty Tanker Routes and the Baltic Clean Tanker Routes[25] (denoted TD and TC respectively). See Appendix 2 for explanation of terms used in table 4.1. All spot market data used in the analyses in this thesis is received from the Baltic Exchange.

Table 4.1: Sample of Baltic Exchange Spot Indexes[26]

Dry-Cargo: Baltic Capesize Index (BCI)				
Name	*From*	*To*	*Cargo*	*Vessel Size*
C2	Tubarao (Brazil)	Rotterdam (Netherlands)	Iron Ore	160000

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[25] Clean tankers transport chemicals, natural gases etc. while dirty tankers is a term for vessels carrying the "dirty" cargoes such as crude oil.

[26] The indices quoted by The Baltic Exchange constitute more routes than the sample shown here.

C3	Tubarao (Brazil)	Beilun-Baoshan (China)	Iron Ore	150000
C4	Richard's Bay (South Africa)	Rotterdam (Netherlands)	Coal	150000
C5	West Australia	Beilun-Baoshan (China)	Iron Ore	150000
C7	Bolivar (Columbia)	Rotterdam (Netherlands)	Coal	150000

Tank: Baltic Dirty Tanker Index (BDTI)			
Name	*From*	*To*	*Vessel Size*
TD3	Arabian Gulf	Japan	250000
TD4	West Africa	US Gulf	260000
TD5	West Africa	USAC	130000
TD7	North Sea	Continent	80000
TD8	Kuwait	Singapore	80000
TD9	Caribbean	US Gulf	70000
TD10	Caribbean	USAC	50000
TD10D	Caribbean	USAC	50000
TD12	Amsterdam, Rotterdam, Antwerp	US Gulf	55000

Tank: Baltic Clean Tanker Index (BCTI)			
Name	*From*	*To*	*Vessel Size*
TC1	Arabian Gulf	Japan	75000
TC2_37	Continent	USAC	37000
TC3_38	Caribbean	USAC	38000
TC4	Singapore	Japan	30000
TC5	Arabian Gulf	Japan	55000
TC6	Algeria	Euromed	30000

Source: The Baltic Exchange.

The routes are quoted on a daily basis (5-day weeks) from January 2, 2002 until July 8, 2005. The price quotations are measured in USD / ton for the dry-bulk routes and in worldscale points[27] for the tanker routes. In Figure 4.1, we present two figures for the fluctuations of 5 selected Capesize routes. The top figure shows the level fluctuations, while the second figure shows the daily changes of the same routes. Not surprisingly, the levels of the routes are moving to a large extent in the same pattern. The interesting observation, however, from a hedging perspective, is that also the changes from day to day of the five routes seem to move in the same pattern. No conclusive evidence can of course be extracted from just looking at this graph, but it can motivate perhaps more substantiated analyses that will be provided later. The figure also seems to show some evidence of heteroscedasticity as the period seems to be divided in two parts with respect to the level of fluctuations. The period up until around March 2003 seems to have a constant variance, but after March 2003, the variance increases dramatically and then seems to level out at this high level.

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[27] Freight rate measure commonly used in the tanker industry. The worldscale flatrate is a benchmark measure of $/t , and is set by the Worldscale Association, London for a number of different routes. Contracts are then negotiated as fractions of this worldscale flatrate. These proportions are reflected in the worldscale points divided by 100.

Figure 4.1: Selected Routes from the Baltic Capesize Index. Levels (top) and daily changes (bottom).
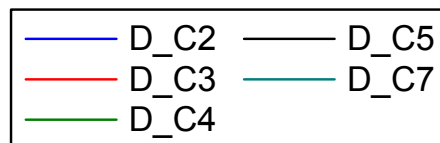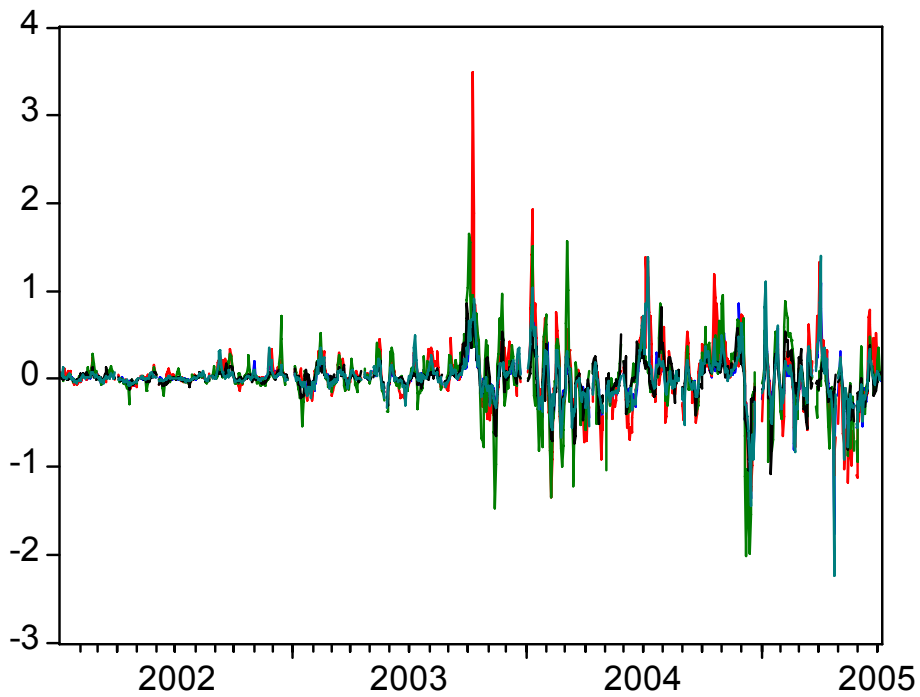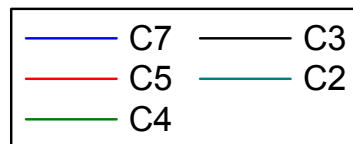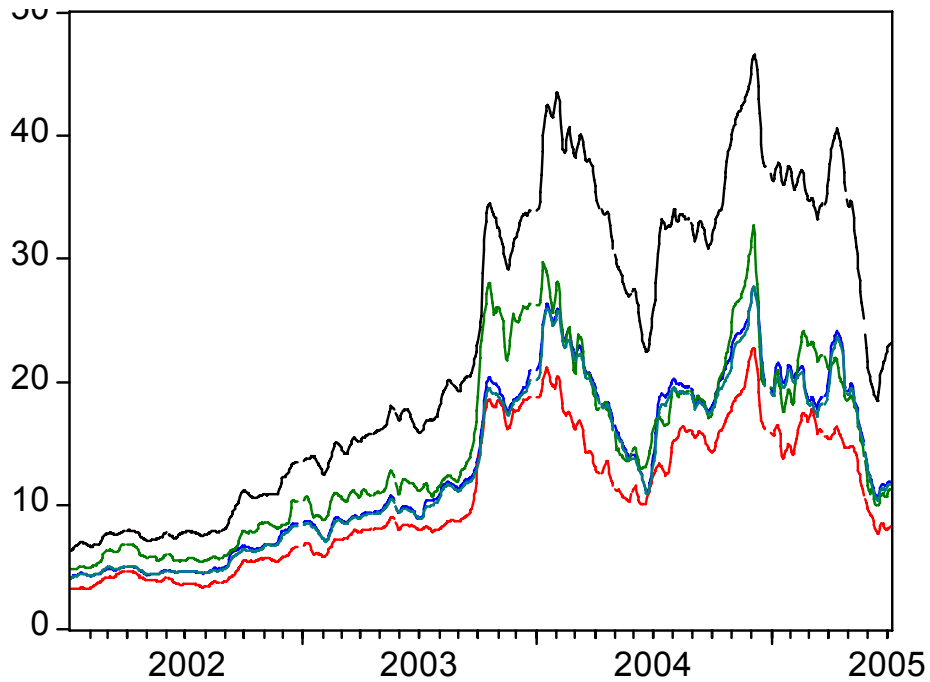
4.2.1 Correlations

Table 4.2 shows correlation coefficients between the different routes in the three indexes. Although this is spot versus spot correlations, these coefficients can give us a basic idea of cross hedging potential in the industry. Cross hedging will be discussed in detail in section 5.4.

Table 4.2: Correlations Between Changes of Selected Routes of the BDTI, BCTI, and BCI indexes

BDTI

	TD3	TD4	TD5	TD7	TD8	TD9	TD10	TD10D	TD12
TD3	1.000								
TD4	0.403	1.000							
TD5	0.205	0.364	1.000						
TD7	0.150	-0.145	0.108	1.000					
TD8	0.057	0.033	0.037	-0.079	1.000				
TD9	-0.030	-0.081	-0.088	0.098	0.131	1.000			
TD10	-0.082	0.011	0.205	0.225	0.097	0.281	1.000		
TD10D	-0.003	0.057	0.182	0.207	0.070	0.369	0.845	1.000	
TD12	-0.186	0.040	0.214	0.424	0.021	0.146	0.447	0.497	1.000

BCTI

	TC1	TC2_37	TC3_38	TC4	TC5	TC6
TC1	1.000					
TC2_37	-0.095	1.000				
TC3_38	0.171	0.305	1.000			
TC4	0.263	-0.073	0.109	1.000		
TC5	0.288	0.122	0.213	0.367	1.000	
TC6	0.054	0.266	0.197	0.188	0.134	1.000

BCI

	C2	C3	C4	C5	C7
C2	1.000				
C3	0.855	1.000			
C4	0.656	0.664	1.000		
C5	0.687	0.697	0.817	1.000	
C7	0.955	0.824	0.653	0.677	1.000

Source: The Baltic Exchange

For the BDTI we know that TD3 and TD4 are both routes quoted on the basis of VLCCs[28]. A correlation between the changes of these of 0.403 correlation indicate a substantial relationship between these two even if the routes are very different, while

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[28] Very Large Crude Carrier. See glossary, appendix 2.

there is a very low correlation of 0.057 between TD3 and TD8, two routes traveling approximately the same route but with very different size vessels. On the other hand, routes such as TD4 and TD5 are showing substantial correlation even if one is based on a VLCC and the other one a Suezmax, but here the common denominator is a similarity in underlying route. We cannot, as a result, explain any correlation between routes based solely on vessel size or routes traversed. However, if we look at the BCI, the routes are very different, but the vessels are of a uniform size. Overall, we see a much larger correlation on these routes compared to that of the BDTI and the BCTI.

4.3 IMAREX Freight Futures

4.3.1 User Compositon

In Figure 4.2 we see the membership distribution between three broad categories of IMAREX members[29]. The industrial players group constitutes both commodity traders, funds, as well as manufacturers. The distinction between pure financial players and traders with physical exposure is difficult to make for this group. Note that this figure shows the member distribution and not trading volume between them, and it is reasonable to believe that the volume of trades is not proportional to the size of the member classes. Derivative markets in the establishment phase such as the IMAREX Freight Futures markets have a tendency to be[30] dominated by speculators and financial users in the beginning. The hedgers, or the industrial users, are only attracted later, as liquidity and efficiency of the market have reached a satisfactory level. Furthermore, financial users are normally more sophisticated in their use of derivatives. Their industrial counterparts who do not have derivatives trading as their principal area of business, are only attracted later.

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[29] Rough categorization from IMAREX website. The member mass is in constant change, and the distinctions between the groups can be difficult to make, as many of the members fit in more than one category.

[30] Abnormal excess return is possible in inefficient markets. We can assume any futures market to be quite illiquid and inefficient in the start-up phase. A high return per unit of risk attracts mean-variance maximisers. Assuming that speculators consider both risk and return, while hedgers only care about risk, we would expect a larger relative fraction of speculators the more inefficient the market is.

Figure 4.2: Membership Distribution: IMAREX

□ Shipowners
■ Industrial Players
□ International Banks
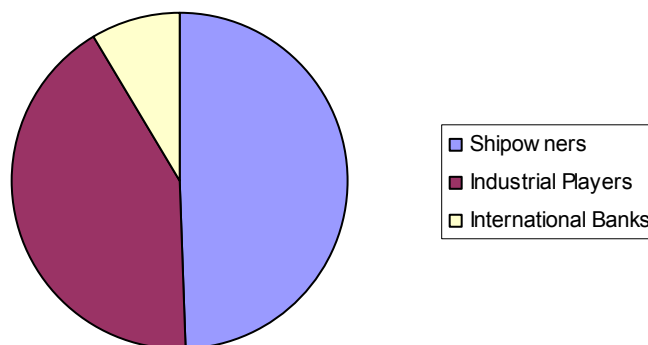
4.3.2 Trading Volume and liquidity.

IMAREX reported 1677 trades for the first quarter 2005. This is an increase of 226% from the same period in 2004. The trades comprised an amount of altogether 51792 lots[31], with around 80% in the tanker segment, and the remaining 20% in dry-bulk.

For investors in a market liquidity is important for many reasons. The most important reason is that they can close out their positions at any time if the market is sufficiently liquid. Another important point is that the prices in the market do not get affected from one transaction. A measure of liquidity in futures market is of course volume. The open interest on the contract measures the extent of the trading on it. Hull (2003) defines this figure as the *number* of all outstanding long contracts (which also equals the number of short positions).

Figure 4.3 shows the development of trades from the start in 2002 until quarter 4, 2004. The statistics shows the two main groups: Tank and Dry-Bulk, and it shows an impressive development in both sectors. The left hand diagram shows the number of transactions, while the right diagram shows the trading volume in number of lots[32]. The histogram does not show the distribution among the contracts, however. IMAREX report that the liquidity is highest in the largest tanker routes, such as the TD3 and TD4, and lowest among some of the dry-bulk contracts.

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[31] See section 3.4.4
[32] Lots = Pre-established number of tonnes depending on the contract. Defined in 4.4.

Figure 4.3: Transactions and trade volume per quarter, IMAREX
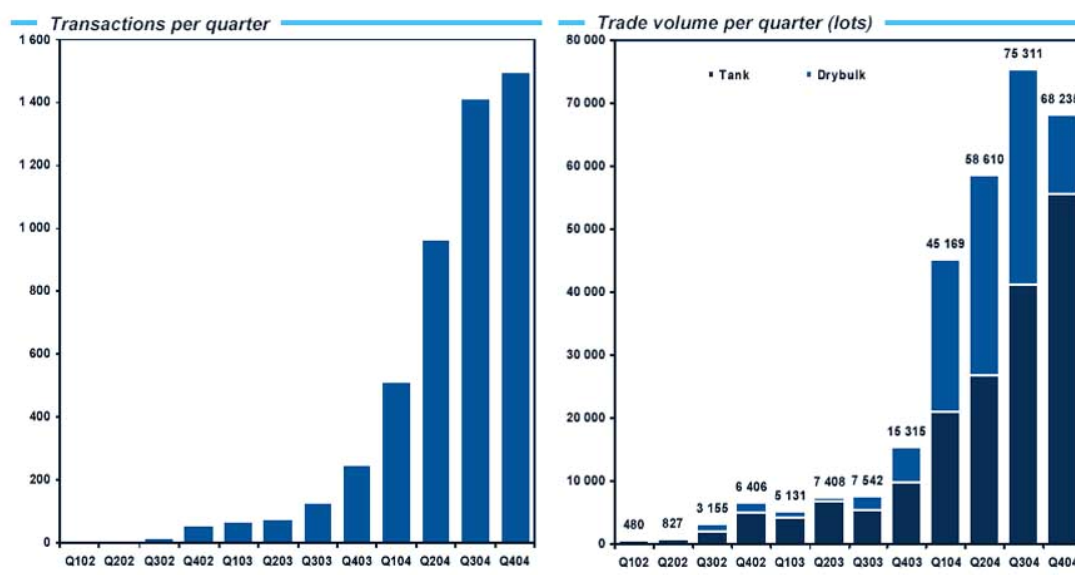
Source: IMAREX presentation 8/4/2005.

4.4 Contract Specifications

Table 4.3 shows the different futures contracts traded and cleared by IMAREX at the time of writing. See Appendix 2 for explanation of terms used in the table.

Table 4.3: IMAREX Freight Futures. Contract Details

Contract	Underlying	Vessel		From	To
		Type	Size		
Tank					
101	**TD7**	Aframax	80000	North Sea	Continent
102	**TD9**	Aframax	70000	Caribbean	US Gulf
103	**TD5**	Suezmax	130000	West Africa	USAC
104	**TD3**	VLCC	250000	AG	East (Japan)
105	**TD4**	VLCC	260000	West Africa	US Gulf
106	**TD12**	Panamax	55000	ARA*	US Gulf
107	**TD8**	Aframax	80000	Kuwait	Singapore
151	**TC4**		30000	Singapore	Japan
152	**TC2**		33000	Continent	USAC
153	**TC1**		75000	AG	Japan
154	**TC5**		55000	AG	Japan
155	**TC6**		30000	Algeria	Euromed
Dry-Bulk					
211	**C4**	Capesize	150000	Richard's Bay	Rotterdam
212	**C7**	Capesize	150000	Bolivar	Rotterdam
213	**C4 AVG**	Capesize	150000	Richard's Bay	Rotterdam
214	**C7 AVG**	Capesize	150000	Bolivar	Rotterdam

					Far East
241	P2A	Panamax	70000	Skaw Gibraltar	(Taiwan/Japan)
242	P3A	Panamax	70000	South Korea	Japan Pacific R/V

Dry Cargo T/C Baskets

220	CS4 TC	Capesize
250	PM4 TC	Panamax
280	HM6 TC	Handymax

Non-Listed (Tank and Dry)

108	TD10	Panamax	50000	Caribs	US Gulf
109	TD6	Suezmax	130000	AG	Continent

Source: NOS, IMAREX Rulebook, Appendix 5.

The underlying products are those quoted by the Baltic Exchange. Each of these routes has a large number of different maturities. Different contracts are traded with respect to lifespan, and each contract can be traded on a monthly, quarterly, or a yearly basis. The IMAREX Freight Futures trades on number of lots of the underlying assets. For month products, the lot sizes are 1000 metric ton, while for quarter and year products the lot sizes are 3000 and 12000 metric ton respectively. The contract value is calculated as follows:

#Lots * Lot Size * Worldscale Flat Rate * (Worldscale Points / 100).   *(4.1)*

The prices are quoted in Worldscale points and the minimum price fluctuations of the contracts are 0,25 points.

There is a vast pool of futures data to draw from. At any given time IMAREX is quoting and trading 6 month contracts, 6 quarter contracts and 2 year contracts for all the underlying routes. This would mean that over a year IMAREX will trade in 525 ((13 + 10 + 2) * 21) contracts. This is a quite large number of contracts, and an analysis of which contracts would be best suited to measure hedge effectiveness is in order.

The last trading day of month contracts are on the 15th of the month in question, or the nearest working day after this day. For quarter contracts, the last trading day is the last

trading day in the first month of the quarter. For yearly contracts, the last trading day is the last trading day of the first month of the year.

The settlement prices of the contracts are set as the arithmetic average of the Baltic or the Platt's quotes[33] over the delivery period. For a month contract with maturity in December, the averaging is done over all index days in December. The contract starts trading long before December, but from the 1st to the 15th of December the contract is in the averaging period. For quarter products, the settlement is calculated as the arithmetic average *of the* arithmetic average of each month in the quarter. The same rule applies to the yearly contracts, with each month average having a 1/12 weight in the final average.

4.5 Settlement as Arithmetic Averages

The implications of the average settlement price are that the IMAREX Freight Futures have Asian[34] properties. A reason for using averages rather than the spot price at maturity as settlement price is that there is less possibilities of manipulations from speculators. In very liquid markets such manipulations are difficult to make, but in markets with lower trading volumes, a strong participant would be able to manipulate the final settlement price. Concerning futures price development over the life of the contract, one can also expect a smoother price-path as market participants know that the contract will at maturity be worth an average rather than the spot price on the last trading day. The effect would be a slimmer volatility.

For month contracts, the theoretical cash flow at maturity should be determined by the following expression:

$$\tilde{\bar{S}}_T = \frac{1}{T} \sum_{t=1}^{T} \tilde{S}_t \qquad (4.2)$$

---

[33] Platt's Clean Tanker Fax. Similar to the Baltic Exchange a provider of spot market data, predominantly for the clean tanker segment.
[34] Asian as in Asian options where the strike or the payoff is calculated as an average over at least parts of the life of the contracts.

Where $\{1 \ldots T\}$ are the days in the averaging period. If the market is rational and participants plan on holding the futures position until final settlement day, it should price the futures by looking both backwards and forwards. The starting point for calculation on any one day within the maturity month must look at all the preceding values over the averaging period as well as look ahead at the stochastic path of the prices for the rest of the averaging period.

The implications for the basis will be that at maturity this equals:

$$\widetilde{b}_T = \widetilde{S}_T - \widetilde{F}_T = \widetilde{S}_T - \widetilde{\widetilde{S}}_T \qquad (4.3)$$

This shows that the IMAREX contract specification will not offset the price movements of the underlying spot movements perfectly, but rather lock in the average rate of the month. Market participants trading in futures contracts for December 2005, will therefore trade in the expected value of the average of the Baltic spot quotes for all index days in December.

From this exercise, we would therefore expect that the price paths of the futures contracts were co-moving with the underlying spot price path, but certainly somewhat dampened. There are however, differences between theory and practice. Consider these figures showing the movements of TD3 and TD5 spot versus futures prices.

Figure 4.4: Spot and Futures Price Level and Price Change Developments: TD3[35]

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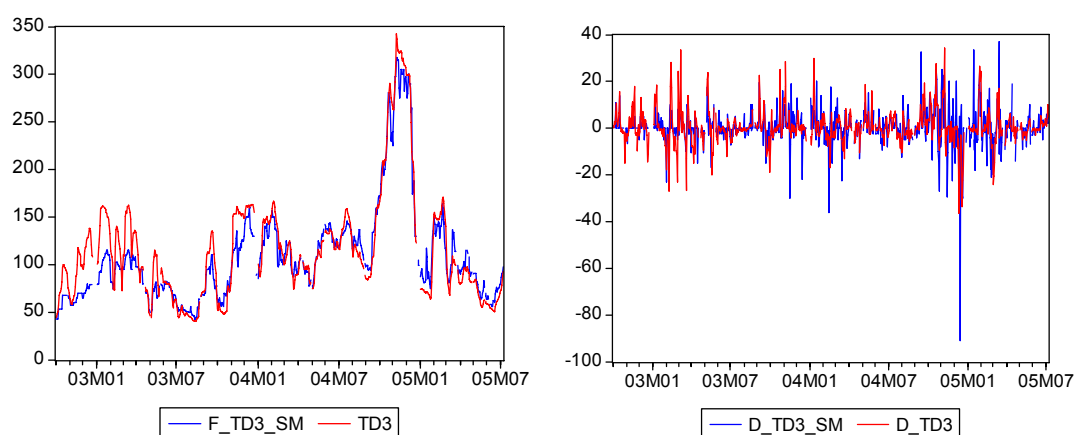
[35] Legend: F_TD3_SM are the futures prices, TD3 are the spot price series. D_TD3_SM are the changes of the futures price series and D_TD3 are the changes of the spot prices.

The time series in figure 4.4 are daily observations of the spot rates and the futures prices of the two different routes. The futures prices have been made into a continuous series according to the spot-month algorithm which I will elaborate on in section 4.8. These figures clearly show that the fluctuations of the futures contracts are co-moving. This suggests that the market does may not actually include the averaging in their expectations when they trade the futures. The following descriptive statistics suggests the same. In particular we would expect the standard deviation to be lower and the kurtosis higher for the futures price series.

Table 4.4: Descriptive Statistics for Futures and Spot price changes: TD3 and TD5

	Futures TD3	**Spot TD3**	**Futures TD5**	**Spot TD5**
Mean	0.280	0.291	0.123	0.088
Std. Dev.	8.202	7.422	7.691	7.923
Skewness	-2.084	0.358	0.420	0.694
Kurtosis	28.561	8.326	15.093	10.528

We see that the first four moments of the observed distribution functions for the spot versus the futures price changes do to some extent capture the averaging property. As we would expect, the kurtosis is larger for the futures price changes, indicating a distribution with slimmer tails. Evidence from similar comparisons for the TD4 contract shows the same, but for the TD7 contract the situation is reversed. This is therefore not conclusive evidence that the market does price the futures according to the averaging property, but it is an indicator pointing in that direction.

4.6 Sampling Periods and Intervals

The available data material stretches over 3,5 years, from 2002 to mid 2005. Stoll and Whaley (1993) discusses sampling intervals for the case of S&P 500 index futures, and concludes that different sampling intervals gives very different slope coefficients and secondly that weekly observations gives the lower standard errors of the coefficients compared to that of daily and biweekly samples in their sample. Stoll and Whaley argues that the foremost reason for this seemingly paradoxical find is the so called bid/ask price effect. Daily closing prices are generally at either the bid or the ask level, and the fluctuations of the prices within the bid/ask spread are largely random and contribute to negative serial correlation of the price changes. Stoll and

Whaley moreover argues that the bid/ask effect tend to bias the estimates downwards, and that this is the reason why the estimates are different across sampling intervals. The futures we are discussing are of course largely different from these financial index futures, and a similar analysis is made in table 4.5. We see that the picture is slightly different in our case. As we would expect in most cases, the standard error is larger for the weekly sample. We see, however, that the daily samples give a significantly lower estimate for the slope coefficient.

Table 4.5: TD3 Spot vs Month-futures. Different Sampling Intervals

TD3	n	b1	SE(b1)	R-sq
Daily	666	0.418	0.031	0.212
Weekly	110	0.867	0.079	0.520

IMAREX daily closing prices are set as follows:

The best bid if last price < best bid

The best offer if last price > best offer

Or else use last price

This algorithm ensures that the daily closing prices are either at the upper and lower bound of the best offer and the best bid during the day and otherwise somewhere in between. From this algorithm we could possibly see a certain bid/ask price effect, as this is based on daily negotiations. To provide the estimates of optimal hedge ratios and thereby the best estimates of correlations and standard deviations that would probably have the greatest predictive value, I will use a weekly sample in the analysis from here on.

The next issue to address is which futures to use: Yearly, quarterly or monthly, and secondly, how do we splice the different maturity contracts together so they form a continuous price series?

4.7 Absolute or Log Price Increments

Duffie (1989) argues that: For most securities it is widely believed that weekly price changes do not meet the OLS conditions. The OLS conditions are sometimes felt to be

more appropriate, however, for the continuously compounding percentage rates of prices…these are equivalent to the changes in the logarithms of the prices, that is, the log-price increments. (Duffie, chapter 6.2: eq. 6)

$$X_t = \log(F_t) - \log(F_{t-1}) \qquad\qquad\qquad (4.4)$$

This is equivalent to the continuously compounded return of the futures: $F_t = F_{t-1}e^{r_t}$.

In appendix 4, a comparison is made from residual diagnostics on regressions conducted on both price increments and log-price increments. The conclusion is that the log-transformation does not meet the OLS condition any better than the price increments for our sample of data. For this reason, and for the sake of simplicity, I will then proceed to use the simple price increments (prices on the first difference form). If we had a very long sample, this decision should be reconsidered, as other factors such as inflation could make both the price levels and its corresponding variance greater.

4.8 Notes on splicing futures data

In order to obtain the samples large enough to conduct meaningful regressions with satisfactory accuracy, we need to splice futures data of different maturities in order to get continuous price series. There is no right or wrong answer as to how this is done, and the method of splicing is only as good as its usefulness. In other words, the price series should be spliced so they represent the cash flows of a trader rolling the contract forward or the fair value of his futures position if liquidated any one day. This would paint the most realistic picture of hedge effectiveness in later analyses.

Perhaps the most popular approach to splicing data is the so-called spot-month continuous. This approach quotes the month closest to maturity, and when this contract is no longer available for trading, the series shifts to the subsequent maturity contract.

A problem with splicing data is that we get discontinuous time series. Futures contracts of different maturities are different products altogether. For month products spliced together, the splice points will constitute a jump in the timeframe of one month. If the market has expectations of high freight rates over the next month, but

lower expectations for the month following that one, the futures prices will exhibit a jump downwards at the splice points.

When rolling the hedge forward we are exposed to multiple risks, reflected by the rollover basis[36]. By employing this strategy we are exposed to multiple basis risks, arising from the differences between the two futures prices at the rollover points. In real life the hedge can be rolled over at any time during the rollover period. Given that the future is uncertain, however, the timing in this matter is no more than educated guesses.

Another problem associated with this are effects as hypothesized by Samuelson, reviewed in section 3.2.3. If futures prices tend to fluctuate more heavily as the contracts approaches maturity, there will also be a higher variance immediately prior to the splice points. As I reviewed in section 3.4.5, the Samuelson effect would be expected to be partly dampened by the average price settlement of the IMAREX Freight Futures, but I did not provide conclusive evidence of this being incorporated into the actual pricing. Furthermore, the futures contracts cease to be traded at least two weeks before final maturity. This, combined with the relaxed assumption regarding the convergence property would probably reduce erratic behavior for the last weeks of trading.

The jumps associated with month contracts spliced together can disrupt any meaningful time series. A method for dealing with this is the so-called "Back-Adjusted Continuous Contract".[37] By working backwards, we start with the last splice point, and we adjust all prices preceding this point with the amount of the jump (rollover basis) between the two contracts. This way the price series will have a smooth transition.

To illustrate this algorithm, we have:

14/09/2004:   TD3 Sept 04: Closing at 101.5 WS

                TD3 Oct 04: Closing at 132.0 WS

---

[36] Expression used by Hull (2003) in his chapter 4.6 to describe the additional source of basis risk arising from the difference between the two futures prices at the time of rolling the hedge forward.
[37] Norgate Investor Services provides an excellent presentation of such algorithms on their website, (author unknown).

15/09/2004   TD3 Oct 04: Closing at 134.0 WS

We can see that there is a difference of 30.5 WS at the time the position is rolled forward. In the back-adjustment we add the difference of 30.5 to all the September closing prices such that the closing prices of the two contracts are equal at the time of the rollover[38].

Figure 4.5 shows two price series with spliced futures data for the TD3. The thin line is spliced according to the spot-month continuous and the thick line according to the back-adjusted continuous. The black line shows the adjustment levels between the different contracts. We see that the back adjusted series does not exhibit the same jumps as the spot-continuous. It can be argued that the back adjustment does not show the correct prices and indeed it does not[39]. However, it is consistent with a buy-and-hold strategy where the committed futures position is measured in absolute amounts, keeping the dollar exposure fixed. If the buy-and-hold strategy is measured in terms of a constant hedge ratio, however, the amount committed to the futures position will

Figure 4.5: Spot Month Continuous vs. Back Adjusted Continuous Futures Series: Levels, TD3

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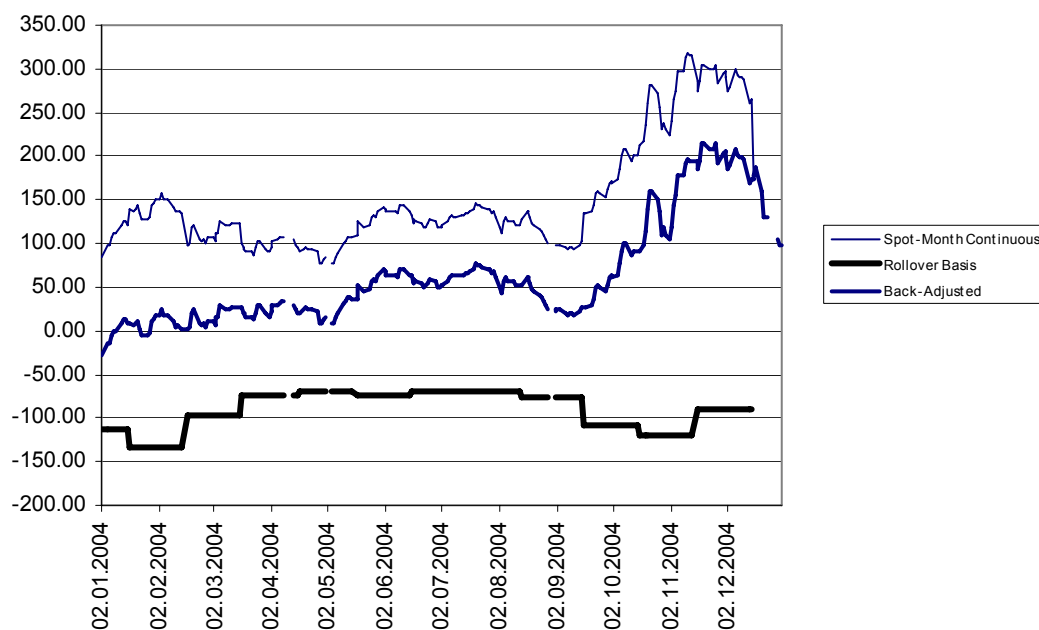
[38] For simplicity I will not adjust by using the two values of the same day, but rather by the difference between the old contract on the last day and the new contract on the next day.
[39] This algorithm can even produce negative futures prices, exhibited in the beginning of Figure

be variable. This is consistent with the spot-month continuous series. In our analysis we measure the hedge effectiveness in terms of a constant hedge ratio over the period. In this case the spot-month continuous series will be the appropriate series to use in the regressions. This means that at the rollover points the trader stays invested in the same ratio of futures to long positions at the rollover points.

Since we want the price series that are the most consistent with holding the hedge ratio constant over the period, I choose to employ the simple spot-month continuous algorithm.

4.9 Measuring HIE

Figure 4.6: Hedging coefficients from regression coefficients
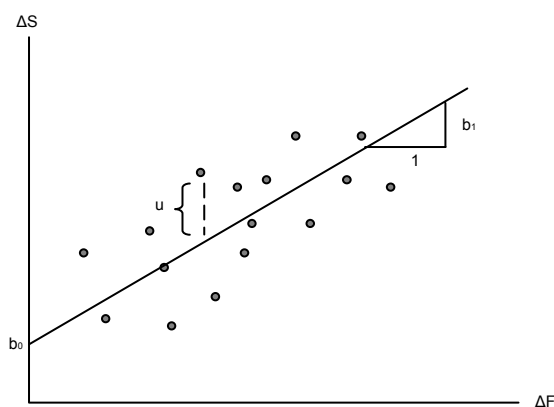
In order to determine figures such as hedge effectiveness, basis, and optimal hedge ratios, we need estimates of variance and covariance between futures prices and spot settlement prices. As shown in section 3.2.3, we can employ classical linear regression between spot and futures prices to determine relationships between changes in spot prices and changes in futures prices. Consider the regression presented in expression 3.13. Graphically, such a regression with one independent variable may look like Figure 4.6.

$$\Delta S_t = b_0 + b_1 \Delta F_t + u_t$$

The intercept point shows the expected change in spot price for no expected change in futures prices. If the expected future spot prices truly equals the futures price, the intercept point will show the basis as $E(\Delta S) = E(S_t) - S_0 = F_0 - S_0$. Stoll and Whaley (1991) elaborate further on this in their chapter 4.5. In our case, as we saw in section 3.4.5, the picture gets complicated as we are dealing with random basis hedges, and that the futures price in theory does not reflect the expected maturity spot price, but

rather an arithmetic average of this. We will therefore disregard the intercept term, and we will also see that this will systematically be insignificant in the regressions.

Relation 3.13 in section 3.2.3 indicates that the regression has to be conducted on the first difference level in order for the relation between regression R^2 and hedge effectiveness to be valid. These regressions will firstly be carried out for a selection of the IMAREX Freight Futures, that is, regress the underlying route on the futures contract specified for that particular route. In the examples I will present, other issues will be addressed. Among others, I will be looking at the less liquid routes such as the C3 and determine how such routes can be cross hedged with IMAREX futures, even if no contract is written on that particular route and vessel size.

4.10 Words of Caution

Prior to any analysis it is important to review properties of the products underlying the IMAREX futures. For all the IMAREX contracts the underlying product is freight. Any IMAREX contract is specified on a future contract settlement of either a time charter for a specified period/route or a specified voyage with a specified vessel size.

Is freight a commodity? In the shipping industry there is a large number of participants both on the supply and the demand side. Furthermore, the service provided does not differ significantly within the industry. Surely one company may have higher quality vessels than others, and some vessels are more fuel efficient, but the actual product, which is freight from A to B is made regardless of such differences. Microeconomic theory states that in a market with perfect competition, there will be zero economic profit. However, in the freight market, the output (ton-miles) is bulky. If one day there is a great demand for freight, a large number of vessels will be fixed this day. One week later these vessels are still sailing and supply will be relatively limited. If demand is the same the prices will remain high until these vessels are off-hire again. The prices from day to day are therefore not identically and independently distributed, and the price series will most certainly show a level of autocorrelation consistent with the assumption of mean reversion in section 2.2.

Among further properties of underlying commodities on which futures contracts are written are whether they are deliverable and storable. Storability refers to if the commodity can be stored for future delivery, and has traditionally been considered a necessity for successful futures contract specification. Freight rates are non-storable commodities, as it is a service and not a physical good. However, in a broader perspective the potential freight lies in the ton mile potential of the world fleet. Analogies can be made to the electricity markets. Hydro electric power is not storable in the common sense, but the water reservoirs in the mountains make the electricity storable and deliverable in a broader sense, as the water stores potential energy and it can be released at any time to generate the electricity for delivery. The deliverability is only a theoretical assumption. It is very unlikely that a vessel will be at the right place at the right time.

Some additional points complicate the freight futures market provided by IMAREX. Firstly, there is the problem of bulky supply of the underlying product. Secondly, the fact that the final settlement price is based on the period average makes the future price path unable to follow the price of the underlying commodity. As we discussed in section 4.5, however, we cannot be sure if the market actually prices the futures according to this property. Given the scarcity of explicit pricing models available for such futures contracts, a lot of practitioners in the market will use "guesstimates" to price the futures rather than estimates, relying on gut instinct on which way the market will move within the time interval before maturity.

Section 5 presents the estimates for optimal hedge ratios and HIE based on the sample period discussed. The analysis is restricted to that of 5 tanker futures and 2 dry-bulk futures for the Capesize segment.

5. IMAREX FREIGHT FUTURES

Findings and Examples for Hedging

5.1 Hedging Instrument Effectiveness Estimates

The following table shows the output of the estimations conducted for Hedging instrument effectiveness (HIE) presented in section 3.2.3. The regressions are based on monthly futures contracts, and the futures time series are spliced according to section 3.4.8. The regression is conducted based on weekly observations, and for the tank futures, the sample period stretches from October 2002 to July 2005, with 110 weekly observations. The C4 and the C7 regressions are conducted on the basis of 91 and 49 weekly observations respectively. How the time series are calculated and details on how the regressions are conducted are presented in Appendix 1.

Table 5.1: Hedging Instrument Effectiveness (Weekly Changes)

	Basis*		Optimal Hedge Ratio		Correlation	St. Dev S	St. Dev F	HIE
	Fitted Value	Std. Error	Fitted Value	Std. Error				R Sq.
Tanker Futures								
TD3	*0.612*	*1.667*	**0.867**	0.079	0.724	25.102	20.968	**0.5199**
TD4	*-0.103*	*1.417*	**0.631**	0.078	0.613	18.624	18.072	**0.3695**
TD5	*0.200*	*1.920*	**0.917**	0.100	0.662	26.707	19.282	**0.4335**
TD7	*0.960*	*1.567*	**1.131**	0.074	0.827	29.062	21.247	**0.6812**
TD9	*-2.058*	*2.888*	**1.225**	0.102	0.756	46.031	28.408	**0.5675**
Capesize Futures								
C4	*0.093*	*0.134*	**0.478**	0.054	0.684	2.017	2.492	**0.4673**
C7	*0.085*	*0.110*	**0.676**	0.065	0.835	1.387	1.714	**0.6969**

Source: The Baltic Exchange and IMAREX. Own table

For the fitted values, bold typeface indicates significance of the estimates at the 5%-level. The HIE tells us that the optimal hedge ratio can at best achieve a risk reduction of 68% for the case of the TD7. This is a highly satisfactory result. For TD4, the HIE is the lowest among our cases. Here we see a risk reduction of 37%. All the intercept estimates are non-significant. I still chose to keep these, as forcing the regression through the origin would mean that we assume a zero basis. Rather we interpret the insignificance of the intercept terms as an effect from the fact that we are considering random basis hedges. As expected, we also see a close link between correlation and

HIE. The contracts can be ranked from low to high in terms of correlation: TD4, TD5, TD3, TD9, TD7. We see that this ranking is the same when ranking HIE from low to high. As we know from (3.24), such a ranking would, by definition, tend to be identical, assuming that h* is the employed hedge ratio and holding the time horizon and the amount of parameters fixed.

5.2 Diagnostic Tests

We need to elaborate on whether the OLS assumptions are satisfied for our analysis. I will here conduct tests on each of the five assumptions, and if they are not fulfilled, I will discuss possible problems that may arise from such violations.

OLS Assumption 1: $E(u_t) = 0$

The mean of the residuals from a regression including the intercept term will always be zero from the definition of the OLS procedure. Since I have included and intercept term in all of the above regressions, the assumption holds.

OLS Assumption 2: $var\ (u_t) = \sigma < \infty$

To test this property I will use White's general test for heteroscedasticity[40]. The test statistics and p-values are presented in table 5.3. The test statistic is the "obs*r-squared" figure. The null hypothesis is that of no heteroscedasticity, while the alternative is of heteroscedasticity of some unknown general form.

Table 5.3: White's Test for heteroscedasticity of the residuals

TD3	F-statistic	0.521815	Probability	0.595
	Obs*R-squared	1.062526	Probability	0.588
TD4	F-statistic	2.102402	Probability	0.127
	Obs*R-squared	4.159249	Probability	0.125
TD5	F-statistic	1.725658	Probability	0.183
	Obs*R-squared	3.437213	Probability	0.179
TD7	F-statistic	22.28954	Probability	0
	Obs*R-squared	32.35076	Probability	0
TD9	F-statistic	3.097077	Probability	0.049

---

[40] Proposed by White (1980). For a presentation of the test I refer to Brooks (2002) Chapter 4.6

	Obs*R-squared	6.019365	Probability	0.049
C4	F-statistic	42.18432	Probability	0
	Obs*R-squared	44.54143	Probability	0
C7	F-statistic	0.266852	Probability	0.767
	Obs*R-squared	0.56199	Probability	0.755

We see that out of the seven different contracts, only TD7, TD9, and C4 are significantly homoscedastic on the 5% level. This means that the remaining four contracts seem to display some evidence of heteroscedasticity. Brooks (2002) points out that the consequences of this heteroscedasticity may be false standard error of the regression coefficient, but the model still displays unbiased estimates. I will however, not deal with the heteroscedasticity in my analysis, but we should be careful about making inferences, as these can possibly be misleading.

OLS Assumption 3: cov (u_i , u_j) = 0

A priori, we do expect some autocorrelation of our residuals given our discussion about bulky supply and lags in the supply of freight, presented in 3.4.10. To test for autocorrelation in the residuals, we use the Breusch-Godfrey test using five lags. Be advised that the test is conducted on the basis of one period differences, while the regressions I have presented so far are based on weekly differences.

Table 5.4: Breusch-Godfrey Test for Serial Correlation in residuals (lags = 5)

TD3	F-statistic	1.013826	Probability	0.444
	Obs*R-squared	5.556835	Probability	0.352
TD4	F-statistic	0.393427	Probability	0.846
	Obs*R-squared	2.550634	Probability	0.769
TD5	F-statistic	0.347984	Probability	0.876
	Obs*R-squared	2.286643	Probability	0.808
TD7	F-statistic	0.139594	Probability	0.980
	Obs*R-squared	0.978171	Probability	0.964
TD9	F-statistic	0.454869	Probability	0.803
	Obs*R-squared	2.896528	Probability	0.716
C4	F-statistic	1.601677	Probability	0
	Obs*R-squared	7.657404	Probability	0
C7	F-statistic	1.497869	Probability	0.249
	Obs*R-squared	7.326386	Probability	0.197

We see that only C4 shows significant autocorrelation. We can expect that some of the autocorrelation has been removed by using weekly changes rather than daily

changes. The consequences of ignoring autocorrelation if present are to a large extent the same as ignoring heteroscedasticity. We should be careful with relying on standard error estimates.

OLS Assumption 4: cov (u_t, x_t) = 0

The discussion if whether the independent variable ΔF is exogenous is a discussion of causality. It is outside of the scope of this paper determining whether ΔF causes ΔS, or the other way around. Again I refer interested readers to Kavussanos and Nomikos (2003). Their findings were that futures prices tend to discover new information more rapidly than spot prices.

OLS Assumption 5: $u_t \sim N(0, \sigma^2)$

To test whether the residuals are normally distributed, we use the Bera-Jarque[41] test for normality. This test jointly tests the third and fourth moments of the probability distribution of the residuals. The null hypothesis is that the skewness is 0 and the kurtosis is 3 (according to the definition of a normal distributions). The Bera-Jarque statistics are presented in table 5.5:

Table 5.5: Bera-Jarque Tests of Normality

	Bera-Jarque	Probability
TD3	2.265	0.3222
TD4	14.674	0.0007
TD5	108.580	0.0000
TD7	11.136	0.0038
TD9	84.329	0.0000
C4	146.430	0.0000
C7	22.151	0.0000

The null hypothesis of normality is rejected if the p-values are not greater than 0.05 on a 5% significance level. We see that only the TD3 residuals can be claimed to be normally distributed. The consequences for our HIE estimates for the regression with non-normally distributed variables are not grave in most cases, according to Brooks (2002). In some cases, such as calculating prediction intervals for out of sample

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[41] As introduced by Bera and Jarque (1981). For more information refer to presentation by Brooks (2002) chapter 4.9.

inferences, non-normality can nevertheless be a source of error. For this application, however, normality will not be the most important assumption.

We will now turn to specific examples and leave the statistics behind. The examples I will present are samples of one and serve purposes different from what we have elaborated on so far.

5.3 Applications under Different Scenarios

In addition to estimating the plain hedging instrument effectiveness (HIE)[42] of the IMAREX contracts, I attempt to look beyond the plain regression analyses by constructing two examples, and review how optimal hedging would be performed under these circumstances. While the HIE only measures the potential risk reduction possible from the derivative instruments, the overall hedge effectiveness (OHE) measures the remaining variance of the hedged portfolio relative to the unhedged portfolio. According to Charnes and Koch (2003) the two components of OHE are the effectiveness of the instrument itself (given the optimal hedge ratio) and the ratio of variance reduction stemming from the actual chosen hedge ratio. What Charnes and Koch does not include is the time-frame, and the fact that there is flexibility in the system. A HIE based on a regression from interpolated futures contracts changes with time intervals. Furthermore, given the wide range of maturity specifications for the IMAREX contracts, there is significant room to financially engineer a hedging portfolio.

The HIE estimates that was presented in section 5.1, do therefore not account for this dynamic environment, and that is the rationale for also presenting actual examples of how hedging with IMAREX derivatives may be done in real life. The two scenarios I will present will highlight different aspects of risk management in this market. Scenario 1 will address issues such as hedging strategies, and how hedgers can obtain parameters useful in determining optimal hedge ratios. This scenario will also delve deeper into the dynamics of the different hedge effectiveness measures that was

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[42] The hedge effectiveness measures are presented in section 3.2.3

presented in section 3.2.3. Scenario 2 will mainly deal with the concept of cross hedging.

The scenarios constructed for the examples will be:

Scenario 1: *Shipowner: owns 1 VLCC. 230.000 ton. Ship will be in Arabian Gulf after discharging crude oil, and will be off-hire on October 4, in 3,5 months.*

Scenario 2: *Mining Company: will complete an order of 150.000 ton of iron ore, scheduled to be delivered in Shanghai. The CoA[43] will be fixed on September 12 in Tubarao (Brazil).*

Firstly, three generic strategies will be reviewed. The exercises will give tentative indications to shipowners on which will be the preferred strategies a priori, but when used on historical data, we will be able to determine which hedging-strategies were the best in retrospect. A word of caution is that even if one strategy stands out as better in this particular example, a different conclusion might be reached in a different time interval and with a different scenario altogether. This is a so-called sample of one problem. Following this discussion, I will provide general guidelines to users of the IMAREX contracts, and review some out-of-sample estimates for our two applications. Lastly I will introduce a tool for hedgers to determine linear combinations of different maturity contracts to construct a futures portfolio that correlates optimally with that of the underlying asset.

The strategies are as follows:

1. Using only the contract with the longest maturity available today.

2. Rolling forward quarter contracts (Spot Quarter Continuous)

3. Rolling forward month contracts using the closest maturity contract (Spot Month Continuous)

5.4 Scenario 1: The Shipowner

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[43] Contract of Affreightment. Shipping contract that is unit based (as opposed to time based).

5.4.1 Hedging Strategies and Hedge Effectiveness

Recall the case description as follows: We consider a shipowner who is concerned with the future income from his VLCC of 230.000 ton. The vessel will be in Arabian Gulf after discharging crude oil, and will be off-hire on October 4, in 3,5 months. The shipowner is privileged in that his starting point is predetermined, but the destination of his vessel is open before a freight contract is negotiated. This means that the shipowner can choose freely from routes in which freight is demanded. Let us assume that out of different reasons he wants to traverse the TD3 route, and also assume that there is no risk that his vessel will remain off-hire at maturity. We will therefore limit the analysis to the use of solely the TD3 futures contract.

Figure 5.1A: Spot Prices versus Three Different Hedging Strategies, levels: TD3
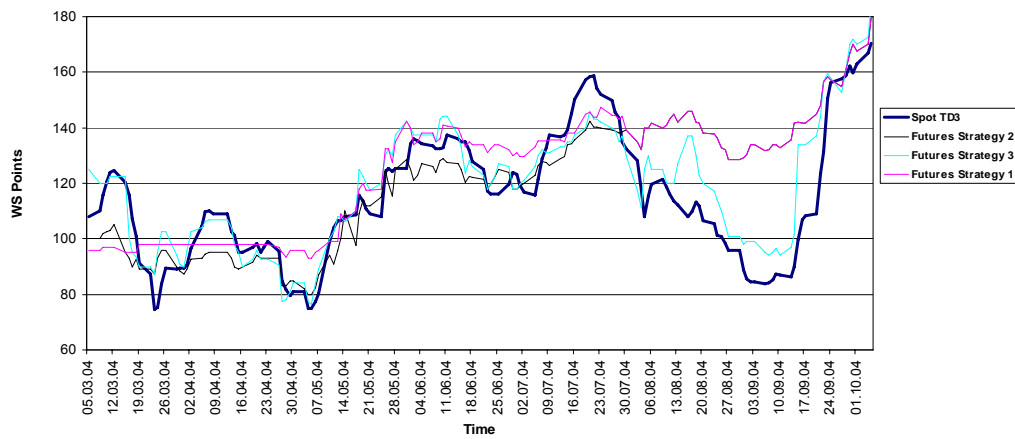
Figure 5.1B: Spot Prices versus Three Different Hedging Strategies, changes: TD3
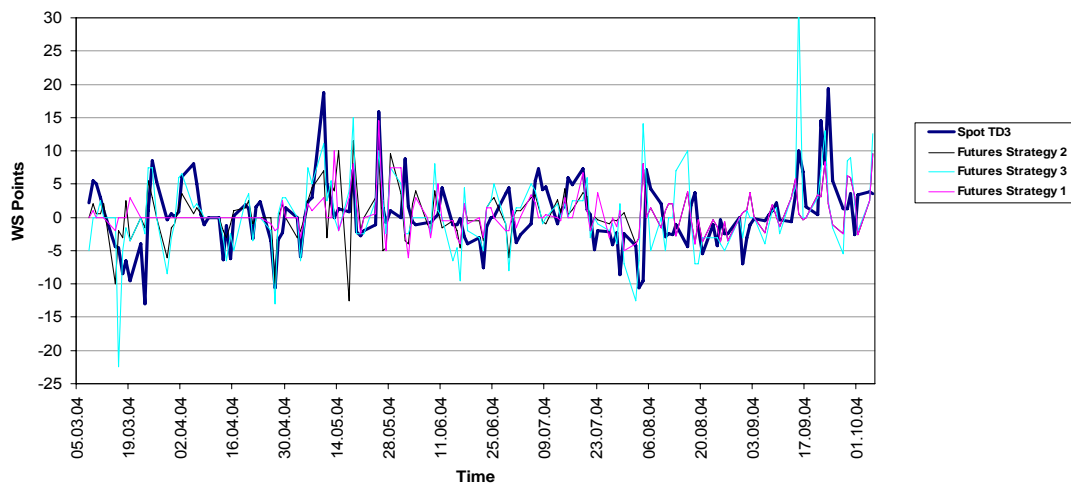
Figure 5.1A shows the ex post *level* fluctuations of the spot prices versus the futures prices under the three different hedging strategies discussed. We can see that strategy 3 by far co-moves closest with the underlying spot fluctuations. Tracing the pink schedule, which is the strategy including no roll-overs, the contract is largely unresponsive to the fluctuations of the spot prices. The month rollover strategy (strategy 3) seems to be the most responsive to the spot price changes, both for the levels and for the changes.

In determining the OHE for the three first strategies, Excel was used to table the unhedged portfolio (i.e. fixing the whole vessel in the spot market) and finding the variance of the first difference of the value of the portfolio. Then, using an arbitrary hedge ratio, the futures portfolio and the developments of the daily marking to market were modeled. Since

$$\Delta CF_t = N_e(1\Delta S_t - h\Delta F_t) \tag{5.1}$$

where N_e is the physical endowment in units, we get the same conclusion with regards to hedge ratio and hedge effectiveness by only considering the expression in the parenthesis, that is, ΔCF_t / N_e. The relation between optimal hedge ratio h* and optimal number of contracts N* is then straightforward and as follows (Equivalent to Hull (2003), Eq. 4.2):

$$N^* = \frac{h^* N_e}{LotSize} \tag{5.2}$$

Lastly the two portfolios were joined and the variance of the first difference of the combined portfolio was found. Having the two parameters of the overall hedge effectiveness (OHE), the Excel solver tool was then used to minimize the OHE with respect to the hedge ratio. As the variance of the spot price changes is exogenously determined and constant, this is equivalent to minimizing the variance. When OHE is optimized like this, (1 – OHE) becomes HIE as the hedge ratio effectiveness (HRE)[44] effectively becomes 1, indicating no deviation between optimal and actual hedge ratio.

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[44] Introduced in section 3.2.3.

Table 5.6 shows the output of this analysis. The variance and correlation estimates are obtained on the basis of the price-*changes*.

Table 5.6: Solver Output Indicating h* and OHE*

Strategy	Var Unhedged	Var Future	Corr(S,F)	h*	Var Hedged	OHE
1: Q4 2004	25.080	8.491	0.263	**0.458**	23.299	**0.9290**
2: Quarter rollover - 2004	25.080	12.446	0.332	**0.477**	22.245	**0.8869**
3: Months rollover - 2004	25.080	32.829	0.440	**0.386**	20.191	**0.8051**

As the hedge effectiveness is greater the smaller the OHE, we see a trend that shorter maturity contracts hedge better in this particular example. The month products rolled over was able to reduce 20 percent of the variance. This is also clear from figure 5.1. The thick line shows the spot price fluctuations, while the three thinner lines represent the prices of the three future price strategies. We see that the month rollover strategy by far co-moves best with the underlying spot price.

In this specific case strategy 3 clearly stands out as the best. Taking the month rollover strategy a bit further I conduct a sensitivity analysis on the estimated hedge ratio. As we discussed in section 3.2.2, the hedged portfolio is on the form $V = S - hF$. As S has a weight of 1 and F has a weight of h (futures contracts / unit of underlying), this portfolio is proportional to the amount of the physical endowments. The hedge ratio minimizing this portfolio will also minimize the actual portfolio. Figure 5.2 shows the development of the variance of the changes of this portfolio using the TD3 contract to hedge TD3 exposure under alternating hedge ratios.

Figure 5.2: Variance of Hedged Portfolio TD3 under Alternating Hedge Ratios
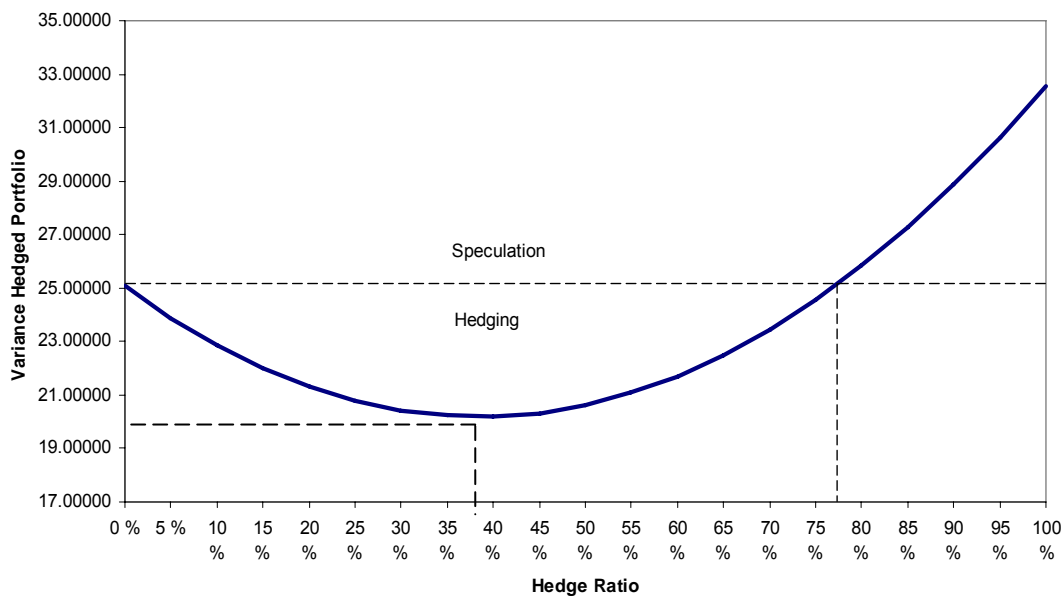
It is interesting to note the significance of the hedge ratio. An unhedged exposure corresponds to a hedge ratio of 0. At around 77.5%, the variance of the "hedged" portfolio actually climbs above that of the unhedged one. If employing a hedge ratio exceeding this, the activity is no longer referred to as hedging, but rather speculation. The figure indeed shows that the maximal risk reduction, or the minimal variance of the hedged portfolio, is reached at the 0.386 units of futures per unit of underlying ratio, corresponding to a minimum variance of 20.19.

Figure 5.3: Hedge Effectiveness Components under Alternating Hedge Ratios
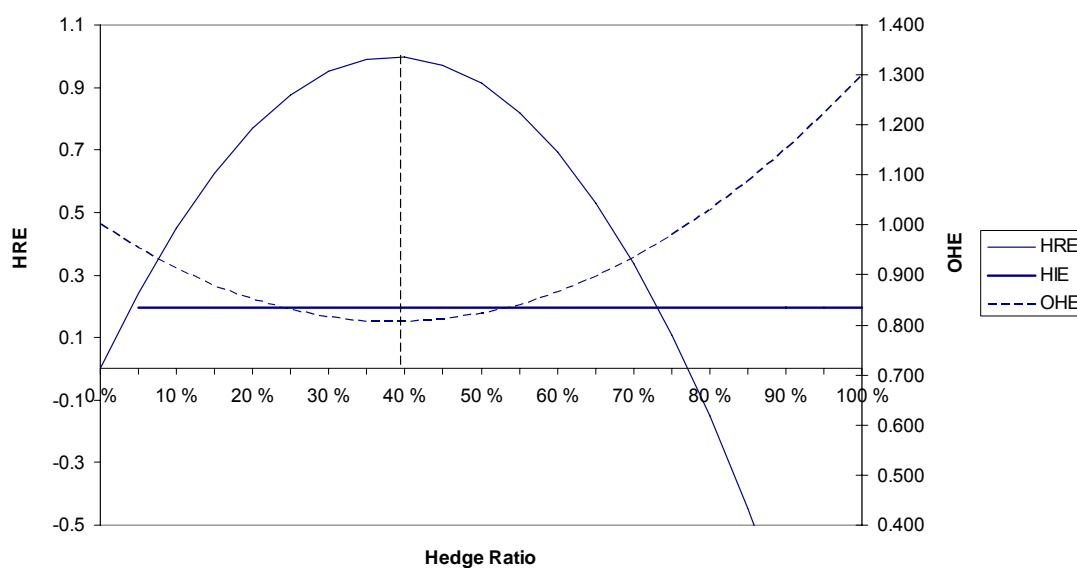
From Figure 5.3 we observe the relationships between HIE, OHE and HRE. HIE is independent of the actual hedge ratio, since this measures hedge effectiveness when the optimal hedge ratio is already chosen. Furthermore we see the inverse relationship between HRE and OHE as indicated by the relation: 1-OHE = HIE * HRE. In the real world this discussion is redundant as no hedger *want* to settle for anything less than optimal. This exercise can however be useful in order to gear hedging activity towards a pre-established target. It can also be useful to speculators who may desire to gear the risk and corresponding return in the opposite direction.

The HIE will nevertheless be the most important measure for an industrial hedger to be concerned about. It is important to note the significance of the correlation coefficient between the changes of the price series. From table 5.6 we see the result we might have expected, that the higher the correlation, the higher the hedge effectiveness.

5.4.2 Out-of-Sample Considerations

The analysis so far in this section has been backward-looking, and I have implicitly assumed that we have known all the spot and futures price movements over the period of the hedge. This is of course not realistic. We have furthermore seen that there are three necessary parameters we need to estimate before we can create an optimal hedge. I will now look into out-of-sample estimates of these parameters: $\sigma_{\Delta S}$, $\sigma_{\Delta F}$ and $\rho_{\Delta S, \Delta F}$ for the time preceding time zero in our examples, and review how good these estimates are in predicting the actual parameters over the hedging period in our examples.

If the hedger can access historical spot and futures market data for a period preceding the time of initiation of the hedge, the standard deviation of the futures price changes, the spot price changes and the correlation between these changes can be easily found using for example Excel. From table 5.7, I would recommend utilizing futures data for a period at least greater than the hedging period being considered. If we have 12 months of futures prices, the sample estimates will indicate a optimal hedge ratio of 0.414. As we know, what is actually observed in the hedging period is an optimal hedge ratio of 0.385. This implies that the hedge ratio using the 12 month sample

before overshoots the observed optimal ratio by 2.9%. Conversely, the 6 month estimate undershoots this ratio by 7.1%. The lower part of the table shows the computation of hedge ratio effectiveness (HRE) if the hedge ratio is set ex ante and the optimal hedge ratio is only shown ex post. We know that as the HRE approaches one, the hedge ratio approaches the actual optimal hedge ratio. In this case, we have that for the one month sample, the HRE is only 48.9%, while for the six and twelve month samples the hedge ratio determined ex ante gives a significantly higher HRE. As this is only one specific scenario, I cannot make conclusive inferences. I would still recommend a sample period of minimum six months, but preferably a year or more for other applications.

Table 5.7: Out of Sample Parameter Estimates, different sample lengths

TD3	Sample preceding march 5, 2004			Actually
	1 Month	6 Months	12 Months	Observed
Correlation $\Delta S, \Delta F$	0.243	0.353	0.379	0.440
St Dev, ΔS	4.672	7.147	7.097	5.008
St Dev, ΔF	10.349	8.053	6.509	5.730
Computed h*	0.110	0.314	0.414	0.385
Computed HIE	0.059	0.125	0.144	0.194
Var, ΔS	25.080	25.080	25.080	25.080
Var, ΔC	22.707	20.389	20.251	20.223
Var, ΔC*	20.223	20.223	20.223	20.223
HRE	0.489	0.966	0.994	1.000

Based on above discussions, we can now provide an algorithm for hedgers that want to hedge their positions in the shipping market. The algorithm is by no means exact and involves some educated guesses rather than exact procedures, but it provides a framework on which the decision process can be based.

1. Obtain samples of routes that can be assumed to be similar to the exposure in the freight market.
2. Select one route you want to base the hedge on.
3. Obtain samples of the futures contract written on the route chosen in (2).
4. Decide on an overall strategy (examples in section 5.3)
5. Create a continuous series according to which strategy chosen and according to section 4.8

6. Use Excel or econometric software such as Eviews to obtain estimates of σ_S, σ_F and $\rho_{S,F}$ (on the changes, not the levels)

7. Calculate h* and commit.

So far in the analysis we have assumed that to hedge a TD3 exposure, you use the TD3 contract. But what happens is the physical exposure is a route and vessel size on which no contract is written? We will look at these problems and the activity of cross hedging in the following section.

5.5 Cross Hedging

If there is no contract written on the exact physical exposure one might have in the physical market, steps (1) – (3) in the algorithm above are not so straightforward. In this case a number of different futures contracts have to be considered. The most important variable to consider here is the correlation coefficient. The correlation between the different routes can be a useful indicator, but the best way to choose the right futures contract(s) is to look at the correlation between the different futures contracts and the physical endowment. The latter approach requires data from an additional source, but is the most direct way to determine the right contract for cross hedging. IMAREX futures are good in the way that they have a very wide selection of maturities. The time basis presented in section 3.2.1 can correspondingly be made very small[45]. Correlations should also be viewed on the changes rather than the levels.

Hedging with multiple contracts:
Regressions can be a useful tool for determining the portfolio of futures contracts to hedge a physical exposure. The theory presented in section 3.2.4 can easily be extended to handle hedging with multiple contracts. There are different approaches to how optimal models can be found. Brooks (2002) presents the different schools of thought in chapter 4.15. The so-called general-to-specific approach[46] involves starting with a large models with many parameters and then gradually narrowing it down. By including a number of different contracts in the regressions, we can eliminate one by

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[45] unlike many other futures contracts where there are only quarter contracts available.
[46] Approach associated with Sargan and Hendry. Presented in Brooks (2002) chapter 4.15.

one by judging from their significance. This is a simplification of reality, as regressors that may appear to be insignificant in one model specification, may be significant in others. To a large extent, however, regressors that are very insignificant can *normally* be assumed to actually be so no matter how the model is specified. To aid in the model specification, another useful tool for finding the optimal portfolio of futures contracts is by looking at the information criteria of the regressions. Such information criteria contain two parts. The first term includes the residual sum of squares, while the second term is a penalty for loss of degrees of freedom as more parameters are included in the model. Three such information criteria are presented by Brooks (2002): The Akaike (1974) Information Criterion (AIC), the Schwarz (1978) Bayesian Information Criterion (SBIC) and the Hannah-Quinn Criterion (HQIC). I will present the two first according to Brooks (2002):

$$AIC = \ln(\hat{\sigma}^2) + \frac{2k}{T} \qquad\qquad (3.30)$$

$$SBIC = \ln(\hat{\sigma}^2) + \frac{k}{T}\ln T \qquad\qquad (3.31)$$

In these expression $\hat{\sigma}^2$ is the residual variance, k is the number of parameters estimated and T is the sample size. The object is to minimize these criteria. We furthermore see that SBIC incorporates a stiffer penalty term than the AIC[47].

By trial and error estimating different models we can then choose the model based on these information criteria. It is, however, important to note that the calculated coefficients from the models represent positions in different futures contract. If the best model, say, has a coefficient of 0.03 of one of the coefficients, it may not be worthwhile to invest in that future contract in practice. From a statistical point of view, variables with a small degree of explanatory power may furthermore be removed as adding more variables may not be worthwhile because more variables need to be estimated. Generally, the fewer explanatory variables, the better.

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[47] 3.31 incorporates stiffer penalty for $\ln T > 2 \rightarrow T > e^2$.

As we will see, for case two which I will turn to now, we will need to make use of cross hedging. I will now turn to this specific case where further issues surrounding cross hedging will be elaborated on.

5.6 Scenario Two: The Manufacturer

Recall the case introduced in the beginning of this section: Consider a mining company which has just negotiated a CIF contract for delivery of 150.000 ton of iron ore to a steel plant close to Shanghai (China). The mining company wants to hedge the variability of the freight costs they will incur on this future date. The order will be shipped in full on September 12 from Tubarao (Brazil). Looking at the Baltic Exchange route specification in table 3.2, the route corresponding most closely to the physical exposure is the C3 route. No futures contracts are however traded on this route, and the mining company will have to cross hedge their exposure using a different contract. In this scenario we draw on the findings from scenario one where one of the conclusions was that the month-rollover strategy was the strategy yielding the highest HIE. Strategy 1 and 2 will therefore not be presented in this scenario.

Assuming that the freight rate risk actually corresponds quite closely to the C3 route, we have the correlations between the C3 and different IMAREX contracts[48].

Table 5.8: Correlations Between C3 Spot and Available IMAREX Futures (First Difference, weekly)

Futures	C4	C7	TD3	TD4	TD5	TD7	TD9
Spot C3	0.573	0.809	0.464	0.406	0.013	-0.236	-0.075

In table 5.8 I have included both dry bulk capsize futures as well as dirty tanker futures. We clearly see that the capsize futures are correlation best with the spot C3, with the C7 contract clearly standing out as the best. Although a bit mixed, tanker futures such as the TD3 and TD4 are also showing reasonable correlations with the C3 route.

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[48] I have in this example only used contracts with different underlying route. The analysis could easily to be extended to handle different maturity contract for the same underlying route as well.

Utilizing the two capsize futures, C4 and C5, and the TD3 and TD4 in a regression, we have the regression outputs as shown in table 5.9:

Table 5.9: Different models

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Ranking AIC	SBIC	R-sq
Regression 1							
C4	-0.003503	0.100836	-0.034738	0.9724	2	3	0.677
C7	**0.912272**	**0.151856**	**6.007503**	**0**			
TD3	**0.032222**	**0.012882**	**2.501358**	**0.0162**			
TD4	-0.024601	0.015191	-1.619462	0.1125			
Intercept	0.186675	0.165651	1.126915	0.2659			
Regression 2							
C7	**0.872639**	**0.105158**	**8.29839**	**0**	1	1	0.672
TD3	**0.014691**	**0.006851**	**2.144496**	**0.0373**			
Intercept	0.177652	0.166517	1.066873	0.2916			
Regression 3							
C7	**0.956058**	**0.10137**	**9.431381**	**0**	3	2	0.647
Intercept	0.212343	0.171957	1.23486	0.223			

We see that from four initial parameters, we sort out the insignificant parameters. In regression two we use the remaining significant parameters. However, we see that the hedge ratio for TD3 is around 1.47 %. The third regression includes only C7. We see that the 1.47 % / 1 unit of underlying invested in TD3, contributes to an improved HIE of about 2.5 %. For a hedger to take the trouble of allocating such a small fraction to a contract, the physical exposure needs to be of a very large scale. Most likely, the HIE improvement of 2.5 % by committing to this small hedge ratio in TD3 would be eaten away by transaction costs.

In this particular case, the C7 proved to be able to hedge a C3 exposure quite well. In fact the HIE of C7 on C3 proved to be only marginally less than C7 on C7 in our sample. Having indicated that the C7 may be the best fit in this particular scenario, the analysis becomes equivalent to that presented for scenario 1. Note that I have in this analysis used all the available data material to produce our estimates. In an actual setting, these samples would also be collected from historical data, but one must bear in mind the discussion about lengths of sample intervals presented in Table 4.5

5.7 Summary and Limitations

The main objective of the analysis conducted up to this point has been twofold. Firstly: Evaluate the hedging performance of the IMAREX Freight Futures and secondly: How to determine the optimal hedge ratio for potential users of IMAREX Freight Futures. The analysis has utilized two different (but similar) ways to derive this hedge ratio, with price series and futures price series as the main input. I have discussed different hedging strategies, and based on these made the decision on how to transform the different futures contracts into one continuous series. How to determine meaningful sampling intervals was discussed, and transformations of the raw data were conducted. Based on all these considerations the regressions were conducted on the weekly changes (price increments) of both the futures price and the spot prices. The futures data were spliced according to the spot month continuous algorithm. The output for the seven contracts we considered was presented in Table 5.1 which showed the optimal hedge ratios to be between 63% and 123% for the different contracts.

After the optimal hedge ratios had been obtained, the performance of the hedges was evaluated and also presented in Table 5.1. Measuring the total risk reduction possible, the hedging instrument effectiveness proved to lie between 37% for the TD4 contract and 70% for the C7 contract. This must be said to be very good results for such random basis hedges. Furthermore, being a young market still working on improving liquidity in the individual contracts, we can expect the HIE to improve further over time, as more participants are drawn to the market, and the prices will develop to move more in tune with the underlying assets.

I have also attempted to show how hedging decisions might be made in a real life setting by providing two fictitious cases. In these examples, other aspects of hedging with the IMAREX futures were highlighted. This exercise will hopefully serve as an illustration of some of the aspects and questions that may arise in a real situation.

I conclude this section by turning to some limitations of the presented analyses.

Being the young market it is, a more detailed examination of the liquidity of the IMAREX contracts would be useful. I have in my analysis implicitly assumed there is no problem closing out a futures position, and that single transactions will not be able to alter the prices. An evaluation of whether the contract specifications of the IMAREX futures are optimal with respect to the trade-off between standardization and liquidity would be useful. All I can suggest based on my analysis is that the IMAREX futures are able to reduce the risks of the market participants more effectively than the old BIFFEX contract could, and that a solution with separate contracts for each route is better than one contract based on an index of routes.

This tentative analysis has also been somewhat descriptive and empirically limited. The analysis has been conducted based only on the observed market prices. Although I have presented some a priori notes on how the futures prices would be expected to be determined, a full pricing model has not been presented. So far a theoretically well founded model does not exist, but an analysis of causality and price discovery function in this market would be useful. In such an analysis, the effects from the averaging property could also be highlighted further.

6. IMAREX FREIGHT OPTIONS

6.1 Section Outline

The IMAREX Freight Options started trading June 1, 2005. So far only one option is trading, with the TD3 route as the underlying. The details of the contract specification will be further explained in section 6.3.

I will start by reviewing some basic option theory, before I proceed to discuss the particulars of the IMAREX contract. The analysis will for the most parts be highly general and founded on ex ante considerations.

6.2 Option Properties and Pricing

6.2.1 How Do Options Work?

Similar to futures contracts, options are also instruments to reduce risks associated with future transactions. While futures and forwards have a completely symmetrical payoff-profile given that any gain by a short position is offset by an equivalent loss on the long position and vice versa, the holder of an option have the choice whether to exercise his right or not. A forward or future contract gives the holder both the right *and* the obligation to undertake a transaction in the future, while the holder of an option has a right *but not* the obligation to make the corresponding transaction. Broadly we can categorize options into call options and put options. The holder of a call option has the right at maturity to buy the underlying asset at a specific price (the strike price), while the holder of an equivalent put option has the right to sell the same asset at the same maturity. Furthermore, we can distinguish between European options (where the option can be exercised at maturity only), American options (the option can be exercised at any time up until maturity), and more exotic options such as Asian options (the payoff or the strike is determined by some average over a specified period). The payoff from options at maturity is shown in figure 6.1. Here S denotes

the price of the underlying, K is the strike price and c and p is the respective values of the call and the put.

Figure 6.1: Payoff Profiles for European Options (puts and calls)

PAY-OFF FROM CALL OPTION   PAY-OFF FROM PUT OPTION
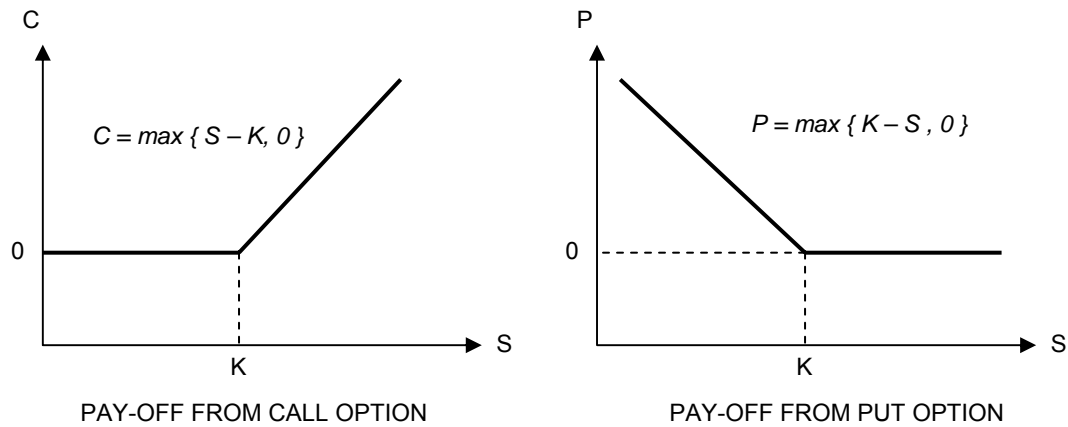
6.2.2 The Black-Scholes Option Pricing Model

The most significant breakthrough in the pricing of options contracts was made in the early 1970s by Fischer Black, Myron Scholes and Robert Merton. Their model for pricing European options has had a significant role in the modern day pricing of options, and many of the models employed today are various applied versions of their original model. I will present this model briefly and refer interested readers to more detailed presentations made by for example Hull (2003), chapter 12 or McDonald (2003), chapter 12.

For the ease of later analyses, we present the generalized Black-Scholes option pricing formula according to Haug (1998). 6.1 gives the price of a call option, while 6.2 gives the equivalent price of a put option:

$$c = Se^{(b-r)T} N(d_1) - Ke^{-rT} N(d_2) \qquad (6.1)$$

$$p = Ke^{-rT} N(-d_2) - Se^{(b-r)T} N(-d_1) \qquad (6.2)$$

$$d_1 = \frac{\ln(S/K) + (b + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

(6.3)

The function N(x) is the cumulative probability distribution function for the standardized normal distribution. The b is the cost of carry term, which differs across the different applications. This general model can be used to price European stock-options, stocks paying a continuous dividend yield, futures options and currency options. Again according to Haug (1998), page 7:

$b = r$ Gives the original Black-Scholes (1973) model for pricing of plain European stock options.

$b = r - q$ Gives the Merton (1973) stock option model with continuous dividend yield, q.

$b = 0$ Gives the Black (1976) futures option model

$b = r - r_f$ Gives the Garman and Kohlhagen (1983) currency option model.

For more exotic options and other cases where the assumptions of Black-Scholes are violated, such as in the case of heteroscedasticity, Black-Scholes is not sufficient. In this case closed-form solutions may not be available and we have to turn to other numerical procedures or analytic approximations.

6.3 IMAREX Freight Options

According to the NOS Rulebook Appendix 5, IMAREX freight options are of the Asian kind with the settlement price set as the arithmetic average of the Baltic Exchange or the Platt's quotes for all index days in the months. Three different strike prices are set prior to trading and clearing for both calls and puts and in intervals of 10 Worldscale points. Settlement is performed automatically upon maturity.

Premium calculation is made as follows: #Lots * Lot Size * Worldscale Flatrate * (Worldscale Points / 100) … and the lot size is set to 100mt. Minimum number of lots in any contract is 5 lots.

So far the options contract is trading on the monthly basis of TD3 exclusively. The settlement price of the option is as we can see the same as for the TD3 IMAREX Freight Futures contract (IFF). It is useful to note that

$$S_{avg,T} = F_T \qquad\qquad (6.4)$$

6.4 Pricing Models

6.4.1 Black (1976) Futures Options Pricing Model

In 1976, Fischer Black introduced a modified version of the model he had introduced together with Scholes three years earlier. This model is often referred to as Black 76 (here: B76). The model is based on the generalized Black Scholes Model, but uses futures prices discounted at the risk free rate rather than the current spot price. A futures option is an option on futures and involves delivery of a futures position rather than a position in the underlying asset.

The model is presented in 6.1 and 6.2, but more explicitly, we have:

$$c = e^{-rT}\left[FN(d_1) - KN(d_2)\right] \qquad\qquad (6.5)$$

$$p = e^{-rT}\left[KN(-d_2) - FN(-d_1)\right] \qquad\qquad (6.6)$$

where the d_1 and d_2 terms are the same as in 6.3, but b=0 and S = F. As seen in 6.3, the IMAREX Freight Options have the same underlying as the IMAREX Freight Futures. The options are not specified to be options on the IFF, but in practice this will be the case. Since the options are European, the property that futures options will give you a futures position rather than a position in the underlying will not be an issue here, since at maturity, the futures and the asset underlying the option will be the same anyways. A simple solution may then seem to be that the B76 model for pricing options on futures is the optimal choice. This would indeed be true if the futures prices were unbiased predictors of the future spot prices. If the futures prices did reflect the correct expectation of the settlement price, and its corresponding volatility,

B76 would be the ideal model to price the options on these futures. As we saw in section 4.5 however, we cannot be sure that the market actually prices the futures according to this averaging property. For the IFF, this is not necessarily a problem since a futures position and a futures price is independent of the volatility of the underlying. For options, however, the volatility is of crucial importance in calculating the probabilities of exercise or no exercise of the option, and will directly affect the option value. We therefore need to incorporate this averaging into the option prices. Abandoning the B76 will possibly be the best choice if we cannot be sure of the "quality" of the futures prices. We will now review pricing of so-called Asian options, and will elaborate on the appropriateness of the B76 as we go.

6.4.2 Asian Options (European Average Options)

Asian options are the term for options where the payoff depends on the average price of the underlying asset during a specific part of its life. The average can either be the strike price or the price of the underlying asset. For the latter specification, which is the case for the IMAREX Freight Options (IFO), the payoff at maturity is as follows:

$$C_T = \max \{ S_{avg} - K , 0 \} \text{ and } P_T = \max \{K - S_{avg} , 0 \}$$

For the IFO, S_{avg} is based on an arithmetic average. In general S_{avg} can be based on either arithmetic or geometric averages, although the arithmetic averaging is most widely used.

When you take the geometric average of a set of lognormally distributed variables, the average itself will also be lognormal. This is not the case for arithmetic averages of lognormally random variables. Due to this problem there exist no exact pricing formulas for Asian options specified on arithmetic averages. When no closed-form solutions are available, one must resort to numerical procedures or to approximations.

6.4.3 Numerical Procedures

Depending on whether we are operating in discrete time or in continuous time, and also depending on the specification of the options, various numerical procedures have

different strengths and weaknesses in terms of valuing the options. If the maturity price is path dependent, such as the case for Asian options, using binomial trees will be virtually impossible, since you would have to keep track of 2^n different paths along the tree. In such a case Monte Carlo simulations would be preferred. If the option is of American specification, however, giving the holder a right to exercise at any time from now until maturity, the binomial approach is superior to the Monte Carlo simulation. Other approaches involve finite difference methods, variance reduction procedures etc. For a presentation of these approaches, see Hull (2003), chapter 18. I will briefly present the basics of two such procedures, but they serve only as an introduction, and no such procedures will be used in the IMAREX analysis.

6.4.3.1 Monte Carlo Simulation

Monte Carlo Simulation is a numerical procedure that can be utilized to price most European type options when no closed form solution is available. Originally introduced by Boyle (1977), the method can simulate a wide range of stochastic processes. The procedure involves sampling random outcomes for the processes of prices of the underlying assets. As the procedure is repeated[49], a complete probability distribution of the underlying asset at time T is obtained.

6.4.3.2 Binomial and Multinomial Approaches

Prices can also be simulated in discrete time using binomial or multinomial frameworks. If prices are observed at discrete points in time, and can move either up or down a certain fraction at each observation point, we can simulate the process of the options values, working backwards through these binomial trees. Using risk neutral probabilities for each sequence of states, you can discount at the risk free rate. I will refer readers interested in the details of such procedures to Hull (2003), chapters 11 and 18, or McDonald (2003), chapters 10 and 11.

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[49] (Haug, 1998) recommends around 10.000 simulations to reach satisfactory accuracy.

6.4.4 Turnbull and Wakeman Approximation

Since a Monte Carlo Simulation or a binomial procedure cannot be performed on the back of an envelope, many practitioners utilize approximations which can be obtained as closed form in simple spreadsheets. S.M. Turnbull and L.M. Wakeman developed in 1991 an approximation for pricing of European average options with arithmetic averages. They made use of the fact that even if the arithmetic average of a set of lognormally distributed variables is not lognormal, it is *approximately* lognormal.

For an option not yet in the averaging period, the approximations are given, as presented by Haug (1998), section 2.12.2. These are the same formulae as 6.1 and 6.2, but we need to adjust the cost of carry and the variance terms to be consistent with the exact first and second moments of the arithmetic average (Haug (1998), Eq 2.61-2.62):

$$c_{TW} \approx Se^{(b_A-r)T_2}N(d_1) - Ke^{-rT_2}N(d_2) \qquad (6.7)$$

$$p_{TW} \approx Ke^{-rT_2}N(d_2) - Se^{(b_A-r)T_2}N(d_1) \qquad (6.8)$$

$$d_1 = \frac{\ln(S/K) + (b_A + \sigma_A^2/2)T_2}{\sigma_A\sqrt{T_2}} \qquad (6.9)$$

$$d_2 = d_1 - \sigma_A\sqrt{T_2}$$

Where T2 is the remaining time to maturity. Furthermore, the cost of carry rate b_A and variance σ_A^2 have to be adjusted so that they are consistent with the first and second moment of the arithmetic average:

$$\sigma_A = \sqrt{\frac{\ln(M_2)}{T} - 2b_A}$$

$$b_A = \frac{\ln(M_1)}{T} \qquad (6.10)$$

M_1 and M_2 constitute the exact first and second moments of the arithmetic average. These can be shown to be equal to:

$$M_1 = \frac{e^{bT} - e^{b\tau}}{b(T - \tau)} \qquad (6.11)$$

$$M_2 = \frac{2e^{(2b+\sigma^2)T}}{(b+\sigma^2)(2b+\sigma^2)(T-\tau)^2} + \frac{2e^{(2b+\sigma^2)\tau}}{b(T-\tau)^2}\left[\frac{1}{2b+\sigma^2} - \frac{e^{b(T-\tau)}}{b+\sigma^2}\right] \qquad (6.12)$$

If the options are already in the averaging period, the strike price K must be replaced with $\hat{K}$ and the option value must be multiplied by T_2/T.

$$\hat{K} = \frac{T}{T_2}K - \frac{T_1}{T_2}S_A \qquad (6.13)$$

where S_A is the average price already observed in the period $T_1 = T - T_2$.

It would initially seem as though the Turnbull Wakeman will be a safer choice with respects to pricing the IMAREX Freight Options. We will now compare the different pricing models using the same example as in the article by Turnbull and Wakeman (1991).

6.5 Comparison of Pricing Models

If we price an option with the same parameters, but with different models, we can obviously get quite different results. Consider Table 7.1, which shows the prices of puts and calls under alternative models.

Table 6.1: Example of Option Prices under Different Pricing Models

Strike (K)	Call			Put		
	BS	B76	TW	BS	B76	TW
90	13.25	13.25	12.74	0.63	0.63	0.49
100	6.11	6.11	5.50	3.20	3.20	2.96
110	2.09	2.09	1.64	8.88	8.88	8.80

Start Date	03.07.2001	BS - Black Scholes (1973) model for standard European options
End Date	31.10.2001	B76 - Black (1976) model for pricing of futures options
T (Days)	120	TW - Turnbull & Wakeman (1991) Approximation for pricing of European average options
Price	100	
Risk Free rate	9 %	
Volatility	20 %	

We see that under these circumstances the values of BS and B76 approaches are the same. This is because I have used the theoretical futures price (no dividends) according to relation 3.1 and not the actual observed futures price such that would be the case for valuation of futures options.

The most interesting difference, however, is the difference between these two approaches and the approximations of TW. This example has assumed that the averaging starts on the first index day of October. For simplicity, week-ends have been ignored, and 30 averaging points have been assumed. It is thus 90 days to the averaging starts.

We see that the TW approach gives systematically smaller values than the other approaches. This can be explained from the Greek letter Vega:

$$V = \frac{\partial c}{\partial \sigma} > 0 \ \text{ and } V = \frac{\partial p}{\partial \sigma} > 0 \qquad\qquad (6.14)$$

In other words, increased volatility of the underlying increase the values of both call and put options before maturity. It is already established that the volatility of an average of prices is less than that of the prices themselves. Asian options such as the ones we are considering are, therefore, worth less than standard European options.

What happens if the market uses the wrong models to price the options? Having established that the TW approximation may possibly be the best model to price the IMAREX Freight Options under the circumstances, the consequences of wrongful pricing can lead to arbitrage opportunities. There are strict definitions of what can be referred to as arbitrage opportunities, but if the market systematically prices the options with too high a volatility, there are great sources of relatively riskless profits from shorting such options. In general, we can say that if the market price is greater than value, the general arbitrage strategy is to sell the asset, and then offset this position with a synthetic and opposite cash flow which would then be slightly cheaper. This is of course if creating such a synthetic is feasible in practice.

If we were dealing with financial assets and options on these, arbitrage arguments could be made from relation 3.1, using the risk free rate. The IMAREX Freight Options cannot however be synthesized with risk-free positions through simple arbitrage arguments, and therefore we cannot use propose that the market will price the options correctly, and that deviations from this "real value" will even itself out. The picture is complicated further in that TW is only an approximation and that we are dealing with an average of consumption assets that cannot be exactly replicated[50]. The implications would be that the market will probably not adjust the price itself if such an overpricing should be detected.

An effect from this is that we cannot call the market efficient, as implied volatilities cannot be used to price other assets. Even if the arbitrage arguments cannot be used, speculators who identify such wrongful pricing will probably be able to make an excess return if consequently staying on the short side of these options.

In table 7.2 we see the implied volatility for the example we have used given that the options are priced according to B76. The latter option prices the futures used in the formula according to 3.1. This may work for stocks and other investment assets, but not for freight.

Table 6.2: Example of Implied volatility for TW if priced with B76

	Call		Put	
Strike	B76	TW	B76	TW
90	20.000 %	24.902 %	20.000 %	31.849 %
100	20.000 %	23.047 %	20.000 %	29.897 %
110	20.000 %	22.518 %	20.000 %	23.382 %

We see that if the options are priced according to the B76 formula, the implied volatilities for TW pricing yielding the same price is as follows. In all the cases, the volatility yielded from TW pricing is above that of the B76. Another point to note is that none of the volatilities are the same, neither across the same strikes, nor across puts and calls. This serves as an example of the wrongful pricing that can be done in the market if market participants cannot agree on pricing models, but still we need to

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[50] Theoretically we cannot say that such an exact replication is infeasible, but such a replication would be highly complex. I will not investigate this relationship further as this would be outside the scope of this thesis.

recall that the Turnbull and Wakeman procedure is only an approximation, and no exact pricing formula.

6.6 Summary

I have in this brief analysis reviewed some pricing methods for options. I have specifically reviewed the most relevant for the case of the IMAREX Freight Options and made the point that if the IMAREX Freight Futures is "correctly priced" for the lifetime of the contract, based on final price at maturity, these prices could be used as input in the B76 model, and the model would yield the true values of these options. The IMAREX Freight Futures have, however, a final settlement price specified on an arithmetic average rather than the settlement price at maturity. I furthermore reviewed in section 3 that futures on consumption assets could not be priced using arbitrage arguments. Given these arguments, the IMAREX Freight Options should not be priced according to B76. We introduced the concept of numerical procedures to price such options, and we presented the Turnbull and Wakeman (TW) approximation for pricing such options. Based on the IFO contract specification, I would assert that pricing of these options with the TW approximation would yield option prices closer to their true values than any other closed form analytical method. This assertion was based on no empirical evidence, however, and only from ex ante perspectives.

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Data material used for analytical purposes at the courtesy of:

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Appendix 1: Estimating HIE using Eviews.

The time series used in the regressions presented in table 5.1 is specified as follows:

The monthly futures contracts are spliced at the last trading day of the nearest contract. Then the second nearest contract becomes the nearest, the third nearest becomes the second nearest etc. The splice points are (with a few exceptions) set to the 15th of each month (or the nearest working day), being the last trading day for the futures contract of the month in question. The 15th displays prices from the old contract, while on the 16th, the contract is replaced. This means that each contract have about 20 daily observations (5-day-weeks).

The spot price series and the futures price series are made into weekly changes, by using the series command in eviews:

series weekly_difference = level – level(-5)

Then smpl @weekday=1 turns the 5-day-weeks into a series with consecutive Mondays.

Then the equations are estimated by the least squares approach with the spot price held as the dependent variable. As discussed in section 3.2.4, the coefficient for the independent variable then gives us the optimal hedge ratio, and the r-sq adjusted gives us the so-called hedging instrument effectiveness.

The estimates presented in Table 5.1 are extracts from the following Eviews regressions. Only a three regressions are given in full. In these regressions D_XX is the spot series, while D_XX_SM is the futures series (spot month continuous splicing):

Dependent Variable: D_TD3
Method: Least Squares
Date: 07/28/05   Time: 15:36
Sample(adjusted): 14/10/2002 4/07/2005 IF WEEKDAY=1
Included observations: 110
Excluded observations: 21 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.61213	1.66716	0.367172	0.7142
D_TD3_SM	**0.86682**	0.07945	10.91017	0

R-squared	0.5243	Mean dependent var	2.47973
Adjusted R-squared	**0.51989**	S.D. dependent var	25.1016
S.E. of regression	17.3929	Akaike info criterion	8.56801
Sum squared resid	32671.3	Schwarz criterion	8.61711
Log likelihood	-469.24	F-statistic	119.032
Prob(F-statistic)	0		

Dependent Variable: D_TD4

Method: Least Squares

Date: 07/28/05   Time: 15:37

Sample(adjusted): 14/10/2002 4/07/2005 IF WEEKDAY=1

Included observations: 110

Excluded observations: 21 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.103052	1.416904	-0.07273	0.9422
D_TD4_SM	**0.631333**	0.078381	8.054671	0

		Mean dependent var		
R-squared	0.375281			1.019
Adjusted R-squared	**0.369497**	S.D. dependent var		18.62447
S.E. of regression	14.78862	Akaike info criterion		8.243607
Sum squared resid	23619.94	Schwarz criterion		8.292707
Log likelihood	-451.3984	F-statistic		64.87773
Prob(F-statistic)	0			

Dependent Variable: D_TD5

Method: Least Squares

Date: 07/28/05   Time: 15:37

Sample(adjusted): 14/10/2002 4/07/2005 IF WEEKDAY=1

Included observations: 110

Excluded observations: 21 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.199966	1.919786	0.10416	0.9172
D_TD5_SM	**0.917419**	0.099852	9.187797	0

		Mean dependent var		
R-squared	0.438715			1.221636
Adjusted R-squared	**0.433518**	S.D. dependent var		26.70708
S.E. of regression	20.10108	Akaike info criterion		8.857439
Sum squared resid	43637.78	Schwarz criterion		8.906539
Log likelihood	-485.1591	F-statistic		84.41561
Prob(F-statistic)	0			

Descriptive Statistics and Correlations as presented in Table 5.1

	D_TD3	D_TD3_SM	D_TD4	D_TD4_SM	D_TD5	D_TD5_SM	D_TD7
Mean	2.479727	2.154545	1.019	1.777273	1.221636	1.113636	2.148
Median	0.48	3.35435	0.32	0	-0.53	0	-0.75
Maximum	70.85	68.5	57.5	68.5	93.37	60	144.77
Minimum	-87.96	-99	-58.75	-75	-82.5	-60	-90.45
Std. Dev.	25.10161	20.96828	18.62447	18.07188	26.70708	19.28191	29.06228
Skewness	-0.20122	-0.697815	0.23503	-0.126243	0.405662	-0.280178	1.48346
Kurtosis	4.892647	8.382084	4.596813	7.377275	4.713729	4.84634	11.21016
Jarque-Bera	17.16032	141.6919	12.69936	88.11131	16.47759	17.06361	349.2928
Probability	0.000188	0	0.001747	0	0.000264	0.000197	0
Sum	272.77	237	112.09	195.5	134.38	122.5	236.28
Sum Sq. Dev.	68679.88	47923.9	37808.91	35598.63	77746.2	40525.33	92063.16
Observations	110	110	110	110	110	110	110

	D_TD7_SM	D_TD9	D_TD9_SM	D_C4_SM	D_C4	D_C7	D_C7_SM
Mean	1.05	-0.805727	1.022727	-0.111224	-0.169918	0.081061	-0.00612
Median	0.25	0.34	0.5	0.2	0.122	0.1	0
Maximum	84	140.45	115	4.35	2.922	4.362	4.25
Minimum	-61	-160.68	-76.1214	-6.75	-7.633	-4.461	-5.05
Std. Dev.	21.2468	46.0305	28.4075	2.491637	2.016534	1.387484	1.713902
Skewness	0.439797	-0.004466	0.256996	-0.533988	-1.135548	0.145589	-0.0817
Kurtosis	7.064418	5.448915	5.276782	3.101283	5.319942	5.494205	3.958295
Jarque-Bera	79.26039	27.48746	24.96965	2.349615	21.51918	12.87443	1.929426
Probability	0	0.000001	0.000004	0.308878	0.000021	0.001601	0.381093
Sum	115.5	-88.63	112.5	-5.45	-8.326	3.972	-0.3
Sum Sq. Dev.	49205.48	230949.9	87961.5	297.9963	195.1876	92.40535	140.9982
Observations	110	110	110	49	49	49	49

Correlations:

	F:TD9	D_TD9	F:TD7	D_TD7	F:TD5	D_TD5	F:TD4	D_TD4	F:TD3	F:C7	D_C7	F:C4	D_C4
F:TD9	1.00	0.75	0.27	0.22	0.20	0.09	0.15	0.14	0.20	-0.01	-0.06	-0.02	0.03
D_TD9	0.75	1.00	0.17	0.18	0.07	0.25	-0.04	0.19	0.06	0.14	-0.03	0.21	-0.04
F:TD7	0.27	0.17	1.00	0.90	0.43	0.34	0.13	0.25	0.13	-0.25	-0.28	-0.23	-0.32
D_TD7	0.22	0.18	0.90	1.00	0.25	0.34	-0.08	0.21	-0.13	-0.22	-0.30	-0.21	-0.34
F:TD5	0.20	0.07	0.43	0.25	1.00	0.66	0.48	0.58	0.34	0.09	0.07	0.07	0.16
D_TD5	0.09	0.25	0.34	0.34	0.66	1.00	0.39	0.75	0.17	-0.01	0.12	0.09	0.21
F:TD4	0.15	-0.04	0.13	-0.08	0.48	0.39	1.00	0.63	0.87	0.42	0.40	0.32	0.49
D_TD4	0.14	0.19	0.25	0.21	0.58	0.75	0.63	1.00	0.48	0.23	0.28	0.21	0.37
F:TD3	0.20	0.06	0.13	-0.13	0.34	0.17	0.87	0.48	1.00	0.37	0.43	0.22	0.45
F:C7	-0.01	-0.14	-0.25	-0.22	0.09	-0.01	0.42	0.23	0.37	1.00	0.83	0.74	0.79
D_C7	-0.06	-0.03	-0.28	-0.30	0.07	0.12	0.40	0.28	0.43	0.83	1.00	0.59	0.79
F:C4	-0.02	-0.21	-0.23	-0.21	0.07	0.09	0.32	0.21	0.22	0.74	0.59	1.00	0.83
D_C4	0.03	-0.04	-0.32	-0.34	0.16	0.21	0.49	0.37	0.45	0.79	0.79	0.83	1.00

Appendix 2: Notation and Abbreviations

In the following text I will make use of some mathematical notation. I decide to use the notation found in Hull (2003), and supplement with additional notation where required.

S_t Prevailing spot price at time t {0…T}
F_t Prevailing futures price at time t {0…T}
r   risk-free rate, continuous compounding unless otherwise stated
U   Present value of storage costs over the life of the contract
c_t Price of a call option at time t {0…T}
p_t Price of a put option at time t {0…T}
σ   Volatility of the underlying asset over the time {0…T}
K   Strike price for options

Glossary:

Dwt: Deadweight ton. The largest weight of cargo, bunkers and stores a ship is able to carry. (Expressed in metric tons (1,000 kg) or long tons (1,016 kg)). The deadweight tonnage is the most important commercial measurement. Normally the maximum payload for a ship is three to ten per cent lower than the deadweight, due to the weight of bunkers and stores, etc. (Source: www.rederi.no)

Ton Miles: Measure of output in the shipping industry.

HANDYSIZE = 20,000 - 30,000 DWT
HANDYMAX = approx 45,000 DWT
PANAMAX = approx 79,000 DWT
AFRAMAX = between 79,000 - 120,000 DWT
CAPESIZE = between 80,000 – 200,000 DWT
SUEZMAX = between 120,000 - 180,000 DWT
V.L.C.C. (Very Large Crude Carrier) = between 200,000 - 300,000 DWT

Continent: Anywhere on the European Continent, not Mediterranean.
ARA: Amsterdam, Rotterdam, Antwerp
USAC: US Atlantic Coast (New York)
USG: US Gulf (The Gulf of Mexico)
AG: Arabian Gulf

Appendix 3: Regressions, Example 2 (Section 5.5)

Regression 1

Dependent Variable: D_C3
Method: Least Squares
Date: 08/01/05   Time: 16:21
Sample(adjusted): 27/10/2003 20/12/2004 IF WEEKDAY = 1
Included observations: 49 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_C4_SM	-0.003503	0.100836	-0.034738	0.9724
D_C7_SM	0.912272	0.151856	6.007503	0
D_TD3_SM	0.032222	0.012882	2.501358	0.0162
D_TD4_SM	-0.024601	0.015191	-1.619462	0.1125
C	0.186675	0.165651	1.126915	0.2659

R-squared	0.703959	Mean dependent var		0.20649
Adjusted R-squared	0.677046	S.D. dependent var		2.025752
S.E. of regression	1.151215	Akaike info criterion		3.215965
Sum squared resid	58.31306	Schwarz criterion		3.409007
Log likelihood	-73.79113	F-statistic		26.157
Prob(F-statistic)	0			

Regression 2

Dependent Variable: D_C3
Method: Least Squares
Date: 08/01/05   Time: 16:24
Sample(adjusted): 27/10/2003 20/12/2004 IF WEEKDAY = 1
Included observations: 49 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_C7_SM	0.872639	0.105158	8.29839	0
D_TD3_SM	0.014691	0.006851	2.144496	0.0373
C	0.177652	0.166517	1.066873	0.2916

R-squared	0.685708	Mean dependent var		0.20649
Adjusted R-squared	0.672044	S.D. dependent var		2.025752
S.E. of regression	1.160097	Akaike info criterion		3.194154
Sum squared resid	61.90795	Schwarz criterion		3.30998
Log likelihood	-75.25678	F-statistic		50.18046
Prob(F-statistic)	0			

Regression 3

Dependent Variable: D_C3

Method: Least Squares

Date: 08/01/05   Time: 16:28

Sample(adjusted): 27/10/2003 20/12/2004 IF WEEKDAY = 1

Included observations: 49 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_C7_SM	0.956058	0.10137	9.431381	0
C	0.212343	0.171957	1.23486	0.223

R-squared	0.654287	Mean dependent var		0.20649
Adjusted R-squared	0.646931	S.D. dependent var		2.025752
S.E. of regression	1.203693	Akaike info criterion		3.248626
Sum squared resid	68.09722	Schwarz criterion		3.325843
Log likelihood	-77.59133	F-statistic		88.95095
Prob(F-statistic)	0			

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Appendix 4: Residual Diagnostics for Log Price Increment Regressions

The following output is the same as in chapter 5.2, the only difference being that the regressions are conducted on the basis of log price increments instead of absolute price increments.

White's Test for Heteroscedasticity of the residuals (logarithmic)

TD3	F-statistic	1.618379	Probability	0.203
	Obs*R-squared	3.229806	Probability	0.199
TD4	F-statistic	1.298809	Probability	0.277
	Obs*R-squared	2.607155	Probability	0.272
TD5	F-statistic	0.83423	Probability	0.437
	Obs*R-squared	1.688905	Probability	0.430
TD7	F-statistic	11.18059	Probability	0
	Obs*R-squared	19.01444	Probability	0
TD9	F-statistic	0.003637	Probability	0.996
	Obs*R-squared	0.007477	Probability	0.996
C4	F-statistic	7.015266	Probability	0
	Obs*R-squared	12.48336	Probability	0
C7	F-statistic	4.006154	Probability	0.025
	Obs*R-squared	7.268772	Probability	0.026

Breusch-Godfrey Test for Serial Correlation in residuals (lags = 5) (logarithmic)

TD3	F-statistic	19.38523	Probability	0
	Obs*R-squared	85.39568	Probability	0
TD4	F-statistic	23.94744	Probability	0
	Obs*R-squared	102.4029	Probability	0
TD5	F-statistic	12.42917	Probability	0
	Obs*R-squared	57.39356	Probability	0
TD7	F-statistic	14.2845	Probability	0
	Obs*R-squared	65.1231	Probability	0
TD9	F-statistic	19.07777	Probability	0
	Obs*R-squared	84.2125	Probability	0
C4	F-statistic	41.57519	Probability	0
	Obs*R-squared	150.5073	Probability	0
C7	F-statistic	46.01435	Probability	0
	Obs*R-squared	129.8465	Probability	0

Bera-Jarque Tests of Normality (logarithmic)

	Bera-Jarque	Probability
TD3	1.0141	0.6023
TD4	3.5551	0.1691
TD5	3.1467	0.2074
TD7	8.3888	0.0151
TD9	337.0440	0.0000
C4	15.7751	0.0004
C7	6.1904	0.0453