Optimal freight rate management for VLCC

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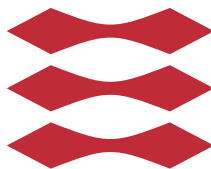
Summary (English)

The objective of the thesis is to develop a stochastic framework as a practical decision support tool for managing VLCC chartering, and to analyse the efficiency of such a framework. The efficient managing process, determined by the modelling framework, is within the usage of FFA contracts in fixing future prices on voyage contracts. Prices on voyage contracts are determined by a volatile spot market, which can be hedged using FFA's. The work is divided into three different parts with the main purpose of developing a stochastic programming model. The three parts are divided into a presentation of the freight rate market and financial derivatives, the development of a statistical framework making predictions in spot rates and the development of a stochastic programming model making allocation decisions. The scope of the thesis is limited by the lack of previous prepared studies in the dirty tanker freight rate market.

When it comes to the usage of financial derivatives in the tanker market, studies are almost none existent. Only very few studies has been made to introduce the derivative market. The thesis therefore introduces the derivative market in the form of introducing Forward Freight Agreements and FFA Options. It is examined how the financial derivatives are structured, with the purpose of disseminating knowledge of financial derivatives in the market, and to examine the efficiency and limitations in using derivatives, such as lack of liquidity. Furthermore, the entire set-up of doing VLCC chartering is examined to give the reader the understanding of the chartering process. The work is based on the Dirty Tanker 3 (TD3) index published on the Baltic Exchange, in the form of Worldscale points.

A minor statistical analysis is made on the dirty tanker index with the purpose

of developing a statistical framework in which to make reasonable predictions on the future level of freight rates. There has not yet been made any studies that determines a precise way to make predictions on tanker freight rates. It has therefore been chosen to make a well known time series analysis on the TD3 index. It has been examined how autoregressive processes and ARMA-GARCH processes performs in the freight rate market. It seems that none of these processes perform significantly better than a simple bootstrap method. The bootstrap method has therefore been chosen in the thesis as the most adequate choice of making predictions on the TD3 index, even though it is a very naive way of doing predictions.

The final work of the thesis is to develop a stochastic programming framework, in which to make optimal decisions on how to manage VLCC chartering. The framework adopted in the thesis is a well known decision model in financial engineering, proposed by Stavros as a CVaR programming model. The model optimizes the expected income of the chosen strategy, and minimizes the down side risk exposure in terms of Conditional Value at Risk. The results from implementing and analysing the framework on prior historical records seem reasonable. It is very clear that introducing FFA in the managing process is indeed controlling risk exposures in a positive way. All strategies including FFA's seem to outperform strategies without using FFA's, both in risk exposure and in expected income.

Summary (Danish)

Målet for dette speciale er at udarbejde en stokastisk metode til på en praktisk og effektiv måde at supportere administration af VLCC udlejning. Desuden er formålet at analysere resultater fra den udviklede metode for at vurdere graden af forbedringer, et rederi kan opnå i indtjening af VLCC udlejning. Den optimale administrationsproces, bestemt af den udarbejdede metode, er inden for brugen af FFA kontrakter til at fixe fremtidige priser på voyage kontrakter. Priser på voyage kontrakter er bestemt af et volatilt spotmarked, som kan blive hedged med brugen af FFA. Udarbejdelsen er opdelt i 3 dele, med det hovedformål at udvikle en stokastisk programmeringsmodel. Specialet er begrænset af den betydeligt manglende udarbejdelse af forudgående studier inden for fragtratemarkedet for dirty tankers.

Når det kommer til brugen af financielle derivater i tankermarkedet, er forudgående studier nærmest ikke eksisterende. Det har kun været muligt at finde 2 tidligere studier, der introducere derivatmarkedet for fragt rater. Specialet introducerer derfor derivatmarkedet i form af FFA og FFA optioner. Det gennemgås, hvordan derivater er opbygget, med hendblik på at udbrede kendskabet til financielle derivater i tankermarkedet. Desuden gennemgås effekten fra brugen af derivater, samt begrænsningerne i markedet, såsom manglende likviditet. Derudover gennemgås fragt rate markedet, for at introducere læseren til, hvordan udlejning af VLCC foregår. Specialet er baseret på Dirty Tanker 3 (TD3) index, som offentliggøres på Baltix Exchange, i form af Worldscale point.

Herefter foretages en mindre statistisk analyse på tankerindexet, med henblik på at udvikle en statistisk metode til at lave fornuftige forudsigelser omkring den fremtidige udvikling af fragtratemarkedet. Der har ikke tidligere været udarbej-

det studier, der på en effektiv og præcis måde har kunne forudsige fragtraterne. Det er derfor blevet valgt at lave en velkendt tidsserie analyse på TD3 indexet. Det er blevet analyseret hvordan autoregresive processer og ARMA-GARCH processer præsterer i fragtratemarkedet. Det er vurderet, at ingen af tidsseri- eprocesserne analyseret i denne afhandling præsterer beytdeligt bedre end et simpelt bootstrap. Det er derfor valgt at bruge et bootstrap sample til at lave forudsigelser på TD3 indexet selvom det er velkendt at, bootstrapmetoden er en naiv måde at lave forudsigelser.

Den afsluttende del af specialet omhandler udarbejdelsen af en stokastisk pro- grammeringsmodel, hvorfra den optimale beslutningsproces omkring admini- stration af udlejning af VLCC er bestemt. Modellen, som er brugt i specialet er en velkendt beslutningsmodel inden for financial ingeniørvidenskab, foreslået af Stavros som en CVaR programmerings model. Modellen optimerer over den forventede indtjening af den valgte strategi, og minimerer risikoeksponeringen i form af Conditional Value at Risk. Resultaterne fra at implementere og ana- lysere den stokastiske metode på historiske data virker yderst rimelige. Det ses tydeligt, at brugen af FFA kontrakter ved styring af VLCC udlejning giver en positiv mulighed for at kontrollere risikoeksponeringen. Alle undersøgte strate- gier med FFA'er klarer sig betydeligt bedre end strategier, hvor FFA kontrakter er udeladt, både når det angår risikoeksponering men også den forventede ind- komst.

Preface

This thesis was prepared at the department of Informatics and Mathematical Modelling at the Technical University of Denmark in fulfilment of the requirements for acquiring an M.Sc. in Informatics.

The thesis deals with optimal decision management in the dirty tanker business, of managing freight rates on very large crude carriers.

The thesis consists of an introduction into the market of freight rates and financial derivatives. Furthermore, it consist of a statistical analysis of the freight rates, with the purpose of developing predictions. Finally it consists of the development and analysis of a stochastic programming model, supporting the need for optimal decision making within the dirty tanker chartering.

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Acknowledgements

Notation

Sets, indices and general notation used throughout the thesis.

$\mathcal{T} = \{t_0, t_1, \ldots, t_\tau, \ldots, t_T\}$ set of time periods, from today t_0 until maturity t_T. Unless stated otherwise in the text all time periods are of equal duration which is typically taken to be one month.

$\Omega = \{1, 2, \ldots, N\}$ index set of scenarios.

$\Sigma_t = \{1, 2, \ldots, S_t\}$ index set of states in economy at period t.

Γ_l index set of random numbers i for scenario l.

$K = \{\text{spot,ffa\_m0},\ldots,\text{ffa\_q5}\}$ set of contracts that can be used by the shipping company

t index of time periods from the set $\mathcal{T}$.

l index of scenario from the set Ω.

i index of observation in historical data set.

κ index of contracts from the set K.

T number indicating planning horizon.

N number of scenarios.

$\lambda \in (0, 1)$ number determine the risk profile in the stochastic programming model.

α number determine the confidence interval of the downside risk.

p_i observed price in the historical data set at index i.

r_i rate of price development from index $i - 1$ to index i.

d_i date at index i.

X_l scenario l.

X_l^t state of scenario l at time t.

p^l probability of scenario l.

$a_l^{t_\tau}$ item in scenario state X_l^t, indicating the average of spot prices in the period from $t_{\tau-1}$ to t_τ.

b_l^t item in scenario state X_l^t, indicating the price of settling a spot contract at time t.

$f_l^{t_\tau}$ item in scenario state X_l^t, indicating the price of a FFA contract purchased at time t_0 and settled on the average spot prices in the period from $t_{\tau-1}$ to t_τ

$\mu_{\kappa,l}^{t_\tau}$ income of contracts κ at time t_τ.

$x_{\kappa,l}^{t_\tau}$ amount of contracts κ at time t_τ, as a percentage of spot contracts for the settlement period.

$x = (x_{\kappa,l}^{t_\tau})$ the holdings for the entire portfolio of all contracts $\kappa \in K$

ζ value at risk.

ξ conditional value at risk.

Contents

Introduction

A freight rate is the price one is charged for getting cargo carried from one place to another. This thesis focusses on maritime freight rates in the dirty tanker business, this is the rate a tanker company charges for taking a maritime delivery of crude oil from one place to another. Furthermore, it focusses on how a tanker company can manage the chartering of vessels in an optimal and efficient way.

Dirty tankers are known as cargo vessels with the main purpose of carrying crude oil. Their size is measured in deadweight tonnage (DWT), which is defined as the maximum weight in tonnage a vessel can carry. It is the sum of the weight of cargo, fuel, fresh water, ballast water, provisions, crew, etc. Oil tankers are divided into different classes, which are defined primary by their size. The primary dirty tanker classes operating crude oil world wide are:

- Ultra Large Crude Carrier (ULCC) is defined as an oil tanker vessel with size in the range from 320.000 DWT to 550.000 DWT. These types of vessels are the largest tanker vessels world wide.

- Very Large Crude Carrier (VLCC) is defined as an oil tanker vessel with size in the range from 200.000 DWT to 320.000 DWT.

Other classes of vessels operating crude oil are doing this in more local environments, where their limited size become an advantage. The VLCC and ULCC classes offer the best economies of scale for the transportation of crude oil, where pipelines are non-existent. This is one of the reasons why these classes are used to export oil from the Persian Golf to the worlds' largest economies, the United States of America, China and Japan. Needless to say, these classes of vessels are important factors for handling the global supply. In a review report from 2011 of maritime transport from UNCTAD, it is said that VLCC and ULCC accounted for approximately 44% of the worlds tanker fleet in DWT terms in 2010 [sec11]. Less sized dirty tankers, such as Suezmax, works in local areas where their limited size become an advantage. For instance, the Suezmax class is referencing a naval architecture term for the largest ship measurements capable of transiting the Suez Canal in a laden condition.

A tanker company is a company owning tanker vessels with the purpose of making profit, when chartering out the vessels. A charterer may own cargo of crude oil or have the need for getting cargo carried between ports. The charterer therefore pays the tanker company a negotiated price, called the freight rate, to deliver the cargo at an agreed port. The relationship between tanker company and charterer can be seen in figure 1.1 as the solid lines. The tanker company sells freight service, in response the charterer pays the freight rate. The payment of freight service is determined by market conditions, and is agreed between the tanker company and the charterer. It is a physical service that is traded between the charterer and the tanker company, and the company is therefore limited in negotiating contracts on the amount of open vessels. If the tanker company has future expectations of a decreasing freight rate market, they will expect to get a gain in fixing the price today. If no vessels are open, then the company cannot settle any freight contracts. The company therefore has to wait until a vessel comes open, before they can enter into new contracts. If the freight rate market indeed decreases, then the tanker company will experience a loss in profit. This is where the financial derivatives market can be beneficial. In the financial market a derivative called Forward Freight Agreement (FFA) exist, which is a forward agreement on the freight rate. FFA's are swaps in the meaning that only cash flows are traded and no physical deliveries are made. The cash flows traded are a fixed cash flow agreed between parties, and a floating cash flow determined by the future level of freight rates, also denoted as the future spot price. The tanker company therefore has the opportunity to fix the price of a future freight service today, if the expectations of the future freight rate market is decreasing. This is how the tanker company can benefit from the financial market and get a dynamic way of managing their future spot positions. An investor outside the tanker market may find it beneficial to enter the tanker market. But the investor do not have any intention in investing in expensive physical equipment, such as vessels. The investor then has the opportunity in entering a FFA contract in that way he gets the market spot price as if he was
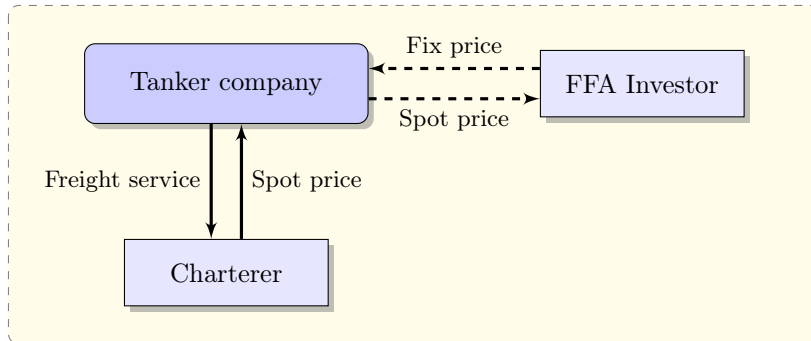
Figure 1.1: The concept of trading freight service, and possibilities of manage chartering.

chartering out vessels. However, the investor has to pay the fixed price of the agreement. The charterer can also act like a FFA investor and in that way hedges his position of future spot prices. The relationship between investor and tanker company can be seen in figure 1.1 as the dashed line. In the figure is also shown how the cash flows are traded between charterer, tanker company and investor. It shows that the tanker company has the opportunity to get the floating spot rate from the charterer, but also to swap the floating spot rate into a fixed price, from the investor, when entering the financial market of derivatives.

The act of hiring a vessel to carry cargo is called chartering. Tankers are normally chartered by three types of charter agreements: the voyage charter, the time charter (TC), and the contract of affreightment (COA). In a voyage charter, the charterer rents the vessel from the loading port to the discharge port. One of the key aspects of any charter contract is the freight rate, or the price specified for carriage of cargo. The freight rate of a tanker charter agreement is normally specified in one of two ways: by a time charter equivalent rate, or by a Worldscale rate. The Worldwide Tanker Normal Freight Scale, often referred to as Worldscale, is established and governed jointly by the Worldscale Associations of London and New York. Worldscale establishes a baseline price for carrying a metric ton of crude oil between any two ports in the world. In Worldscale negotiations, operators and charterers will determine a price based on a percentage of the Worldscale rate. The baseline rate is expressed as WS 100. If a given charter agreement settles on 85% of the Worldscale rate, it would be expressed as WS 85. Similarly, a charter agreement set at 125% of the Worldscale rate would be expressed as WS 125. The prices on the dirty tanker freight rate market are represented through the Baltic Dirty Tanker Index (BDTI). This

index is quoted on the Baltic Exchange on a dayli basis. The index represents the dayli level of settled voyage charter agreements for transporting crude oil on different voyage routes. The VLCC segment is represented through 4 different indices of spot quotes, calculated both in Worldscale rates and time charter equivalent rates. The 4 indices are:

TD1: Cargo weight of 280,000 mt, from Middle East Gulf to US Gulf. Ras Tanura to LOOP with laydays/cancelling 20/30 in advance. Maximum age of vessel 20 years.

TD2: Cargo weight of 270,000 mt, from Middle East Gulf to Singapore. Ras Tanura to Singapore with laydays/cancelling 20/30 in advance. Maximum age of vessel 20 years.

TD3: Cargo weight of 265,000 mt, from Middle East Gulf to Japan. Ras Tanura to Chiba with laydays/cancelling 15/30 days in advance. Maximum age of vessel 15 years.

TD4: Cargo weight of 260,000 mt, from West Africa to Us Gulf. Off Shore Bonny to LOOP with laydays/cancelling 15/25 days in advance. Maximum age of vessel 20 years.

The most traded dirty tanker index on the VLCC class, is the TD3 index. Therefore the price movements on the TD3 index will be the baseline for this thesis. The price developments on the different indices are compared in chapter 3.

In a time charter agreement, the vessel is hired for a set period of time, to perform voyages as the charterer directs. Time charter arrangements specify a daily rate, and port costs and voyage expenses are also generally paid by the charterer. Time charter agreements are settled for time periods of 3, 6, and 9 months, and 1, 3, 5 and 7 years, where 1 year time charter agreements are the most traded ones. Finally, in a contract of affreightment, or COA, the charterer specifies a total volume of cargo to be carried in a specific time period and in specific sizes. For example, a COA could be specified as 1 million barrels (160,000 mt) of crude oil in a year's time in 25,000-barrel (4,000 mt) shipments. The only type of charter agreement that is examined in the thesis for analysis and decision making, is the voyage charter agreements. The Worldscale rate of a charter agreement is used, and referenced to as the price of a charter contract or simply, the freight rate. The different charter agreements and ways to determine freight prices are more precisely examined in chapter 2.

Freight rates gives the income in the tanker business. But it is a hard earning business to be in these days. Bunker expenses, as the absolute largest expenses

when doing maritime freights today, are taking most of the profit. The tanker industry focusses on different ways to lower bunker expenses such as using slow steaming. These actions, though, are not enough to compensate for the huge increase in expenses. Today tanker companies have no real possibility of being compensated for the extremely high expenses, forcing many companies to operate with daily losses. Maersk Tankers says in an interview to Shippingwatch that today it costs around 20,000 USD more each day to sail VLCC's than it did 5 years ago. In this period, the low sulphur RMG380 index for Singapore has increased with approximately 188% from 372 usd/mt in average in 2007 to 700 usd/mt in average for 2012. Meanwhile, the freight rates have decreased with approximately 52% from average earnings of 58,797 usd/day in 2007 to average earnings of 30,436 usd/day in 2012. The expenses of doing tanker freight do not explaining the movements in freight rates. It is documented in the shipping economics that freight rates are determined through interaction of demand and supply of freight services [Abo10]. Need-less to say, the tanker companies seem to have the need for an optimal way of make earnings. It therefore seems obvious to look into an efficient way to manage chartering of vessels.

It has been argued that derivatives on freight rates exist in the financial market. Basically two types of derivatives exist, FFA's and FFA options. FFA's are the most common used financial derivative in the tanker market today, even though the usage is very limited. In [Vas06] it is said that the main problem in the derivatives market of freight rates today, is liquidity. This problem is further supported by arguments in chapter 2. A FFA is an agreement between two parties to fix a freight rate on a predetermined tanker index, over a time period, at an agreed price. It is all swap agreements, which is why only cash flows are traded and no physical deliveries are made. The concept of FFA's is a bet on the future price level of the underlying freight service. On the predetermined settlement date, the two parties will settle the difference between the two cash flows, and the part that gets a gain, will receive the difference from the counter party. The one cash flow is usually a fixed cash flow, determined when the FFA contracts are negotiated at the initial date. The other cash flow is usually a floating cash flow determined by the average spot prices of the predetermined tanker index, quoted at the Baltic Exchange, on the predetermined time period. The FFA contracts are typical settled on a monthly basis, meaning that the floating cash flow is determined as a monthly average. The FFA options are constructed like the FFA agreements. It is an agreement, fixing a future fright rate with the same conditions as the FFA contract. The difference between the agreements, is that a FFA option is an option, giving the holder the right and not the obligation to settle the contract. A FFA option is therefore only exercised if it is in the money, meaning that the holder gets a gain of exercising the contract. In compensation for having this opportunity, the buyer of a FFA option has to pay an upfront premium to the counter party, corresponding to the risk exposure taken. A FFA option is typically an Asian styled European

option, meaning that it is settled against an average price of freight rates, and can only be exercised at maturity. It is more carefully explained about FFA and FFA options in chapter 2.

It has been mentioned that the market of freight rate derivatives has a lack of liquidity. This can be explaining why FFA's not are commonly used by all tanker companies. The tanker companies should know that the opportunity of hedging risk are present in the market. The most widely used way of managing market risk exposures in the spot market of tanker freight rates today, is to use time charter agreements. The agreements fix the freight rate in a period of time. Using only time charter agreements seem to be an inflexible way of managing risk, because the management is limited on the amount of vessels. The financial market has not yet got the same gain of acknowledgement by participants in the tanker market.

Studies done on the financial derivatives of freight rates are very limited. Further readings additional on this thesis, on the subject of financial derivatives on freight rates, on market participants, and on historical developments in the derivative market, can be found in the studies of [KV06] and [Vas06]. The two studies, among other things, introduces the derivatives market for the purpose of further studies. The pre-knowledge on the derivative market in this thesis has therefore been very limited.

1.1 Objective

The main objective of the thesis is to develop a stochastic modelling framework as a practical decision support tool for managing VLCC chartering, and to investigate the efficiency of such a framework.

The objective is based on the problem of a managers concern with an active management of chartering VLCC's, that is to generate maximal profit, while at the same time controlling the downside risk exposure. When a tanker company focusses on their risk exposure, they will become aware of their potential revenue losses, and will therefore be able to act on this knowledge before the losses are actualized. This focus will make it possible for the tanker company to hedge their trading profile, and in that way reduce the risk taken making their potential losses as minimal as possible. It will also be possible for the company to increase their earnings, making their collection of freight agreements sold as efficiently as possible, without letting their risk exposure increase. This should all result in increasing average revenue for the company. Nevertheless, it will make the risk exposure visible for the management, making it easier choosing the right

solutions.

The spot rate market is a volatile market, which is why the risk taken when doing freight rate trading can be high. Several products for hedging opportunities in the tanker market have been developed. Such products are time charter agreements or financial derivatives, such as FFA's. This thesis focusses on the effect of managing tanker freight rate trading with respect to a risk assessment, using FFA contracts. As a preview on financial risk one can say that optimization models in financial engineering is about managing risk by controlling the risk exposure in a way that is commensurate with the prospective rewards. Risk control means one of two things

1. limit or totally eliminate specific types of risk

2. take an active position on one or more types of risk.

The decision framework is built upon a CVaR stochastic programming model proposed by Stavros in [Zen07]. The model uses scenarios of predictions in the spot market to determine future expectations in income from following a chartering strategy. Furthermore, it uses the set of scenarios to determine the down side risk exposure from that strategy. In that way, it uses knowledge from a statistical framework to maximize expected income and minimize down side risk exposure. It is therefore necessary to prepare a statistical analysis and framework to make reasonable decisions on expectations of future freight rates. There has been done studies in developing methods, to make predictions in the freight rate market of dirty tankers, such as [JL06] and [MM10]. The studies in developing such methods are unfortunately also very limited, and to the author's knowledge no methods to predict freight rates in a satisfactory way exist today.

The purpose of the thesis is therefore to show market participants how FFA's can be used in an active way to manage VLCC chartering, and analyse the impact on performance when using FFA's as an active tool when managing VLCC chartering.

1.2   Outline

The thesis is basically divided into 3 parts. The 1st part consists of chapter 2, which is an introduction into the freight market of VLCC's. This part reviews, who is acting in the dirty tanker freight market, and what kind of products exist when managing VLCC chartering. The main purpose of part 1 is to introduce

the reader to the freight rate market on dirty tankers. The 2nd part of the thesis, consists of chapter 3 and 4, which is a statistical analysis of the freight rate market on VLCC's. Chapter 3 introduces the data used throughout the thesis, and what transformations the data set is going through. Chapter 4 is the actual statistical analysis of the data set introduced and preprocessed in chapter 3. The main purpose of part 2 of the thesis, is to introduce the data set and develop a statistical framework, which is able to make reasonable predictions on future spot price developments. The 3rd part of the thesis consist of chapter 5 and 6, which is where the development of the stochastic allocation model is elaborated. Chapter 5 explains how the scenarios are computed, and how reality is projected into the modelling framework. Chapter 6 is where the stochastic programming model is introduced, and results from optimizing the model on different periods, is analysed. In chapter 7 the conclusions of the work throughout the thesis is represented. This concludes on the findings in the thesis, on the modelling framework developed, and how future work could optimize the performance of the framework. Enjoy the reading.

Freight Rate trading

Who, What, How?

The purpose of this chapter is to introduce the different products used in the tanker shipping industry when it comes to trade freight services, and to give the reader understanding of how these products are working. The products can mainly be divided into commodities and financial derivatives. Commodities are agreements for physical deliveries such as voyage contracts or time charter contracts, where the charterer get the opportunity for a carriage of cargo. Derivatives are financial agreements priced on the basis of the price level of a predetermined commodity agreement. Derivatives are used for hedging or investment purposes and are composed as swaps, so with these agreements no physical deliveries are made and only cash flows are traded.

In the commodity market of trading dirty tanker freight services there exist mainly two parties trading commodities; the ship owner and the charterer, this is visualized in 1.1. The charterer needs a carriage of crude oil and the ship owner, owns tanker vessel, with the purpose of making earnings on selling freight services. When trading a freight service, it is a physical carriage of crude oil that is traded. Companies buying dirty tanker freight services are typically companies that has a need of getting a cargo of crude oil on a voyage to a refinery. This could be oil producing companies selling crude oil or processing crude oil. Companies selling freight services are companies owning or chartering

oil tankers making their earnings on selling freight services. The trading is typically done through a broker, where the charterer and the ship owner can negotiate the price for a voyage and agree on the terms of the contract.

When managing freight rate trading, the vessel owner has to manage the operating fleet of vessels and make sure to cover all open vessels with charter contracts. If a vessel comes open and the owner has no contract on this, then the owner will lose money on that vessel. This thesis will handle VLCC's only, and will therefore be based on a fleet of this class. VLCC's are vessels operating in a global environment. If the turnover is higher on one route than another, then the vessels will be operating on the route with the highest turnover. The VLCC route with the highest liquidity is TD3. In this thesis it will therefore be assumed that the tanker route index on TD3 is a measure of the global freight rate level on the entire VLCC class. In chapter 3 a small correlation analysis is performed between the 4 different dirty tanker indices, showing that this is a reasonable assumption. The TD3 index measures the price level on a voyage from the Persian Golf to Japan. Today a return voyage from Persian Golf to Japan takes approximately 55 days with a modern VLCC, which is slow steaming. The vessels are only taking cargo from the Persian Gulf to Japan, why the contract has to cover the return expenses.

2.1   Voyage agreements

Freight services on dirty tankers are mainly traded as spot contracts or Time Charter contracts. A spot contract is a contract of freight service on a quantity of cargo on one single voyage, and is also known as a voyage contract. The contract can be made with different terms depending on the market conditions and the customer's needs. Spot rates are dayli measuring the price level of the traded spot contracts. The rates are calculated in two ways; as World Scale rates (WS) and as Time Charter Equivalent rates (TCE), which both are published dayli on the Baltic Exchange.

The WS rate is a unified system of establishing payment of freight services for a given oil tanker's cargo on a predefined voyage. The WS rate is measured on a per tonnage basis. The WS establishment is traded upon a baseline rate, which is expressed as WS 100 and referred to as the flat rate. The calculation of the flat rate is based on the last year of expenses on the particular voyage, such as bunker expenses and port charges. The flat rates are published annually by the World Scale Association, which is publishing 320,000 different rates on different routes. The freight for a given vessel and voyage is normally traded in a percentage of the published flat rate and is supposed to reflect the freight

market demand at the time of fixing. The actual price negotiated between shipowner and charterer can range from 1% to 1000% of the flat rate, and is referred to respectively as WS1 to WS1000, depending on how much loss the shipowner is willing to take on that voyage and how much the charterer is willing to pay. An example could be if the flat rate is 26.5 and a voyage was traded at WS65, then the price of that voyage can be calculated into US dollar terms by $\frac{26.5 \cdot 65}{100} = 17.225$ usd/mt.

The operating performance of a tanker company's fleet can be measured in net revenues per revenue day. Consistent with general practice in the tanker shipping industry, TCE is a measure of the average daily revenue performance of a vessel on a per voyage basis. One method of calculating TCE, consistent with industry standards, is to divide net voyage revenue by voyage days. Net voyage revenues are calculated as voyage revenues minus voyage expenses. Voyage expenses usually consist primarily of port, canal and fuel costs that are unique to a particular voyage, which would otherwise be paid by the charterer under a time charter contract, as well as commissions. Ship owners are interested in trading the spot contracts as close to the load date as possible to get the best price for the voyage but still have all vessels covered with contracts such that all vessels are operating at all time. A spot contract is therefore typically traded within 2-4 weeks before loading the vessel with cargo.

In a low and decreasing spot market, as of today, the most common traded freight service agreement is the spot agreements. The charterer has no interest in entering long term contracts, and fix the price, when spot prices are decreasing. On the other hand, the ship owners do not have the interest in entering long term agreements when the price level are so low as of today, because they will fix a vessel for a long period of time at a too low price. Historical seen, the long term contracts seems to get a gain when spot market becomes high, because it gets reasonable for the charterer to enter long term contracts to cover the exposures from increasing spot market.

2.2 Long term agreements

In a time charter agreement, the vessel is hired for a set period of time, to perform voyages as the charterer directs, under the terms of the contract. One huge difference between spot and TC agreements is that in the TC agreement the charterer takes all risk relative to operating the vessel such as bunker price development, port expenses and weather risk. In the spot contract the shipowner typically takes all operating risk. Therefore the ship owner is guaranteed to get the running cost covered in a TC contract. When determine the price level of

a TC contract, the shipowner looks into historical expenses on that particular voyage and into future expectations in the spot rate market. The expectations can be estimated by stochastic process or by looking into financial derivatives on freight rates such as FFA's. Time Charter agreements are typically measured in usd/day and price levels can be directly compared with spot contracts measured in TCE rates. To a certain degree, the TC contracts can be used as a hedging tool against the downside risk exposure in the prices of spot agreements. To sell long term agreements, there have to be charterer that want to enter into the TC agreement rather than into a spot agreement. When spot rates are low, it is cheaper for the charterer to enter into spot contracts than TC contracts. Furthermore, the charterer does not take any operational risk when entering into a spot agreement, and therefore it is difficult to get charterer to buy TC contracts when spot prices are low. A trade of a TC contract is typical done within 2 months before the actual chartering begins, depending on the time horizon of the contract. The time horizon for TC contracts typically runs over 3, 6 or 9 months or 1, 3, 5 or 7 years, where 1 year TC contracts are the most liquid ones. A ship owner can also be interested in chartering a vessel on a TC contracts, and then charter out the vessel on the spot market instead, if the price on the spot market is high enough and if the shipowner expects the spot market to increase. However, many ship owners are not interested in chartering vessels to competitors.

Besides TC contracts there exists Contracts Of Affreightment (COA) which also are long term contracts. In a COA, the charterer specifies a total volume of cargo to be carried in a specific time period and in specific sizes. In this way the charterer can get a cargo loaded eg. once a month, or what time frame is needed.

2.3   Financial derivatives

In the financial market exists derivatives on freight rates, these are all swap agreements, therefore only cash flows are traded and no physical deliveries are made. The concept of these agreements is a bet on the future price level on the underlying freight service. The cash flows swapped are typical a fixed cash flow for a floating. The floating cash flow is then determined, as a monthly average price quoted on the dirty tanker index, over a future predetermined period. The fixed cash flow is agreed when entering the agreement. The concept of trading cash flows with FFA's, is visualized in figure 2.1. Historically seen the dry bulk market has experienced a greater development of liquidity in financial derivatives than seen in the dirty tanker market. Today basically two types of derivatives on tanker freight rates exist, these are Forward freight agreements
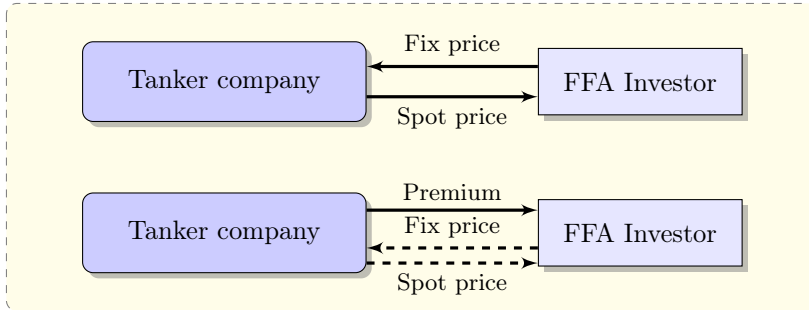
Figure 2.1: The concept on swap of cash flows, in FFA's (top) and FFA options (bottom).

(FFA) and FFA options. Financial derivatives are introducing new parties into the tanker freight market. These are investors that can see potential earnings of getting into the market, but are not interested in investing in physical equipment and taking the risk of acting in the physical market. This kind of participants typically invest large amounts in a market if they feel they can benefit from it. Freight derivatives can be used of participants in the commodity market providing them a means of hedging exposure to freight market risk, through the trading of specified time charter and voyage rates for forward positions. Time charter contracts can also be used for hedging exposure to downside risk on voyage rates, as financial derivatives. Derivatives are a much more flexible way of managing hedging strategies, because these contracts can be purchased very fast, and if the liquidity in the market allows it, in a very large amount.

Forward Freight Agreements are the most commonly used financial product in the tanker market today. It is an agreement between two parties to fix a freight rate on a predetermined tanker route, over a time period, at an agreed price. The main terms of an FFA covers:

- The agreed route which defines the floating price of the contract.
- The time horizon of the settlement.
- Contract size which is measured in mt of the cargo.
- The fixed price at which differences will be settled.

If the floating price on the predetermined tanker route exceeds the fixed price then the buyer of the contract pay the seller the difference between the two

cash flows. Conversely, if the floating price falls below the fixed price then the seller of the contract pays the buyer the difference between the two cash flows. Settlement is effected against a relevant route assessment, usually one published by the Baltic Exchange.

FFA contracts are historically seen sold as custom made contracts, to fit the specific needs of the participants entering into the contract, they could therefore vary in terms and structure. This made it difficult for investors to enter the FFA market with big volumes, because all contracts were different and they therefore had to relate to each individual contract. A cooperation between the Baltic Exchange and the FFA Broker Association (FFABA) was established in 1997 to develop and promote standardized FFA contracts. The reason for doing this was to standardize the FFA market and thereby make it easier for investors with big potential volume to enter the FFA market, and thereby add liquidity to the market. The standardized FFA contracts are the most common used derivative on the tanker market, today. The prices of these standardized contracts are gathered from the FFABA brokers and are published daily on the Baltic Exchange. These contracts are all settled monthly on the last working day in the settlement month(s), against the monthly average price of the freight rate index defined in the contract. The time horizon for the contracts can be divided into:

- Monthly settlement, from current month to plus 5 month

- Quarterly settlement, from current quarter to plus 5 quarter

- Yearly settlement, plus 1 and 2 calendar year.

Even though much has been done for the purpose of providing liquidity into the FFA market, the hot issues still remains liquidity, which also is of concern in [Vas06]. The amount of traded FFA contracts on the dirty tanker indices is to small. In September month 2012 the volume of traded FFA contracts covering dirty tankers, is published by the Baltic exchange, to be covering 3625 lots, ie. 3.625 millions mt of crude oil. Lets say that a VLCC in average is lifting 260 thousands mt of crude oil, then September month was covering 13.94 VLCC liftings. On Clarkssons, it has been published that the world wide fleet of VLCC's consist of approximately 600 vessels, why the amount of FFA contracts traded in September month 2012 will cover up 2.3% of the entire fleet of VLCC's. [1]. This is a very rough estimate, but it is pointing the issue.

Another issue in the FFA market, mentioned by [Vas06] , is the WS method of determine freight rate prices. WS is a cost-based schedule that is recalculated

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[1]www.clarksons.com

on an annual basis for a fully loaded standard vessel based upon a round voyage from loading port to discharge port. This means that when changes occur in expenses, such as the bunker prices or the port dues, changed occur in the base-line of the WS system. WS 100 for one year will therefore not be the same, in USD terms, as WS 100 for a previous year. A FFA contract is fixing a future voyage contract, and therefore is adopting the WS system when determine the settlement. This make future FFA settlements, happing across years, opaque, which definitely is unwanted for an investor.

In the financial markets also exist options on freight rates. These are much like FFA contracts, it is an agreement between two parties to fix a future freight rate on a predetermined tanker route over a time period at an agreed price. The difference between a FFA contract and a FFA option is that a FFA option gives the holder the right and not the obligation to settle the agreement at maturity. Therefore the FFA option will only be settled if it is in the money, ie. the holder of the option will get a gain from exercising the it. Because the seller of an option takes the risk and the buyer gets an insurance against price developments on the underlying freight rate index, the buyer pays a premium when entering into the agreement to cover the risk taken by the seller. An FFA option therefore gives the buyer an insurance against future decreasing price developments and the seller an upfront premium.

FFA options are typically Asian styled European options, which means that they can only be exercised at maturity, and if the contract is exercised it will be exercised against a monthly average predetermined spot index. Typical a FFA option will be exercised automatically if it is in the money.
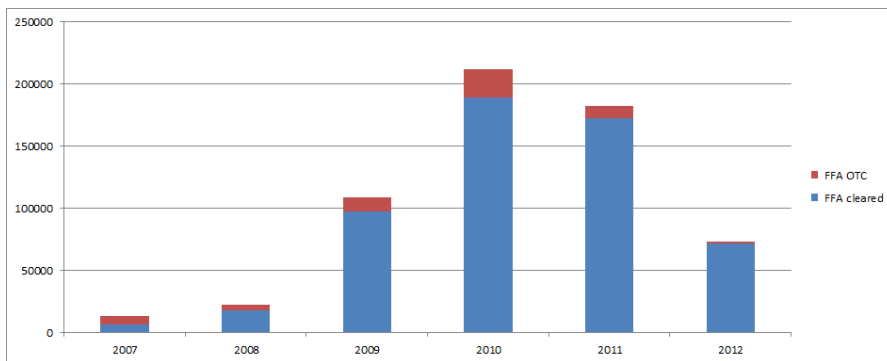
Figure 2.2: Volume of traded FFA contracts on dirty tanker indices, in lots.

FFA's and options can be traded directly between counterparties or through a FFA broker, and when they are traded it can be done Over The Counter (OTC)
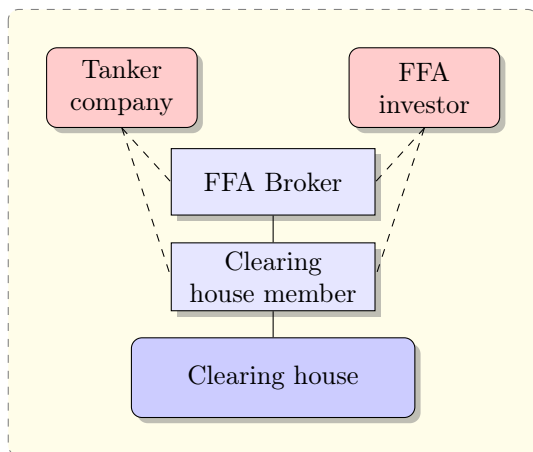
Figure 2.3: The concept of cleared trading

or on a cleared basis as described in figure 2.3. In figure 2.2 the historical
developments of the relationship between OTC and cleared FFA contracts are
seen since 2007. The contract volume is calculated as lots, where 1 lot is equal
to a contract size of 1000 mt of ocean transportation of crude oil. The FFA
trading volumes are estimated from all clearing houses and other data providing
companies in the dirty tanker industry such as Clarkson Securities, etc.[2] It is
seen that the main part of the sold contracts have been cleared, and today
almost all contracts are cleared. It is estimated that in the third quarter of 2012
3625 lots of dirty tanker FFA contracts were sold, and all of them were cleared.
Today, FFA contracts are normally based on the terms and conditions of the
FFABA standardized contracts as adapted by the various clearing houses.

An exchange clearing house acts as a supplement of an exchange and as an inter-
mediate market in futures transactions. It guaranties the performance of market
participants by eliminating the credit or counter party risk of the transactions.
Usually a clearing house is a financial institution with a large capitalisation.
Some times banks can provide clearing services by taking equal and opposite
positions with 2 principles.

A clearing house has an amount of members, and brokers who not are members
have to trade contracts through a house member. The main task of a clearing
house is to summarise its dayli transactions, so that it is able to calculate the net
position of each of its members. Clearing house members are liable to maintain

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[2]data provided by www.balticexchange.com

margin accounts, also known as clearing margins, within the clearing house for every transaction they make. These margins, just as in an exchange market, are readjusted dayli depending on the members losses or gains and based on a close-of-play forward assessment published by the Baltic Exchange.

Clearing services are provided by

- London Clearing House (LCH)

- The Norwegian Futures and Options Clearinghouse (NOS)

- Singapore Exchange (SGX)

- Chicago Mercantile Exchange (CME)

Brokers or market participants who are not a clearing house member have to keep margin accounts at a clearing house member. The purpose of the margin system is to reduce the risk of a participant suffering losses because of another participant's default. The margin system has proved to be highly successful since losses from defaulting counter parties have almost diminished in major exchanges. Market participants using brokers and clearing houses have to pay commissions to the broker and the clearing house for maintaining the margins. Commissions are agreed between principal, broker and clearing house. The broker, acting as intermediary only, is not responsible for the performance of the contract, neither is the clearing house.

The Forward Freight Agreement Brokers Association (FFABA) is an independent association of FFA broking Baltic Exchange members formed in 1997 and is serviced by the Baltic Exchange. The aims of the FFABA is to:

- Promote the trading of forward freight agreements (FFAs)

- Promote high standards of conduct amongst market participants

- Liaise with the Baltic Exchange to ensure the production of high quality indices for use by the freight futures industry

- Provide a forum for brokers and principals to resolve problems as they arise

- Develop and promote the use of standard contracts

- Develop the use of other 'Over the Counter' and exchange traded derivative products for freight risk management.

2.4   Case study

The following section is a hypothetic example of how to work with FFA agreements and to show the difference between a FFA agreement and a FFA option.

It is the 2nd of April 2012 and a VLCC vessel owner has a vessel sailing on the route from the Arabic Gulf to Japan (Ras Tanura/Chiba), which will come open in the beginning of May and again at the end of June. The shipowner wants to cover his exposure to a possible decrease in freight rates, and therefore wants to enter into a FFA contract covering May's exposure and a FFA contract covering June's exposure. The world scale spot rate today is 70,53 ws/mt, and the shipowner's expectation for May is that spot rates will decrease to a level below 55 ws/mt, and for June that spot rates will decrease to a level below 50 ws/mt.

The ship owner calls his FFABA broker and wants to enter into a FFA contract covering May at a price above 55 ws/mt and a FFA contract covering June at a price above 50 ws/mt. Both contracts should cover the entire exposure for both months and should therefore have a size of 260.000 mt which corresponds to a lot size of 260. The FFA broker finds a counter party to the contracts and the parties agree on a FFA contract at a price of 56.7 ws/mt against the TD3 spot rate average for May quoted on the Baltic exchange. The contract will be settled at the last working day of May. The second FFA contract covering June is agreed at a price of 53.6 ws/mt against the TD3 spot rate average for June quoted on the Baltic exchange. This contract will be settled at the last working day of June.

The contracts are agreed upon, and will be cleared through a clearing house. Both parties of the contracts will therefore pay into the margin in the clearing house an amount of money, which will cover their loss if the contracts were settled today. In this way the credit risk for the counter parties will be covered. The margins will then be maintained daily by both parties to cover the proportional daily change in spot rate.

On the last working day of May the average spot rate on TD3 is determined to be 57.363 ws/mt. This is higher than the ship owner expected, and he therefore looses money on the FFA contract. The calculation of the settlement price can be seen in table 2.1. It can be seen that the ship owner has to pay his counter party, covering the exposure of May, 46,439 US dollar. This amount should be on the ship owners margin account and will be payed through the clearing house to the counter party.

On the last working day of June the average spot rate on the TD3 index is

	May	June
Fixed leg	56.700	53.600
Floating leg	-57.363	-42.822
Flat rate	26.94	26.94
Size of contract	260,000 mt	260,000 mt
Value at maturity	-46,439 usd	754,934 usd

Table 2.1: The table shows the calculation of the FFA contracts.

determined to be 42.822 ws/mt. This is less than the ship owner expected, and he therefore gains on the FFA contract covering the exposure of June. It is calculated in table 2.1 that the counter party, covering the exposure of June, has to pay 754,934 US dollar to the ship owner, which should be one his margin account.

If the ship owner had entered into a FFA option agreement instead of the forward contract, covering the exposure of May, he would have paid the premium to the counter party when entering the contract. At maturity the option would have been out of the money and the ship owner would not have exercised the contract. The ship owner would therefore not have experienced any loss from the agreement additional on the premium that was paid when entering the agreement. The ship owner could also have entered an option covering the exposure of June. At end of June he would then have exercised the option, because it was in the money, and still experienced the gain from the agreement. He would, though, have paid the premium when entering the agreement making the gain smaller than with the forward contract.

Part I

Statistical freight rate analysis.

CHAPTER 3

Preprocessing data

This chapter is an introduction into how data is structured and where data is extracted from. All data used throughout the thesis is introduced in this chapter.
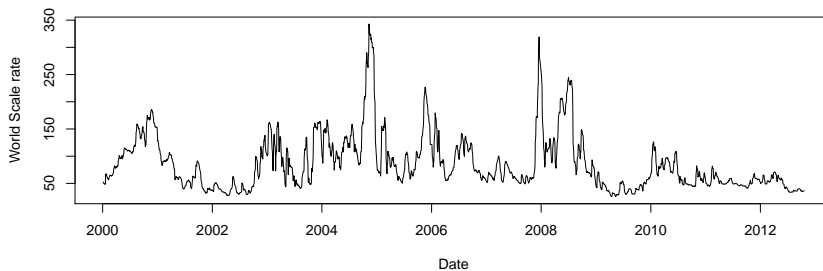
Figure 3.1: The figure shows the historical sample of spot prices on the TD3 index.

Data used in the thesis consists of dayli world scale spot prices on dirty tanker freight agreements. The sample is analysed and used as a basis to generate scenarios, which the optimization framework is built upon, and which is dealt

with in chapter 4 and 5. All data on spot prices and forward prices used in the thesis is extracted from the Baltic Exchange [1]. On the Baltic Exchange basically 4 different dirty tanker indices exist on the VLCC class, each measuring the price of freight service on different routes, namely;

TD1: Cargo weight of 280,000 mt, from Middle East Gulf to US Gulf. Ras Tanura to LOOP with laydays/cancelling 20/30 in advance. Maximum age of vessel 20 years.

TD2: Cargo weight of 270,000 mt, from Middle East Gulf to Singapore. Ras Tanura to Singapore with laydays/cancelling 20/30 in advance. Maximum age of vessel 20 years.

TD3: Cargo weight of 265,000 mt, from Middle East Gulf to Japan. Ras Tanura to Chiba with laydays/cancelling 15/30 days in advance. Maximum age of vessel 15 years.

TD4: Cargo weight of 260,000 mt, from West Africa to Us Gulf. Off Shore Bonny to LOOP with laydays/cancelling 15/25 days in advance. Maximum age of vessel 20 years.

index (i)	date (d_i)	spot price (p_i)
1	04-01-2000	52.59
2	05-01-2000	52.22
3	06-01-2000	50.83
4	07-01-2000	50.39
5	10-01-2000	50.11
$\vdots$	$\vdots$	$\vdots$
3203	19-10-2012	36.25

Table 3.1: Sample of historical data of spot prices.

The most liquid of these indices is the TD3 index. This index measures the price of a contract on freight service on double hull VLCC vessels with a maximum age of 20 years. The contracts have an average size of 260.000 mt of cargo on the route from the Middle East Gulf to Japan, Ras Tanura to Chiba. The prices are published on a dayli basis at 16 o'clock on the Baltic Exchange from Monday to Friday on European work days. Prices are not published e.g. during the Easter holidays, during the Christmas period from 25 of December to 31 of December, etc [2]. The extracted data sample consists of dayli published prices in the period

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[1]www.balticexchange.com
[2]The exact publishing dates for spot prices can be found at www.balticexchange.com

from 4/1 - 2000 to 19/10 - 2012, and therefore includes 3203 observations. A sample of the data set are seen in table 3.1.

3.1 BDTI comparisons
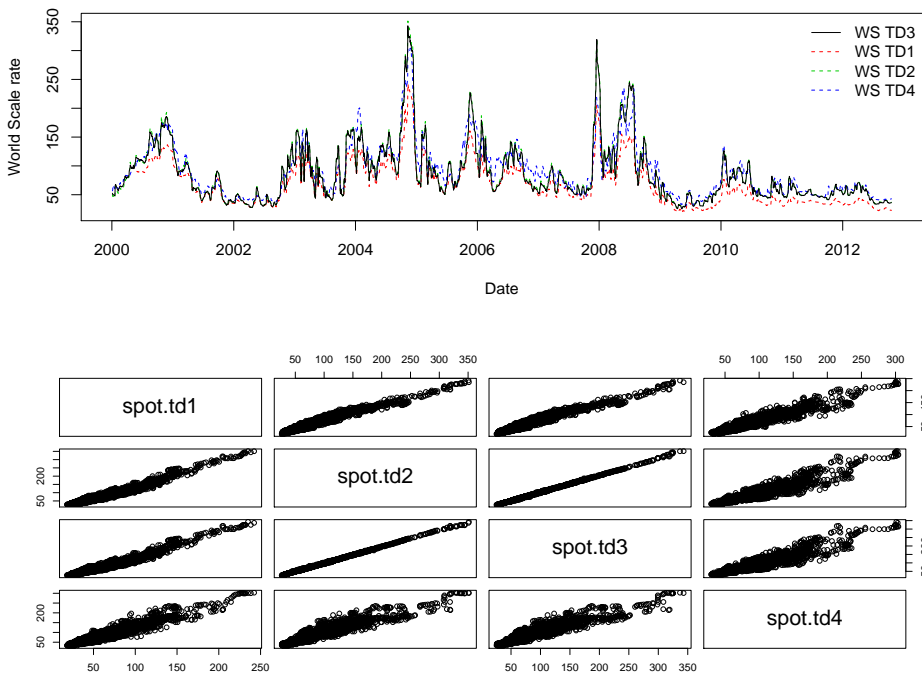
Figure 3.2: The figure compares the 4 different VLCC dirty tanker indices quoted on the Baltic Exchange.

A hypothesis on the VLCC indices is that the trend in each index should be highly correlated with each other. The reason for this hypothesis is that VLCC's work in a global environment, where minor classes of tanker vessels are working in more local areas and therefore is more problematic to move between areas. If the price development of freight service provided by VLCC's should be significant higher in one area than in others, then it would be expected that the shipping company would move their vessels to the route where the turnover are

the highest. The indices measures the purchase level of freight services on one particularly route. In this way, the trend in each index would be assumed to be stable compared to each other. In figure 3.2 it is seen that the 4 indices indeed seem highly correlated. The top figure illustrates the time series of each index, and the lower figure illustrates the scatter plot between each index. Both figures indicates that the hypothesis seems correct. To reduce complexity in modelling the time series for scenario generation and optimization, it is chosen only to work with the TD3 index. All analysis and models in the thesis is therefore based only on the TD3 index, used as an index measuring the purchase level of the entire VLCC class.

3.2   Spot price transformation

The sample of historical prices is used in the thesis for generating scenarios, which the optimization will be based upon. Technical analysis and forecasting of dirty tanker freight rates in the FFA market is something that probably most FFA brokers and shipping companies do today, for their own purpose. In the academic world, however, as to my best knowledge no publications has been able to develop a precise way of forecasting freight rates. It has been proposed in [MM10] and [JL06] to use neural network, as a prediction tool. The results from using neural networks in the publications, and in the industry, has had limited results. The prior known time series tools from the field of statistical analysis and stochastic modelling is therefore applied for the purpose of generating meaningful scenarios for the future level of freight rates.

The expected pay-off of a FFA contract is determined from the price of the FFA contract at the time of purchasing, and the corresponding expected average price of spot contracts for the settlement month. Scenarios are then used to compute expectations on the future level of spot prices such that the expected pay-off of a FFA contracts can be determined. The optimization process is then computed to determine the optimal portfolio of FFA contracts for a given point in time d_i, using the scenarios to compute expected FFA pay-off's. Scenarios can be computed in several ways, more on this is introduced in chapter 4. This chapter focusses on processing the data set of historical spot prices towards generating scenarios.

A normal approach in econometrics when analysing and modelling price structures, like stock market indices or price indices, is to transform the price into the logarithm of the rate of return. The transformation of the price has some interesting theoretical statistical properties, i.e. it is assumed to be independent and follow a normal distribution. This makes the modelling process less com-

plex, eg. the data transformation ensures that the computed prices always will be positive. Furthermore, the transformation keeps the same information about the historical movements as the prices themselves do. It should be denoted that, when rates are small, like in dayli rates, the logarithmic transformation only makes a small numerical change in the rates.

Let therefore p_i denote the price of settling a spot contract at date d_i and let r_i denote the rate of development of the spot prices between date d_{i-1} and d_i, which will also be known as just the rate. The rate of development in spot prices should not be mistaken by the rate of return on a spot contracts. The spot price is the price on a contract of getting a physical delivery, and in this case the return can be calculated as the spot price minus all expenses of keeping the vessel running. The rate is just denoting the relative change in spot prices. The relationship between the price p_i and the rate r_i can then be defined as

$$r_i = log\left(\frac{p_i - p_{i-1}}{p_{i-1}}\right) = log\left(\frac{p_i}{p_{i-1}}\right) \quad \forall i > 1 \tag{3.1}$$
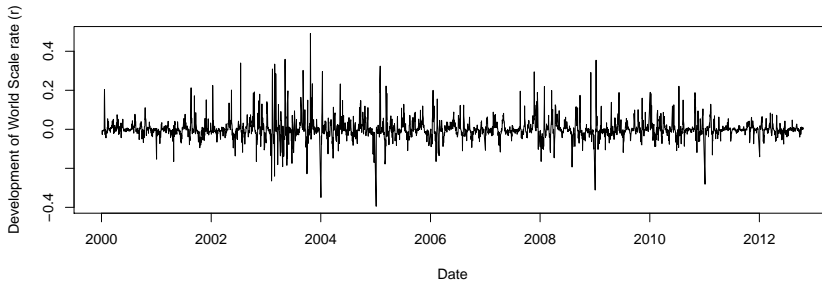
Figure 3.3: The figure shows the rate of developments r_i on historical quotes on the TD3 index.

In [Vas06] it is suggested not to use freight rates in WS terms, when making technical analysis. Instead it is proposed to recalculate the WS term into USD terms. In this thesis it has been chosen to make the statistical analysis on WS term. First of all, the analysis in this thesis is developed with the purpose of decision making in the forward market, and the forward market is using the WS term in settlements. If the analysis was done on USD terms, the decision making process would become more complex to handle. Furthermore, making the analysis on the rates and not the prices, makes the differences between term methods vanishing. Let f_i denote the WS flat rate in percentage at index time

i, then the rate in USD terms would become

$$log \left(\frac{f_i p_i}{f_{i-1} p_{i-1}} \right) \tag{3.2}$$

It is only one day per year that f_i and f_{i-1} is different, this is the day where the annual flat rate changes. The differences in the wo terms would therefore vanishes in this analysis. Another advantage in using the WS term when making analysis in this thesis, is that it is enough to analyse only one index. The costs of operating the different routes are not the same, why the level of USD term freight rates would not be the same. It could happen that changes in costs between years on the different routes not was the same, why it would be necessary to make analysis on all 4 dirty tanker indices.

From a theoretic point of view the transformed sample of rates should now be originated from an iid. normal distributed population. In figure 3.3 the time series of rates on the entire period from 2000 to 2012 can be seen. It is seen that the mean structure seems stationary around 0, which is as expected. However, it seems as if there is some variance clustering in the time series, which indicates that the series is not originated from an iid. population. This subject is addressed in chapter 4, where the technical analysis of the rates is done.

3.3   FFA data

FFA Contract	Number of records	Number of NA's	Fraction
FFA_0M	1950	0	0.00
FFA_1M	1950	0	0.00
FFA_2M	1950	0	0.00
FFA_3M	1950	0	0.00
FFA_4M	1800	150	0.08
FFA_5M	1800	150	0.08
FFA_0Q	1950	0	0.00
FFA_1Q	1950	0	0.00
FFA_2Q	1950	0	0.00
FFA_3Q	1800	150	0.08
FFA_4Q	1712	238	0.12
FFA_5Q	930	1020	0.52

Table 3.2: The table shows the number of records on FFA contract prices

FFA prices used in this thesis are based on dayli forward prices on the BDTI TD3 index. The FFA contracts used in this thesis are the standardized FFABA

broker contracts. The dayli prices of the contracts are published through the Baltic Forward Assessments (BFA), and are an estimated mid price of bids and offers for the tanker market based on submissions from FFABA brokers at 17:30 (London) on each work day. FFA prices from the standardized FFABA broker contracts have been published on the Baltic Exchange since 04/01-2005, which is why the data set consists of FFA contract prices based on the period from 04/01-2005 to 19/10-2012.

Name of contract	FFA contracts	Settlement month(s)
FFA_M0	Current month	January
FFA_M1	1 month	February
FFA_M2	2 month	March
FFA_M3	3 month	April
FFA_M4	4 month	May
FFA_M5	5 month	June
FFA_Q0	Current quarter	January, February, March
FFA_Q1	1 quarter	April, May, June
FFA_Q2	2 quarter	July, August, September
FFA_Q3	3 quarter	October, November, December
FFA_Q4	4 quarter	January, February, Marts (next year)
FFA_Q5	5 quarter	April, May, June (next year)

Table 3.3: Settlement month(s) for FFA contracts purchased in January.

The FFA contracts are divided into 12 different products quoted each date. The different contracts can all be purchased on the quote date, but are subsequently settled against different time periods. The settlement time periods are divided into current month, plus 1 month up to plus 5 month, current quarter and plus 1 quarter up to plus 5 quarter. In this way it is possible to work with strategies of no hedging to hedging 18 months of spot contracts in advance, but not any further than this. In table 3.3 it can be seen which months a FFA contract purchased in January is settled against, e.g. a FFA contract purchased in January during plus 1 quarter is settled against the average spot price of April, May and June in current year. The reporting months changes on the last working day of each month, e.g. for April 2012, the roll-over date is the 31 of March 2012. When it is the 1st month of a quarter, there will be 6 full quarters reported on all the tanker routes. For example, on the 12th of January 2012, the reported quarters would be Q1 2012 (as cur. quarter), Q2 2012, Q3 2012, Q4 2012, Q1 2013, Q2 2013. When it is the second or the third month of a quarter, current quarter will be the remaining of that quarter, and further 5 full quarters ahead will be reported. For example, on the 17th of February 2012, a FFA agreement on current quarter would be settled on an average price of February and Marts, and further FFA agreements would be reported on Q2

2012, Q3 2012, Q4 2012, Q1 2013, Q2 2013.
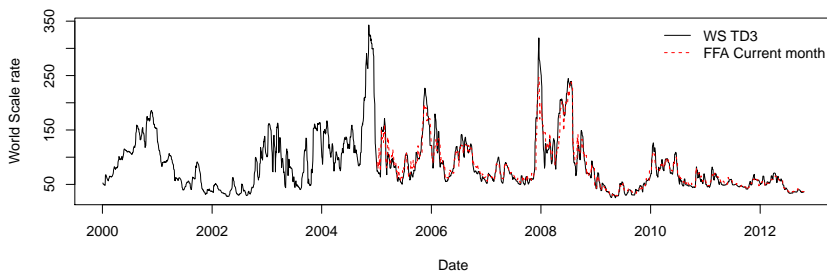
Figure 3.4: The figure compares the price sample from the TD3 index with
dayli qoutes of FFA contracts on current month.

In figure 3.4 it is seen that the prices of FFA contracts settled against the current
month average spot price are highly related with the spot price at the time of
purchase. In appendix A all FFA contract quotes are compared to spot prices,
it is seen that the closer the settlement period is to the current date the more
related the two prices movements are to each other, and vice versa.

The FFA sample is not complete like the spot sample. Table 3.2 shows the
number of FFA records and the corresponding number of missing values. Not
all contracts have been available since 04/01-2005, which gives a period where
no prices have been quoted for those contracts. This is the case for FFA_4M,
FFA_5M, FFA_3Q and FFA_4Q, which has their first quoting date on 08/08-
2005. The last type of contract FFA_5Q had their first quoting date on 02/02-
2009. The FFA prices are only used for calculating the pay-off in the decision
model. Missing values have therefore been replaced with 0, which ensures a
negative pay-off and therefore that the decision algorithm not will choose these
contracts at these dates. This means that these contracts are seen as not avail-
able at these dates where they didn't exist.

CHAPTER 4

Spot rate modelling

The allocation framework developed in this thesis, is deciding on the asset al-
location of FFA contracts from the pay-off on FFA contracts. The pay-off is
then determined from the price level of spot contracts in the future and the
purchase price on the FFA contracts on a given day. One thing is sure, no one
knows the future with certainty! The allocation framework therefore need some
realistic expectations regarding how future levels of spot prices might develop.
The aim of this chapter is therefore to analyse the historical sample of rates and
use this to compute a statistical framework used for deriving future expectation
of price levels on spot contracts. The computational framework derived in this
chapter is then used in chapter 5 to compute the scenarios, which are used in
the allocation process. The data sample $R = \{r_i\}_{i \in \{2,\ldots,3203\}}$ consists of rates,
which the statistical framework is based upon. The sample was introduced and
preprocessed in chapter 3.

When the analysis is done and a statistical process is derived to describe the
rates, it is desirable to test the performance of the process. The performance
should be measured against a historical sample of rates. Therefore the entire set
of rates R is be divided into two distinct parts of equal length. The first part
of the set is $R_{model} = \{r_i\}_{i \in \{2,\ldots,1502\}}$, this set is used to compute and estimate
the process describing the rates, and is denoted as the model sample. Choosing
the set in this way implies that it consists of dayli rates for the first 6 years,
ie. the period from 04-01-2000 to 31-12-2005. The other part the sample

$R_{test} = \{r_i\}_{i \in \{1503,\ldots,3203\}}$ is used for testing the performance of the estimated process, this set is denoted as the test sample. By dividing the set into two distinct parts and only derive the statistical process from the one part and the tests from the other, makes the tests unbiased.

4.1 Bootstrap Computation

The simplest statistic approach for generating scenarios, using only the available observed data sample without any mathematical modelling, is to bootstrap the set of historical records. The bootstrap is a general tool for assessing statistical accuracy to sample estimates. The basic idea is to randomly draw data sets with replacement from the training data, each sample the same size as the original training set. This is done N times, producing N bootstrap data sets. Then the model is refitted to each of the bootstrap data sets, and the behaviour of the fits over the N replications is examined.

The bootstrap computation is implemented in GAMS choosing a set of random indices i with the function `randint`. The set of indices corresponds to a set of rates r_i for each index. This procedure is then replicated $N = 250$ times producing 250 bootstrap scenarios.

4.2 Analysis of bootstrap sample

For a high volatile market, like the spot market of freight rates, it seems unlikely to say any reasonable things about the rate 6 years into the future. The scenarios are used in the allocation process to make the decision whether to hedge a future spot position or not. It is only possible to hedge up to 18 month in advance, it therefore makes sense to use only the first 18 months of prices in the allocation process. Therefore the analysis of the bootstrap sample is done on the horizon of 18 months. The 250 realizations of rates from the bootstrap sampling process can be seen in figure 4.1. The top figure shows the entire sample together with the mean and 95% confidence interval at each day for the period of 18 months, starting at 04-01-2006. The confidence interval is calculated as

$$\left[E(\hat{p}_l^{t_\tau}) + q_{\frac{\alpha}{2}} ; E(\hat{p}_l^{t_\tau}) + q_{1-\frac{\alpha}{2}} \right] \tag{4.1}$$

where q_α denotes the α quantile from the sample. The lowest figure shows the comparison of the bootstrap sample with the test sample. What can be seen in figure 4.1 is that the bootstrap sample seems to take a high level of volatility.
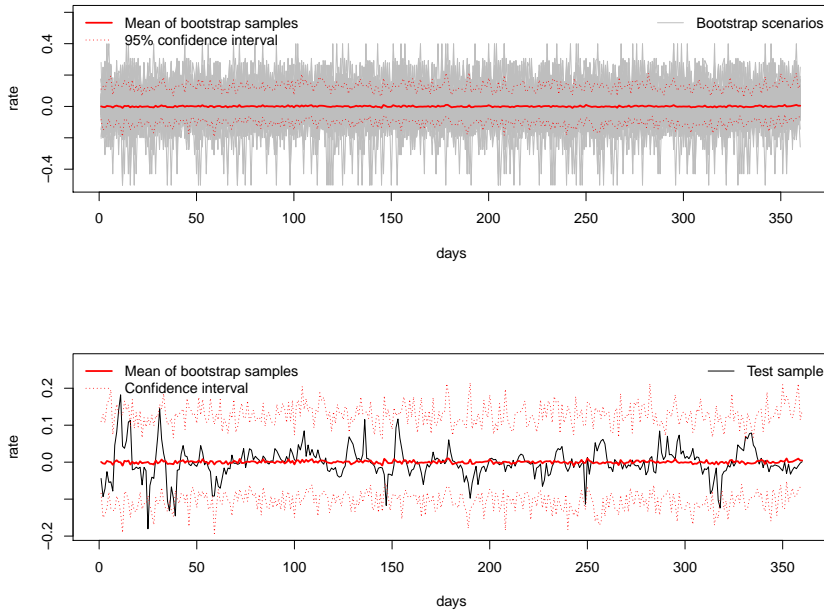
Figure 4.1: The figure shows the 250 realizations from the bootstrap sample.

In figure 4.2 the prices of the bootstrap sample are plotted with the test sample for the same period and the 95% confidence interval. In this figure one may identify a trend, where the bootstrap samples do take higher positive values than what is identified in the test sample. Furthermore it is seen that the bootstrap sample takes a wide confidence interval because of the high volatile estimates. In chapter 3 it was assumed that the observed sample of rates was taken from an iid normal distribution to fulfil the assumptions for doing the bootstrap sampling. It was also indicated that this assumption maybe was to restrictive.

One way to test the distribution assumptions on the model sample is to draw the theoretic normal distribution together with the distribution of the observations. In figure 4.4 one may see the histogram of the rates compared with the theoretic normal distribution. Furthermore, the quantiles of the bootstrap sample are compared with the quantiles of a theoretic normal distribution in a QQ-plot. The two graphs indicates that the tale distribution of the bootstrap sample is heavier than what can be described by the theoretical distribution. This
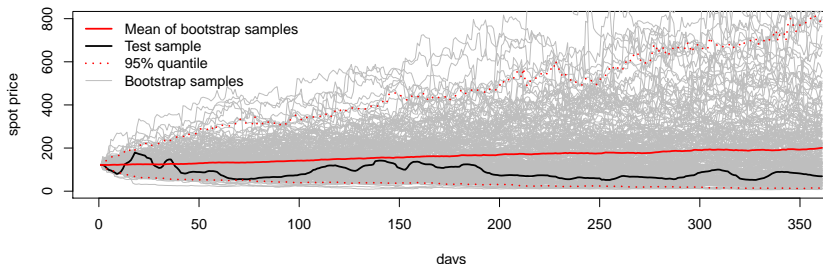
Figure 4.2: The figure shows the monthly average of the mean on generated
bootstrap samples compared with the test sample in the first 18
months. Furthermore is included a 95% confidence interval.

Test	Test-value	p-value
Test for normality	0.8038	< 2.2e-16
Test for stationarity	0.0249	0.1
Test for independecy	841.164	< 2.2e-16

Table 4.1: The table shows the performed test of the model sample on nor-
mality (Shapiro-Wilk normality test), stationarity (Kwiatkowski-
Phillips-Schmidt-Shin test) and independency (Ljung-Box test).

indicates that the bootstrap sample probably not is taken from an iid normal
distribution. A Shapiro-Wilk test is then made on the sample to test whether
the sample can be supposed to originate from a normal distribution. The result
of the test can be seen in table 4.1 where it is seen that the test got a p-value
less than 2.2e-16. This indicates that the test is strongly significant, and the
hypothesis is rejected, which implies that the sample probably not are taken
from a normal distribution.

The auto correlation function measures the relationships in between data points.
In figure 4.3 one may see the estimated auto correlation function for the model
sample R_{model}. One may identify some damping sin oscillation on the lags,
which indicates some kind of autoregressive structure in the mean structure.
If the data sample really was taken from an iid population, there should be no
significant autocorrelation in lag greater than 1, because each observation should
be independent of each other. This again indicates that the sample is not iid.
The Ljung-Box test also makes strong significantly indications that the sample
does have some dependencies. Therefore it may be an idea to look into another
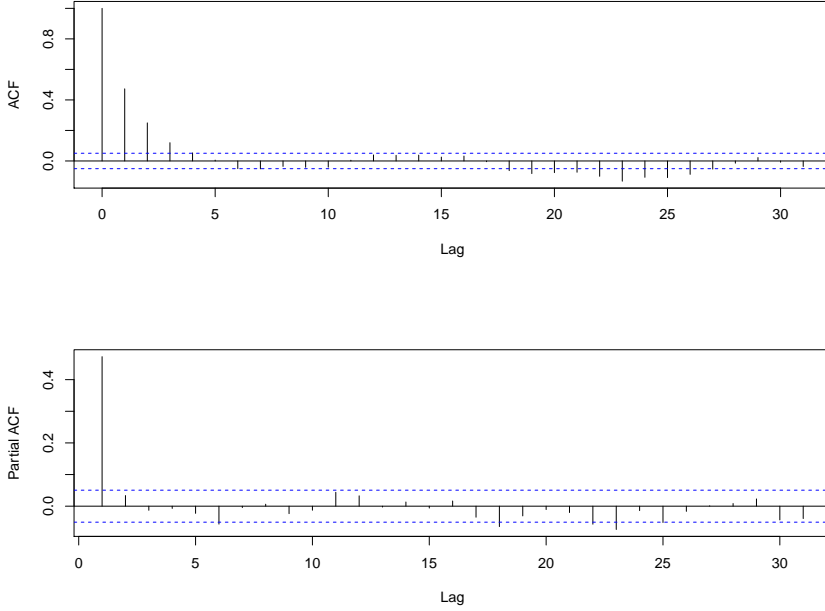
Figure 4.3: The figure shows the auto correlation function and partial auto correlation function for the model sample of historical quotes R_{model} on the TD3 index.

way of generating the expectations of the rates when computing the scenarios, instead of just choosing the rates randomly. One obvious way to proceed when looking at the auto correlation function is to fit an autoregressive process.

4.3   Autoregressive computation - AR(p)

An autoregressive model for the sample R_{model} is a model which captures the relationships in between data points in the sample, and which models the mean structure. Many different forms of AR-models exist, but the pure AR(p)-process can be defined as

$$r_i = \sum_{j=1}^{p} \phi_j r_{i-j} + \epsilon_i, \quad \epsilon_i \sim N(0, \sigma^2) \tag{4.2}$$
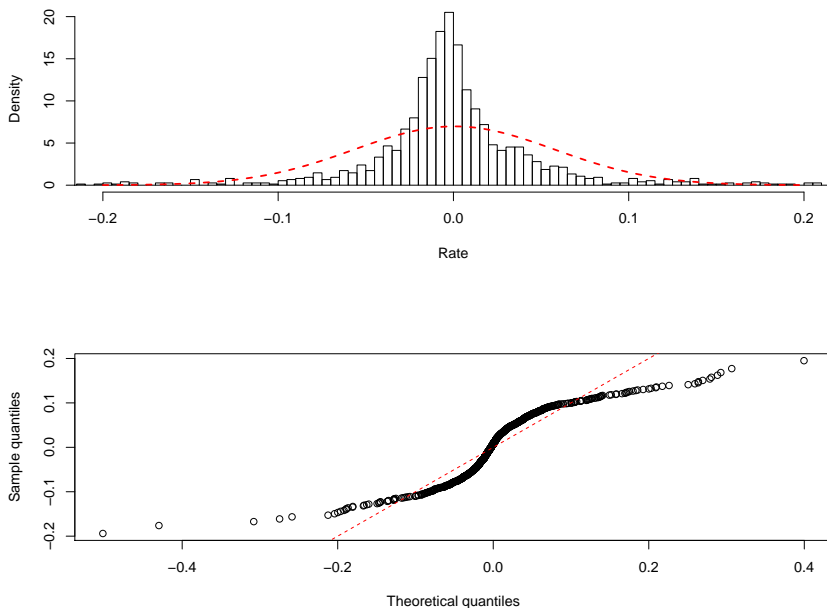
Figure 4.4: The figures shows the distribution of the model sample of rates
compared with the theoretical normal distribution.

When fitting an AR-model to a data sample, one has to choose the model order
p and then estimate the parameters ϕ_j. The values should be chosen to derive
the most adequate model describing the data sample. Madsen is introducing
a framework on how to choose the most adequate AR-model in [Mad07], and
the different tests that can be used in this process. The model selection is an
iterative process, which is proposed to be done using the following three steps.

1. The first part of the modelling process is to find the best guess of the
   model order p with the current knowledge. Here it is proposed to look at
   the loss function and the auto correlation function to get some knowledge
   on where to guess. When the model order is chosen, then the parameters
   should be estimated. This has been done in R with the `arima` package,
   which is using a maximum likelihood approach when doing estimations.

2. In the model it is assumed that the residuals (iid) $\epsilon_i \sim N(0, \sigma^2)$. When the
   parameters are estimated, it is therefore proposed to test the distribution

		$\hat{\phi}_1$	$\hat{\phi}_2$	$\hat{\phi}_3$	$\hat{\phi}_4$	$\hat{\phi}_5$	$\hat{\phi}_6$	$\hat{\sigma}$	$S(\hat{\theta})$
AR(1)	$\hat{\theta}$	0.47	-	-	-	-	-	0.002536	3.808
	$\hat{\sigma}_\theta$	0.02	-	-	-	-	-	-	-
AR(2)	$\hat{\theta}$	0.45	0.03	-	-	-	-	0.002533	3.804
	$\hat{\sigma}_\theta$	0.03	0.03	-	-	-	-	-	-
AR(3)	$\hat{\theta}$	0.4569	0.04	-0.01	-	-	-	0.002532	3.804
	$\hat{\sigma}_\theta$	0.03	0.03	0.03	-	-	-	-	-
AR(4)	$\hat{\theta}$	0.46	0.04	-0.01	-0.01	-	-	0.002532	3.803
	$\hat{\sigma}_\theta$	0.03	0.03	0.03	0.03	-	-	-	-
AR(5)	$\hat{\theta}$	0.4567	0.04	-0.01	0.00	-0.02	-	0.002531	3.802
	$\hat{\sigma}_\theta$	0.03	0.03	0.03	0.03	0.03	-	-	-
AR(6)	$\hat{\theta}$	0.46	0.04	-0.01	0.01	0.00	-0.06	0.002523	3.790
	$\hat{\sigma}_\theta$	0.03	0.03	0.03	0.03	0.03	0.03	-	-

Table 4.2: The table shows the estimated autoregressive models.

assumption on the residuals. If the residuals cannot be assumed to fulfil the distribution assumptions, then the model with the chosen order an estimated parameters is not adequate and cannot be used to describe the sample. Therefore, one should turn back to part one in the model selection process and try to find another model order that would better fit the sample. If the residuals fulfil the assumptions, then the selection process should proceed to part 3.

3. The last part of the model selection process is to test whether the fitted model actually is the best choice describing the sample. If a model with lower model order describing the sample as relatively good as the chosen model exist, then it would be a more optimal model to choose. If such a model can be found, it will be chosen as the most adequate model, and the modelling process must turn back to part one.

When looking at the partial auto correlation function it is seen that at lag 6 a significant correlation is estimated. This indicates that there is some structure in data around lag 6, which could be captured by an AR(6) process. Let M denote the length of the test sample, the loss function is then defined as the
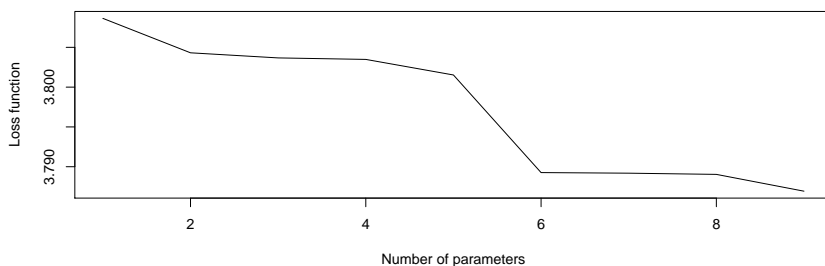
Figure 4.5: The figure shows the loss function of the fitted AR-processes as a
function of model order (p).

residual sum of squares

$$S(\hat{\theta}) = \sum_{t=1}^{M} \epsilon_t^2(\hat{\theta}) \tag{4.3}$$

where $\hat{\theta} = \{\hat{\phi}_i\}_{i=1,...,p}$. The loss function of the estimated AR-process defined
in (4.2), is plotted as a function of the model order (p) up to order 9 in figure
6.6. It is obvious that the loss function is an decreasing function as the number
of parameters increases. What is seen in the figure is that when including 6
parameters in the model, it gives the relatively biggest decrease in losses. From
the partial autocorrelation function and the loss function it indicates that an
AR(6) model seems to be the most adequate model to choose with the obtained
knowledge.

The AR(6) process is estimated in R, with the `arima` package using a maximum
likelihood approach. The estimated parameters and their uncertainty can be
seen in table 4.2. The residuals from the estimated AR(6) process can be seen
as a time series in figure 4.6. The distribution of the residuals can be seen
in figure 4.7 as a QQ-plot and a histogram compared against the theoretical
normal distribution. In the figures it seems as if there may be too much mass in
the tales of the distribution of the residuals, than what can be explained by the
theoretical normal distribution, despite that it seems promising. Another test
that is proposed by Madsen in [Mad07], is to test for changes in signs. If the
residuals are iid normal distributed, then it would be expected that $(\epsilon_t)_{t \in (1,...,M)}$
on average would change sign every second time. This hypothesis can be tested
against a binomial distribution $B(M-1, 0.5)$, which is done. The relative
number of changes in signs is estimated to 0.4843 with a p-value on 0.2351 and
a confidence interval of $[0.4587; 0.5099]$. It seems as if the hypothesis cannot
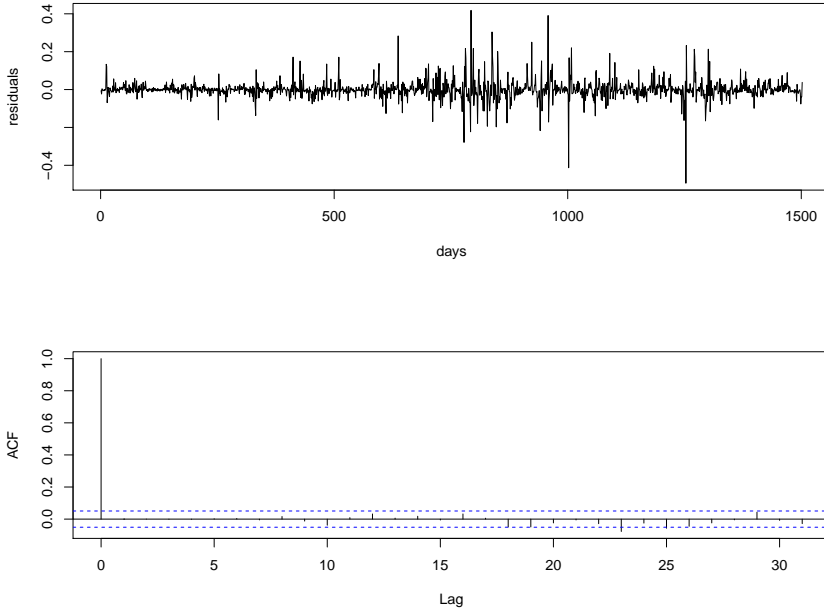
Figure 4.6: The figure shows the autocorrelation function and the time series of the residuals from the estimated AR(6) process.

be rejected, and therefore it may be assumed that the relative change in signs is approximately 0.5. One thing that is left looking into is the autocorrelation function. If the residuals really are iid, then there should be no significant autocorrelation. In figure 4.6 the autocorrelation function for the residuals have been plotted. Only 1 significant autocorrelation at lag 23 exist, this may be assumed good enough, and therefore the residuals may be assumed independent. The conclusion of the residual analysis may be that it seems likely that the residuals $(\epsilon_t)_{t\in(1,...,M)}$ are iid distributed from a $N(0,\sigma^2)$.

Then it remains to test for model reduction; this is to test whether the relative increase in the loss function, when removing model parameters, can be justified by removing the parameters. The first test made has been done removing one parameter, decreasing p to $p-1$ and therefore estimating the AR(5) process. The test for model reduction is done by comparing the loss function on the two processes. Let S_2 denote the loss function of the model with n_2 parameters, and let S_1 denote the loss function with n_1 parameters, where $n_1 < n_2$. The
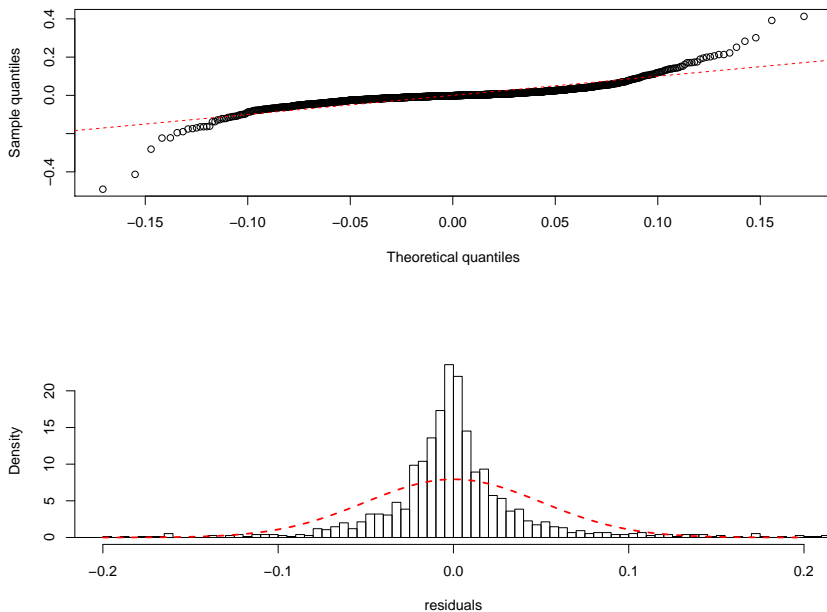
Figure 4.7: The figure shows the QQ-plot and histogram of the residuals from the estimated AR(6) process.

hypothesis, which is tested can then be formulated as

$$H_0 : S_1 = S_2 \tag{4.4}$$

It is then described in [Mad07] that it holds asymptotically that

$$\frac{(S_1 - S_2)/(n_2 - n_1)}{S_2/(M - n_2)} \in F(n_2 - n_1, N - n_2) \tag{4.5}$$

The test is implemented and done in R comparing the AR(6) and AR(5)-processes. The p-value is estimated to be approximately 0.03 which indicates that there is a significant change in the loss function, on a 95% confidence level, when going from 6 parameters to 5. The AR(5) process can therefore not be assumed to be as adequate as the AR(6) process to describe the model sample. The test is therefore performed again on decreasing the AR(6) process to an AR(4) process. This time the p-value is estimated to be 0.06, which indicates no significant changes in the loss function on a 95% confidence level.

n_1	1	2	3	4	5
n_2	2	3	4	6	6
p-value	0.19	0.62	0.78	0.06	0.03

Table 4.3: The table shows the results from making test on model reduction on the AR-processes.

The AR(4) process is therefore now chosen to be the best guess of the most adequate model describing the model sample, and the model selection process therefore begins again. It is then tested whether the residuals can be assumed iid normal distributed. Like with the AR(6) process, there is no reason to reject the hypothesis that the residuals should be iid normal distributed. Therefore the AR(4) process is chosen to be the most adequate model. Again the model should be tested for reduction in the number of parameters. This process is done recursively, and all test values from testing reduction in model order can be seen in table 4.3. The final model chosen becomes an AR(1) process, which is estimated as the most adequate auto regressive model to describe the model sample.
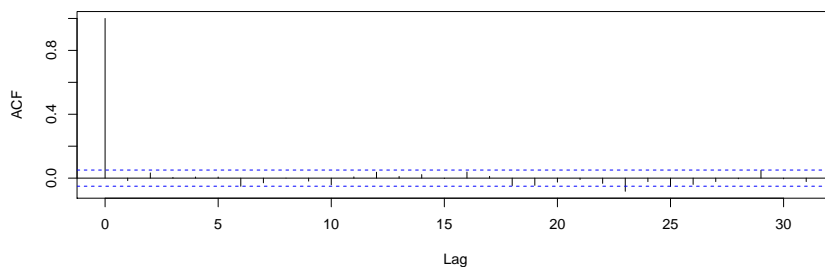
Figure 4.8: The figure shows the autocorrelation function for the residuals of the estimated AR(1) process. It should be noticed that there are no significant changes between this and the autocorrelation function of the AR(6) model seen in figure 4.6.
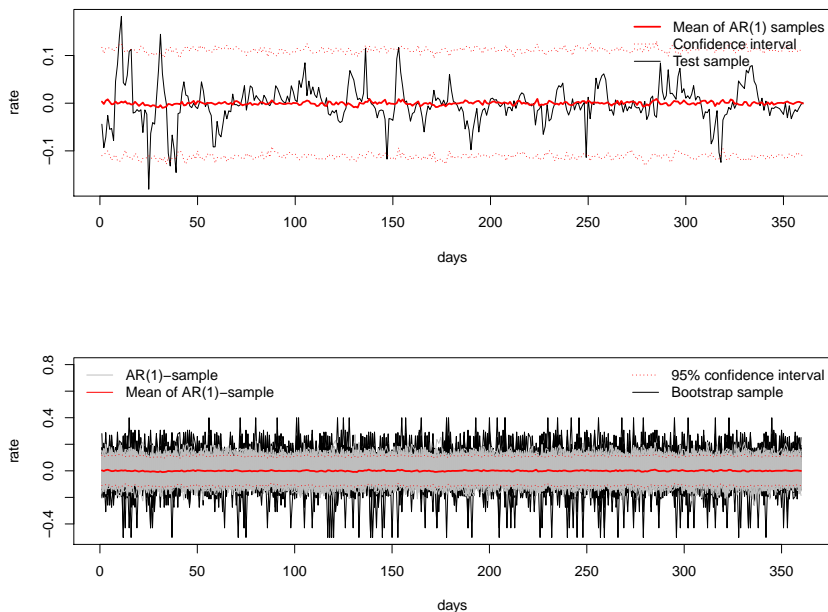
Figure 4.9: The figure shows the generated sample from the fitted AR(1) process compared with the bootstrap sample and the test sample.

4.4   Analysis of AR(1) sample.

Now it remains to analyse the sample from the autoregressive process just derived. There are two things to look for. One thing is to compare the AR(1) sample with the bootstrap sample and analyse whether the complexity introduced in the scenarios can be justified. Another thing is to look at how the scenarios from the AR(1) process performs compared to historical records, and whether another modelling framework than autoregressive process seems likely.

In figure 4.9 250 realizations of the derived AR(1) process is depicted. It shows that the volatility in the generated samples from the AR(1) process gets smaller than the volatility of the bootstrap sample, which means that the AR(1) process seems to gives more reliable estimates of future expectations in the rates.

In figure 4.10 the comparison of the variance on the generated AR(1) process sample and the generated bootstrap sample is depicted, for each day. It again

	Positive values	Shift in sign
Bootstrap samples	43.86%	47.76%
AR(1) samples	49,89%	34.46%

Table 4.4: The tables shows the fraction of positive values and shift in signs in the computed bootstrap sample and AR(1)-sample.
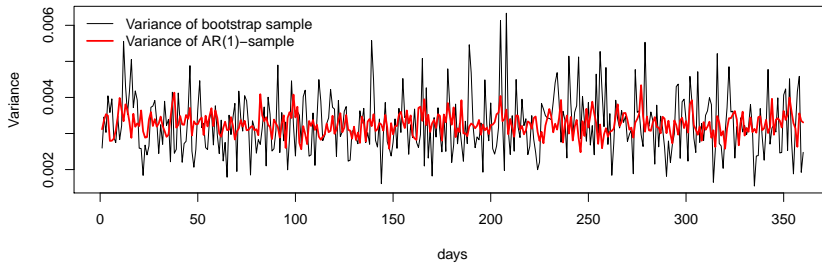
Figure 4.10: The figure shows the variance of the fitted AR(1) process compared with the variance of the bootstrap sample.

shows that the volatility in the variance estimates is much lower in the autoregressive process sample, which results in more reliable estimates of the rates. Looking at figure 4.11, though, seems to give some enormous price developments, when using the rates of the AR(1) process. Indeed, it is seen that the bootstrap samples are performing better than the AR(1) samples, compared to the test sample. The reason for this can be found in table 4.4, where it shows that the AR(1) samples do take more positive rates than the bootstrap samples does, which gives more positive development in the prices. Furthermore it is seen that the samples of the AR process does not shift sign as often as the bootstrap sample does. This indicates that when a positive value is hit, then the process keeps on being positive in longer times, giving the price sample the high positive developments seen in the figure. In chapter 3 it was noticed that there was some volatility clustering in the sample, this was also seen in the time series plot of the residuals of the autoregressive process (figure 4.6). This indicates that there could be some kind of structure in volatility that can be captured by a another model framework than an auto regressive process.
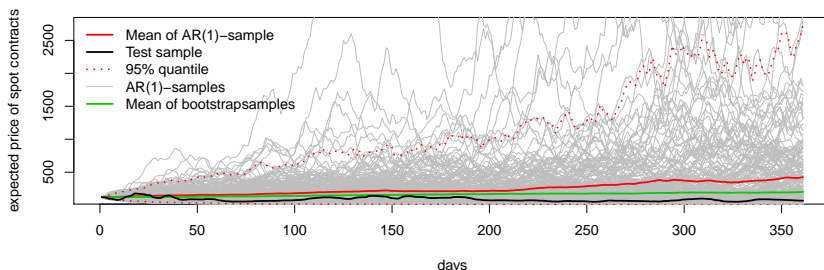
Figure 4.11: The figure shows the estimated price samples from the AR(1) process compared with the bootstrap sample and the test sample.

4.5 ARMA-GARCH computation

A generally high volatility is a common observation in financial data, and the mentioned volatility clusters are a result of dependence on past volatility as well as dependence on past observations, which has also been documented in surveys of financial return series [Eng82] and [Bol07]. These characteristics of financial data are similar to the characteristics of prices in the electricity market, c.f. description of data in [RCGG05]. For electricity price forecast various models have been applied [RCGG05]. These found that the GARCH framework outperforms the general time series ARIMA model framework when volatility and price spikes are present, as is observed in the present data sample. Based on the volatility clustering depicted in Figure 3.3 and 4.6, as well as lessons from the above mentioned studies, a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) process is applied.

The GARCH process was originally proposed by Engle in [Eng82] as an ARCH(q) process, and in 1986 generalised by Bollerslev in [Bol07] to the more generalised form applied in this analysis. The mean term structure is of a more generalized form in Bollerslev's model description than what is used in this analysis. In this thesis the mean term structure is chosen as a pure autoregressive process, as described in previous chapter. The ARMA-GARCH $((m, 0) \times (p, q))$ process is

then defined as

$$r_i = \sum_{j=1}^{m} \phi_j r_{i-j} + \epsilon_i, \quad \epsilon_i \mid \psi_{i-1} \sim N(0, \sigma_i^2) \tag{4.6}$$

$$\sigma_i^2 = \omega + \sum_{j=1}^{q} \alpha_j \epsilon_{i-j}^2 + \sum_{i=1}^{p} \beta_j \sigma_{i-j}^2 \tag{4.7}$$

where

$$q > 0, \quad p \geq 0$$
$$\omega > 0, \quad \alpha_i \geq 0, \quad i = 1, \ldots, q$$
$$\beta_i \geq 0, \quad i = 1, \ldots, p$$

ARMA	GARCH	$\hat{\phi}$	$\hat{\omega}$	$\hat{\alpha}_1$	$\hat{\beta}_1$	$\hat{\beta}_2$	AIC
(1,0)	(1,2)	0.53	0.00	0.07	0.39	0.54	-3.42
(1,0)	(1,1)	0.52	0.00	0.05	0.95	-	-3.41
(1,0)	(1,0)	0.61	0.00	0.76	-	-	-3.32
(0,0)	(1,1)	-	0.00	1.00	0.21	-	-3.22
(0,0)	(1,0)	-	0.00	1.00	-	-	-3.14

Table 4.5: The table shows the fitted ARMA-GARCH processes.

The software used to estimate the processes is the `fGarch` package in `R`, specifically the `garchFit()` function is used. This function can possibly operate with four different optimisation algorithms in the likelihood maximisation, namely `nlminb`, `lbfgsb`, `nlminb+nm` and `lbfgsb+nm`. In [Hel12] the performance of the different algorithms is analysed on dayli returns of financial funds. It is here seen that the algorithm `lbfgsb` outperforms the other algorithms, which is why this is the one chosen to do estimation of the GARCH process in this thesis.

The AR part of the ARMA-GARCH process has been taken its origin in the analysis just derived in the previous chapter. The modelling selection of the ARMA-GARCH process is therefore started out by choosing the ARMA part of the process as a pure AR(1) process. The model selection process for finding the most adequate model describing the model sample, is hereafter done using a forward selection method. A forward selection method is to determine whether it is sufficient with the model order achieved or whether an increase in model order can be justified. The model order is the number of parameters in the model. The selection criteria is to choose the fitted process that minimizes the Akaike Information Criteria (AIC) value. Therefore, a model with increasing model order and decreasing AIC value, which has all parameters significant,

will be accepted as a more adequate model as the one it is compared against. When the model order cannot be increased any more without increasing the AIC value or making parameters insignificant, then the best model has been achieved. Subsequently a backward selection method is used. This is to determine whether a model with lower model order exist, which describes data as good as the model achieved relatively to the decrease in model order. The models is compared with the AIC value, which is defined as

$$2n - 2\log(L(\hat{\theta}))$$ (4.8)

where n is the number of estimated model parameters, and L is the likelihood function with parameters θ. The fitted models can be seen in table 4.5 and will be analysed in the next chapter. In table 4.5 it is seen that the most adequate ARMA-GARCH model fitted, the one with the lowest AIC value, is the $(1, 0) \times (1, 2)$.

	$\hat{\theta}$	$\sigma_{\hat{\theta}}$	t value	$\Pr(>|t|)$
$\hat{\phi}$	0.53	0.03	19.85	0.00
$\hat{\omega}$	0.00	0.00	3.70	0.00
$\hat{\alpha_1}$	0.07	0.01	7.42	0.00
$\hat{\beta_1}$	0.39	0.11	3.58	0.00
$\hat{\beta_2}$	0.54	0.11	5.10	0.00

Table 4.6: The table shows the estimates of the most adequate ARMA-GARCH (1,0)x(1,2) process.

4.6 Analysis of ARMA-GARCH sample

Now it remains to analyse the ARMA-GARCH process derived in the previous chapter. The one thing that should be analysed is the residuals and how they perform. In figure 4.12 the residuals as a time series are plottet. What should be noticed here is that they look much like the residuals from the AR process in figure 4.6. The same test for normality, as with the AR process, has been performed and there is no significant changes in results. From the residual analysis it does not seem as if the volatility clustering is captured by the GARCH process as expected.

A scenario sample of 250 realizations of the fitted ARMA-GARCH process has been computed, with a burn off period on 100 time steps. In figure 4.13 the realizations of the process together with the test sample is depicted. Again it shows that the samples look much the same as the autoregressive samples. The
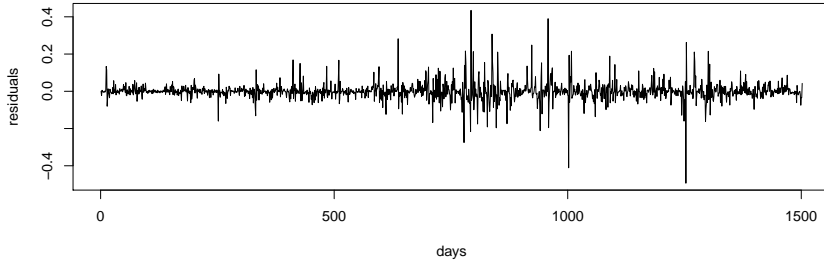
Figure 4.12: The figure shows the residuals for the ARMA-GARCH $(1, 0) \times (1, 2)$ process.
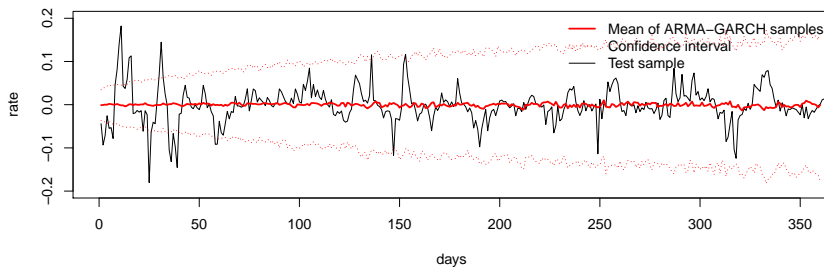
Figure 4.13: The figure shows the generated samples of rates from the ARMA-GARCH process.

difference is found in the confidence interval, which is a increasing function of the time. The price sample has then been computed, which can be seen in figure 4.14. The differences seen between the expected prices arrived from the AR process and the GARCH process, seems to be that the GARCH process controls the volatility in prices at the beginning of the period better than the AR process do. Furthermore, it shows that the volatility increase doing the time, in the GARCH computed prices, into a level that is higher than obtained in the case of the AR process.

The general limitations of the GARCH framework include first of all the assumption that only the magnitude and not the sign of the lagged error determines the conditional variance going forward. This has been proven wrong, as evidence is
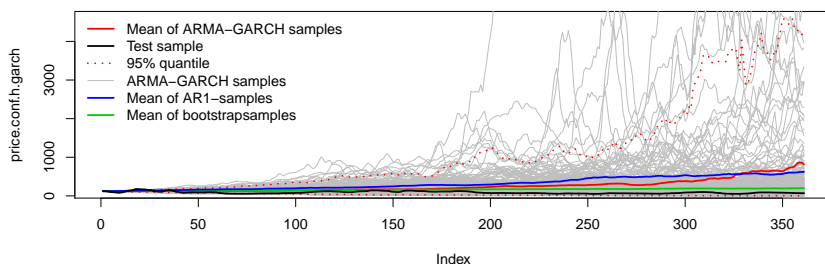
Figure 4.14: The figure shows the generated samples of prices from the
ARMA-GARCH process.

found that volatility tends to rise in response to bad news (negative error) and
to fall in response to good news (positive error) [Nel91]. A technical concern
is the model parameters, on which a non-negativity constraint is imposed to
enforce a positive conditional variance. If a GARCH model is estimated on a
time series that contains parameter changes in the conditional variance process
and these parameter changes are not accounted for, a distinct error in the es-
timation occurs: The sum of the estimated autoregressive parameters of the
conditional variance converges to one. Simulations of the GARCH model show
that the effect occurs for realistic parameter changes and sample sizes for finan-
cial volatility data [Hil05]. Lastly, it is not possible to include time dependent
parameter values. This is to some extent accounted for by the time varying
conditional variance.

4.7   Conclusion

Given the results found in the analysis done in the present chapters, the most
adequate framework of computing expectations of freight rate prices must be
the bootstrap sampling procedure.

There has not been found any evidence that the ARMA-GARCH process be-
haves significantly better than the pure autoregressive process, examined in the
previous chapters. It seems as if the GARCH process does not capture the
volatility clustering as expected. Therefore it makes no sense to choose the
GARCH modelling framework when computing the scenarios. On the other
hand, it has been demonstrated that the autoregressive process does compute

	Positive values	Shift in sign
Test sample	43.29%	22.60%
Bootstrap samples	43.86%	47.76%
AR(1) samples	49.89%	34.46%
ARMA-GARCH samples	50.57%	14.89%

Table 4.7: The tables shows the fraction of positive values and shift in signs in the computed samples comparing the different methods with the test sample.

scenarios that have a to positive trend than what is experienced in the test sample. Therefore none of these statistical frameworks seems adequate when generating scenarios on expectations of freight rate prices. In table 4.7 the properties of the different computed samples are compared with the test sample. The comparisons are made on the fraction of positive values and how often the values of the rates shifts in signs. The more positive values and less sign shifts the sample takes, gives a more positive trend in the price development. In the table it shows that the autoregressive process and the GARCH process do take too many positive values making the price process too positive. On the other hand, they seem to estimate the shift in signs lower, which indicates that when the price process is positive it turns positive in longer time, giving the price process a to positive mean term.

Other methods in predicting freight rates could be examined. In the literature of modelling VLCC tanker freight rates, it is proposed to use neural networks [MM10] and [JL06]. This framework does not give any statistical knowledge of the time series, but is a black box framework that can be used to compute samples of scenarios. The framework of using Neural networks has been deselected in this thesis, because some trials on using it in the industry has had some different results not giving a sufficient goodness of fit compared with the GARCH modelling framework. Furthermore, it is stated in [MM10] that the framework of predicting freight rates in the tanker business is not studied enough to make decisions on a model framework that is precise enough. The framework of predicting freight rates could also be expanded by looking into regime shifting processes or Hidden Markov models. The fact that some volatility clustering has been found in the model sample gives reasons to look these types of frameworks, which is very powerful statistical tools. For this thesis the analysis will stop here, and the scenario generation will be performed with the bootstrap method, computing the best estimates of the future level of spot prices.

Part II

Optimal freight rate management.

CHAPTER 5

Scenario generation

The aim of this chapter is to apply the framework derived in chapter 4 for generating monthly scenarios of freight rates. The scenarios are to be applied towards robust asset allocation when managing tanker freight rates using FFA contracts.

A scenario is a value of a discrete stochastic variable X_l representing uncertain data together with the associated probability $p^l \geq 0$. Each scenario is indexed by l from a sample Ω, and the probability satisfy $\sum_{l \in \Omega} p^l = 1$. Scenarios are a convenient and natural way of representing uncertainty in a model. They can be generated in several ways, for instance, with Monte Carlo simulations, by bootstrapping the sample of observations, or by more advanced stochastic models capturing different types of structures in the original data sample, eg. an autoregressive model capturing the mean structure. The stochastic modelling framework gives a huge range of different ways of computing the scenarios in more or less advanced ways. However, it will only make sense to use an advanced stochastic model if the improvement in choosing the scenarios with such a model corresponds to the complexity introduced by the model in the scenario generation. Said in another way, it will never be reasonable to describe a problem in a more complex way than necessary.

When making financial decisions of managing spot rates on the tanker freight market, the board of decision makers has to make the decision whether a future

spot position should be hedged or not. This is done by taking long or short positions in the spot market using FFA contracts. Spot contracts are managed in a discrete framework. When the contract is agreed between the parties, a chartering period for a vessel is settled, and then the vessel cannot be chartered before it comes open again; this is when the agreed voyage contract expires. FFA contracts are settled against the average of an entire month. When hedging spot contracts on a given future point in time, one has to buy a FFA contract covering the month where the future spot contracts are settled. How FFA contracts are settled was more precisely described in chapter 2. A portfolio can then be put together as a collection of decisions on trading spot contracts and corresponding FFA contracts.
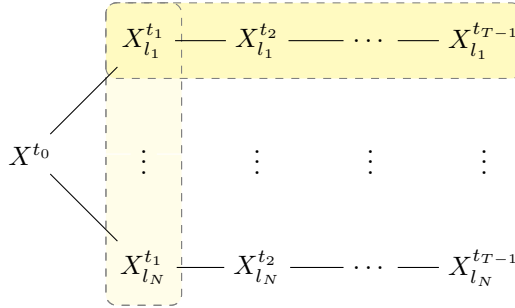
Figure 5.1: Linear scenario tree for a one stage stochastic model.

The portfolio decisions, which are decided today (at t_0) with respect to the knowledge provided from the simulated scenarios, can be divided into a finite number of points in time. The spot trading dates, extend from today t_0 until t_{T-1}, the last date before the end of the planning horizon T. It is then assumed that nothing happens in between trading dates. No portfolio decisions are made, and no contracts are settled. It is furthermore assumed, that at each future trading date a finite number N of states of the economy is possible. Each scenario will then exist of T states defined as $X_l = (X_l^t)_{t \in (t_0, \dots, t_{T-1})} = (X_l^{t_0}, X_l^{t_1}, \dots, X_l^{t_{T-1}})$, where $X_l^t \in \Sigma_t$ for all $t \in (t_0, \dots, t_{T-1})$ and $l \in \Omega$. Each state X_l^t with $t > t_0$ in the scenario stores the new information that arrives at the corresponding trading date, ie. the price information on spot contracts and FFA contracts in the period from $t_{\tau-1}$ to t_τ. The value of the portfolio can then be determined uniquely at each state in the scenarios. The entire scenario framework used in this thesis is visualized as a linear scenario tree in figure 5.1.

The states of each scenario are defined as $X_l^t = (a_l^t, b_l^t, f_l^t)$, where $a_l^{t_\tau}$ is the average spot price from trading date $t_{\tau-1}$ to t_τ, b_l^t is the price, which one can settle a spot contract at trading date t, and $f_l^{t_\tau}$ is the purchase price of a FFA

contract, which is bought today (t_0) and settled at time t_τ. The initial trading date t_0 (today) is a special case of scenario states, also known as the root node in the scenario tree. Here the average spot price $a_l^{t_0}$ and the FFA price $f_l^{t_0}$ are always 0. The price of a spot contracts settled at the initial date $b_l^{t_0}$ is known and can therefore not be hedged, which is why the FFA price does not exist. This is the only point in time where the spot price is known with certainty, all future spot prices are uncertain and are a realization of the chosen stochastic modelling framework. Furthermore, the state at the initial date is the only state where FFA trading is allowed. All trading for the entire planning horizon is therefore made/ planned at this time.

5.1   Bootstrap Computation

In chapter 4 the bootstrap procedure were found to be the best way of computing expectations on future spot prices. The bootstrap sample is computed directly from the set of rates R_{model} in an iterative way running for each $\tau \in \mathcal{T}$. The scenarios are running with a period of one month, where it is assumed that one month consists of 20 working days. The price development in a period of one month is therefore computed from 20 dayli rates. It is known that in reality a month does not always consists of 20 working days and therefore the dates t_τ will not always have a distance of exactly one calendar month. The implementation of the bootstrap computation can then be divided into two parts; an initial part and an iterative part running for each τ.

The initial part of the bootstrap implementation can be divided into:

- First choose a starting date t_0. This is choosing the date where the scenario generating should be originated from, and update the initial states of the scenario by

$$a_l^{t_0} = 0 \quad \forall l \in \Omega \tag{5.1}$$

$$b_l^{t_0} = p_{i|d_i = t_0} \quad \forall l \in \Omega \tag{5.2}$$

  The initial state is the same for all scenarios with starting date t_0. The generated scenarios should be tested against the test sample when back testing the allocation model, therefore it is reasonable to choose the starting date as $t_0 = d_{1503} = $01-04-2006. The planning horizon should also be set. Each bootstrap sample is generated with a length of 72 months. But the time horizon for hedging opportunities in the spot market only runs 18 months ahead. Therefore, the planning horizon T will be set to 18.

- The number N of scenarios that should be generated, should also be set, and then construct the set of indices $\Omega = \{l_1, \ldots, l_N\}$. In this implementation $N = 250$.

The iterative part of the bootstrap implementation running for each τ can be divided into:

- For each $l \in \Omega$ construct a set $\Gamma_l = \{i_k\}_{k \in \{1,\ldots,20\}}$ of 20 random integers i_k chosen from the set $\{i \mid 1 < d_i < t_0\}$, using the `uniformint` function in GAMS. Where i is chosen with the constraint $1 < d_i < t_0$, because we do not know the price development for $i = 1$, and neither do we know the price development in the future. It is here assumed that t_0 is today. If we knew the price development after this date it would not be reasonable to compute it by estimating it with the bootstrap! The reason for choosing 20 numbers is because it is assumed that one month's price development consists of 20 dayli rates of developments.

- Each state in the scenario is now updated by choosing the developments with index from the random generated index set Γ_l, by first computing the expectations of the prices in the period from $t_{\tau-1}$ to t_τ.

$$\hat{p}_l^1 = b_l^{t_{\tau-1}} \tag{5.3}$$

$$\hat{p}_l^{k+1} = \hat{p}_l^k \cdot r_{i_k} \quad \forall i_k \in \Gamma_l \tag{5.4}$$

Then all information used to generate the expectations at each scenario state at time t_τ is known and can be calculated as

$$\hat{a}_l^{t_\tau} = \frac{1}{20} \sum_{k=1}^{20} \hat{p}_l^k \tag{5.5}$$

$$\hat{b}_l^{t_\tau} = \hat{p}_l^{21} \tag{5.6}$$

Each of these calculations are done for all $l \in \Omega$. The prices of the forward contracts in the scenarios are updated from the observed market prices known at time t_0 and settled at t_τ.

When running this iterative process for all $\tau \in \mathcal{T}$ the bootstrap method has computed N scenarios with a horizon of T months as shown in figure 5.1. Because the indices in Γ are sampled from a uniform distribution, every index in Ω has the same probability of being chosen. Therefore each scenario has the same probability $p^l = \frac{1}{N}$. Having the probability defined in this way, makes it meet the constraint $\sum_{l=1}^{N} p^l = \sum_{l=1}^{N} \frac{1}{N} = 1$

CHAPTER 6

FFA allocation

Wisdom consists in being able to distinguish among dangers and make a choice of the least harmful.

Niccoló Machiavelli

Studies have shown that asset allocation is the most significant factor when determine the performance of a portfolio. When deciding on the asset allocation, the shipping company must have an investment strategy, including a risk profile. The investment strategy is a set of rules, set up by the company, to determine the limits on the amounts of contracts to trade and when to trade them. The risk profile is determined by factors such as tolerance for loss and risk averseness in regards to gains and losses of the company. In this chapter the allocation algorithm is explained and the results from optimizing the model on the computed scenarios, is examined. The algorithm is used to make optimal decisions on the amount of FFA contracts to allocate into the portfolio, i.e. the amount of future spot positions to hedge. The optimal allocation is determined with different trading strategies and risk profiles. It is then examined how each of the trading strategies are performing compared to historical movements, by doing back tests on the suggested portfolios.

Why should a tanker company at all enter into the forward market? A shipping company sells a freight service, and for that purpose owns tanker vessels. When

a vessel is open, the shipping company needs to close its position to get the costs covered. Conversely, when a vessel is chartered, then it is not able for the tanker company to charter it out again, before it comes open, no matter how high the spot market goes. Therefore, the tanker company has no opportunity to change its position dynamically and take advantage of knowledge or movements in the spot market. The company is restricted to the physical vessels needed to sell their service. The spot positions can only be changed dynamically by entering into financial derivatives, such as FFA's. More on this subject was presented in chapter 2. The purpose of a shipping company to enter the forward market is basically because of hedging opportunities. Hedging in the meaning to make an investment to reduce the risk of adverse price movements in an asset, where risk is related to uncertainty in the future level of spot prices. Normally, a hedge consists of taking an offsetting position in a related security, such as a forward contract, fixing the risk profile on a certain level.

Reality is often too complex to handle in a single model, therefore some restrictions on reality has to be made to make it fit into a model. The scenario, which the model is built upon, is as follows: A shipping company wants to cover their risk exposure on the spot market in an efficient way, using FFA contracts. The company therefore wants to determine an efficient trading strategy on FFA contracts. This is done on the 1st working day in the year (03-01-2006). The strategy then runs 18 months ahead. It is assumed that the company sells all capacity of freight service at the spot price quoted on the first day (03-01-2006) in the scenario. Furthermore it is assumed that a voyage has a length of exactly one month, making the next settlement of freight service happening at the price quoted the first working day of the second month (01-02-2006). Making the scenario run for 18 months, results in 18 trading dates, which is a simple approximation of the reality, where spot trading is done more often. The allocation algorithm then makes decisions on, whether or not it is worth able for the company to hedge a future spot position with forward contracts.

The algorithm used when making decisions on optimal asset allocation, is an one stage stochastic programming model proposed by Stavros in [Zen07]. The model chooses the allocation of FFA contracts on a trade-off between optimal expected income and minimal downside risk exposure. When entering into a FFA contract the company fixes a future spot price, which decreases the downside risk exposure of the entire portfolio. The decrease in risk exposure has a price, in most cases of decreased expected income. If a FFA contract is priced high, it might get a gain both in downside risk exposure and expected income, so the model should always allocate this contract into the portfolio. The risk exposure is measured as Conditional Value at Risk (CVaR), which is more carefully explained in section 6.1. The model, which chooses the optimal asset allocation

is then defined as.

$$\max_x \quad (1-\lambda)\frac{1}{N}\sum_{l\in\Omega}\sum_{\kappa\in K,t_\tau\in\mathcal{T}}\mu_{\kappa,l}^{t_\tau}x_\kappa^{t_\tau} - \lambda\xi \tag{6.1}$$

subject to

$$\xi = \zeta + \frac{\sum_{l\in\Omega}p^l y^l}{1-\alpha} \leq \omega \tag{6.2}$$

$$y^l \geq L_l(x) - \xi \quad \forall l \in \Omega \tag{6.3}$$

$$y^l \geq 0 \quad \forall l \in \Omega \tag{6.4}$$

$$x_{spot}^{t_\tau} = 1 \quad \forall t_\tau \in \mathcal{T} \tag{6.5}$$

The stochastic programming model maximizes the expected average portfolio income, which is defined as the average portfolio income from the N scenarios generated by the bootstrap procedure. The expected income from each scenarios is defined as the sum of expected pay-off's from all contracts over the entire planning horizon. The expected average portfolio income therefore becomes; $\frac{1}{N}\sum_{l\in\Omega}\sum_{\kappa\in K,t_\tau\in\mathcal{T}}\mu_{\kappa,l}^{t_\tau}x_\kappa^{t_\tau}$. The pay-off parameter $\mu_{\kappa,l}^{t_\tau}$ is defined as;

$$\mu_{\kappa,l}^{t_\tau} = f_l^{t_\tau} - a_l^{t_\tau} \quad \forall l \in \Omega$$
$$\mu_{spot,l}^{t_\tau} = b_l^{t_\tau} \quad \forall l \in \Omega$$

The parameter λ determines the risk profile. Choosing λ near 1 makes the model only minimize the downside risk exposure, thereby giving the company a risk averse profile. Choosing λ near 0 makes the model only maximize the expected income, thereby giving the company a risk neutral profile. Choosing λ in between gives the company a trade-off between expected income and downside risk exposure and thereby a relative risk profile. The loss function $L_l(x)$ is determined as the amount of an investment that can be lost, which normally is defined as $L_l(x) = V_0 - \hat{V}_l(x)$ where V_0 is the upfront investment and $\hat{V}_l(x)$ is the expected portfolio value at scenario l. In this case no upfront investment is made, because the contracts traded are either swap agreements, which is an agreement to swap cash flows at settlement, or spot contracts, which trades a freight service into a cash flow. Therefore no loss of investment will be experienced in the trading strategies. The loss function are therefore defined as minus the expected portfolio value at each scenario, ie;

$$L_l(x) = -\hat{V}_l(x) = -\sum_{\kappa\in K,t_\tau\in\mathcal{T}}\mu_{\kappa,l}^{t_\tau}x_\kappa^{t_\tau} \quad \forall l \in \Omega \tag{6.6}$$

Equation 6.6 defines the loss function $L_l(x)$ as the sum of expected pay-off's, which makes the loss function a linear function. Stavros describes in [Zen07]; when the loss function is defined as a linear function, then the entire stochastic

programming model defined in 6.1 becomes a linear model. The purpose of this thesis is to develop a modelling framework as a practical decision support tool, for managing VLCC chartering. This is to develop an optimal trading strategy, such that a shipping company can control their risk exposure on the spot market. It therefore only makes sense to take long positions in the forward market, i.e. $x_\kappa^{t_\tau} \geq 0$. It has been chosen to show the amounts of allocated FFA contracts as a percentage of the future amount of spot contracts, settled in the same period as the FFA contract. Therefore $x_\kappa^{t_\tau} = 0$ means that the amount of purchased FFA contracts with settlement date t_τ is 0, no FFA contracts are purchased, therefore the income at time t_τ is only determined by the spot price. Conversely $x_\kappa^{t_\tau} = 1$ means that it is proposed by the model to purchase an amount of FFA contracts which corresponds to fixing the entire spot position at time t_τ, making a full hedge. It is assumed that the shipping company always sells full capacity of spot contracts, i.e. fixing $x_{spot}^{t_\tau} = 1$.

Investment strategies can differ greatly from a rapid growth strategy, where an investor focuses on capital appreciation, to a safety strategy where the focus is on wealth protection. The most important part of an investment strategy is that it aligns with the individual company's goals and is closely followed by the portfolio managers. In this thesis 3 different trading strategies supporting the need for hedging risk exposure in the spot market are compared, these are;

- **No hedge**. In this case no forward contracts are purchased, which makes the portfolio income determined only by the level of the spot market at the time of purchasing. The strategy is implemented into the model by expanding the model constraints on the holding parameter $x_\kappa^{t_\tau}$ by;

$$x_\kappa^{t_\tau} = 0 \quad \forall \kappa \in K \setminus \{\text{spot}\} \tag{6.7}$$

- **Full hedge**. This strategy is the opposite to the no hedge strategy. In this case the shipping company always takes long positions in forward contracts covering all possible exposures in the spot market, no matter how high or low the expected gain or loss from entering into the forward market is. The model constraints on the holding parameter $x_\kappa^{t_\tau}$ is therefore changed to;

$$x_\kappa^{t_\tau} = 1 \quad \forall \kappa \in K \tag{6.8}$$

- **Dynamic hedge**. This strategy gives the allocation model the possibility to cover exposures in the spot market by taking long positions in the forward market. Contrary to the two other strategies, this is a dynamic strategy, which gives the model the possibility to allocate forward contracts in the portfolio, only if the pay-off is worth able. The limits set up ensures

that the amounts covered never exceed the amount of spot contracts. The model constraints on the holding parameter $x_\kappa^{t_\tau}$ is therefore changed to;

$$0 \le x_\kappa^{t_\tau} \le 1 \quad \forall \kappa \in K \tag{6.9}$$
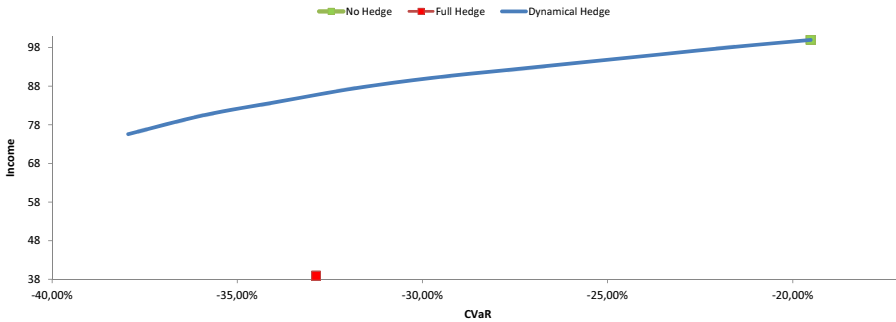
Figure 6.1: The figure shows the efficient frontiers of the 3 different trading strategies, on portfolios chosen with initial data 03-01-2006.

Performance is a relative concept, and therefore has to be measured against some kind of fixed level that can be related to by the reader. One important subject of this thesis is how a shipping company can benefit from entering into the forward market of FFA's. The income of a strategy is therefore chosen to be measured against the no hedge strategy, making the income of the no hedge strategy indexed by level 100. A portfolio with an expected income indexed below 100, implies that the expected income of that strategy is less than the expectations if the shipping company had not entered the forward market, and vice versa. In table 6.1 it is seen that the full hedge strategy gives an expected income of index 38.88, which means that the expected income of the portfolio is 38.88% of the expected income compared to not entering the forward market. The downside risk is measured by the CVaR on a 99% probability level. The CVaR measures the relative losses the company can expect from following the strategy, compared to the expected income from not entering the forward market. Because no initial investments are made all CVaR becomes negative and therefore, in reality, measures the expected income on a 99% probability level. In table 6.1 it is seen that the no hedge strategy has a CVaR at -19.51, which means that in the 1% worst cases the shipping company can expect an average income of index 19.51 compared to the expectation in the spot market. It is also seen in table 6.1 that the full hedge has a CVaR at -22.87, which means that in the 1% worst cases the company can expect an average income of index 22.87.

Month	Contract	No hedge strategy	Full hedge strategy
Jan - 06	FFA_M0/FFA_Q0	0/0	1/0
Feb - 06	FFA_M1/FFA_Q0	0/0	1/0
Mar - 06	FFA_M2/FFA_Q0	0/0	1/0
Apr - 06	FFA_M3/FFA_Q1	0/0	0/1
May - 06	FFA_M4/FFA_Q1	0/0	0/1
Jun - 06	FFA_M5/FFA_Q1	-/0	-/1
Jul - 06	FFA_Q2	0	1
Aug - 06	FFA_Q2	0	1
Sep - 06	FFA_Q2	0	1
Oct - 06	FFA_Q3	0	1
Nov - 06	FFA_Q3	0	1
Dec - 06	FFA_Q3	0	1
Jan - 07	FFA_Q4	-	-
Feb - 07	FFA_Q4	-	-
Mar - 07	FFA_Q4	-	-
Apr - 07	FFA_Q5	-	-
May - 07	FFA_Q5	-	-
Jun - 07	FFA_Q5	-	-
Expected income		100	38.88
Downside risk		-19.51	-22.87

Table 6.1: The table show the holdings of FFA contracts in the portfolio from the No hedge and Full hedge strategies. The contracts FFA_M5,FFA_Q4 and FFA_Q5 are not present at the initial date and can therefore not be allocated into the portfolio.

Financial optimization models are used to generate a set of portfolios that assume the smallest possible risk for a given amount of reward, or conversely, the highest reward for a given amount of risk. Such portfolios are called efficient and lie on the efficient frontier. The efficient frontier visualizes the relative performance in reward with respect to the downside risk exposure. In figure 6.1 the efficient frontier has been made for each of the 3 hedging strategies. The frontiers has been made by optimizing the model with 10 different values of λ in between 0 and 1. The values of λ has been chosen such that the CVaR value has equal distance. The no hedge and full hedge strategies are seen in figure 6.1 as single points, which is as expected. Changing the λ parameter for these strategies does not imply any changes because the holding parameter $x_\kappa^{t_\tau}$ is fixed for all risk profiles. Furthermore it is seen that the no hedge strategy is the one with the largest downside risk exposure and expected income, as expected from an theoretical point of view.

The dynamic hedge strategy is visualized in figure 6.1 as the blue line, arising from the no hedge strategy, and decreasing in expected income as CVaR decreases. It is here seen that when choosing λ close to 0, the model only optimizes income and thereby determines the no hedge strategy, because none of the FFA contracts have an expected positive pay-off. If the expected pay-off from a FFA contract was positive, the model would always allocate it in the portfolio, which makes the expected income of the portfolio exceed index 100. This would be the case, if the FFA market expectations were more positive than the expectation derived from the generated scenarios. In figure 6.1 it is furthermore seen that the efficient frontier is a increasing function of the CVaR, when the downside risk increases then the expected income increases. An interesting observation to see in figure 6.1 is, that the full hedge strategy lies below the efficient frontier. This means that a portfolio exists with the same down side risk exposure but with a higher expected income, which would be more optimal to choose for the shipping company. Furthermore it is seen that the shipping company can obtain a smaller down side risk exposure when using the dynamic strategy than the one obtained by the full hedge strategy. The difference between portfolio holdings in the risk averse portfolio and the full hedge portfolio, is only on the FFA_M0 contract. The difference in risk exposure can therefore be explained by the high expectations of the first month in the spot market (average 295 ws) relative to the expectations in the forward market (110.4 ws), i.e. one would expect to loose to much when entering the FFA_M0 contract, and thereby the model does not allocate it in the portfolio obtained by the dynamic strategy.

The optimal holdings proposed by the allocation model for the different strategies can be seen in table 6.1 and 6.2. The numbers in the tables indicate the amount of future spot contracts that should be covered. In table 6.2 the strategy is divided into 10 portfolios, each with a different risk profile (RP). RP 1 is the risk neutral profile, where $\lambda = 0.001$, the other risk profiles let λ increase until the RP 10 profile, which is the risk averse profile setting $\lambda = 0.999$.

Month	Contract	RP 1	RP 2	RP 3	RP 4	RP 5	RP 6	RP 7	RP 8	RP 9	RP 10
Jan - 06	FFA_M0/FFA_Q0	0/0	0.00/0	0/0.00	0/0.00	0/0	0.00/0	0.00/0	0/0	0/0	0.35/0
Feb - 06	FFA_M1/FFA_Q0	0/0	1.00/0	1/0.00	1/0.00	1/0	1.00/0	1.00/0	1/0	1/0	1.00/0
Mar - 06	FFA_M2/FFA_Q0	0/0	0.91/0	1/0.00	1/0.00	1/0	1.00/0	1.00/0	1/0	1/0	1.00/0
Apr - 06	FFA_M3/FFA_Q1	0/0	0.00/0	0/0.00	0/0.00	0/0	0.26/0	1.00/0	1/0	1/0	0.00/1
May - 06	FFA_M4/FFA_Q1	0/0	0.00/0	0/0.00	0/0.00	0/0	0.00/0	0.69/0	1/0	1/0	0.00/1
Jun - 06	FFA_M5/FFA_Q1	-/0	-/0	-/0.00	-/0.00	-/0	-/0	-/0	-/0	-/0	-/1
Jul - 06	FFA_Q2	0	0	0.00	0.00	0.00	0	0	0.33	0.75	1
Aug - 06	FFA_Q2	0	0	0.00	0.00	0.00	0	0	0.33	0.75	1
Sep - 06	FFA_Q2	0	0	0.00	0.00	0.00	0	0	0.33	0.75	1
Oct - 06	FFA_Q3	0	0	0.25	0.52	0.78	1	1	1.00	1.00	1
Nov - 06	FFA_Q3	0	0	0.25	0.52	0.78	1	1	1.00	1.00	1
Dec - 06	FFA_Q3	0	0	0.25	0.52	0.78	1	1	1.00	1.00	1
Jan - 07	FFA_Q4	-	-	-	-	-	-	-	-	-	-
Feb - 07	FFA_Q4	-	-	-	-	-	-	-	-	-	-
Mar - 07	FFA_Q4	-	-	-	-	-	-	-	-	-	-
Apr - 07	FFA_Q5	-	-	-	-	-	-	-	-	-	-
May - 07	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Jun - 07	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Expected income		100	98.2	96.2	94.2	92.2	90.1	87.5	84.1	80.5	75.6
Downside risk		-19.5	-21.6	-23.6	-25.7	-27.7	-29.8	-31.8	-33.9	-35.9	-38.0

Table 6.2: The table shows the holdings of FFA contracts in the portfolio from the dynamic hedge strategies. The contracts FFA_M5, FFA_Q4 and FFA_Q5 are not present at the initial date and can therefore not be allocated into the portfolio.

6.1 Risk assessment

Risk is a measure of uncertainty in decisions, capturing how bad future expectations can develop. It can be said that optimisation models in financial engineering are about managing risk by controlling the risk exposure in a way that is commensurate with the prospective rewards. Risk control can mean one of two things

1. Limit or totally eliminate specific types of risk.

2. Take an active position on one or more types of risk.

Different types of risk exist, such as market risk, operational risk or credit risk. An investor entering a new market area should relate to all types of risk to know their exposures. The work of this thesis will only be based on market risk, i.e. the exposure to losses experienced from price movements. A risk assessment technique often used to reduce the probability that a portfolio will incur large losses is CVaR. CVaR is typically performed by assessing the likelihood (at a specific confidence level) that a specific loss will exceed the value at risk (VaR). Mathematically speaking, CVaR is derived by taking a weighted average between the VaR and losses exceeding the VaR. This term is also known as Mean Excess Loss, Mean Shortfall or Tail VaR.
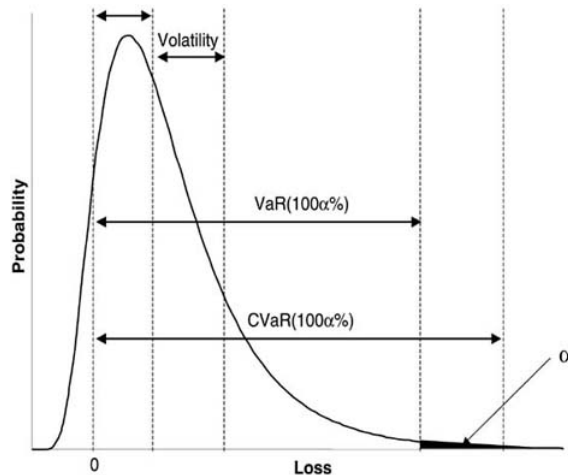
Figure 6.2: Distribution of losses and the quantities used in the definition of volatility, VaR and CVaR.[Zen07]

Other types of risk measures than CVaR exist. The most obvious risk measure, from a statistical point of view, is the volatility. The volatility is a statistical measure of the dispersion in losses. Volatility can either be measured by using the standard deviation or variance in expected losses. Commonly, the higher the volatility, the riskier the asset. The problem with using volatility as a risk measure in finance is, that it only provides knowledge about the most common losses. The volatility is visualised in figure 6.2, where it can be seen that the volatility measures the dispersion around the mean. The volatility provides no knowledge on what is happening in the tale distribution of the loss function, and thereby how big losses a company can expect when following a strategy. Another well known risk measure in finance, is the Value at Risk (VaR). The VaR is defined in [Zen07] as the α-quantile of the losses from the portfolio, i.e. the lowest possible value ζ such that the probability of losses less or equal to VaR is greater or equal to $100 \cdot \alpha\%$. The VaR is visualised in figure 6.2 as the α-quantile of the loss function. The VaR is commonly used in the financial world as a risk measure. And the use of VaR as a measure for supervision is advocated in the Basel Accord of the Bank for International Settlements. In the use of financial engineering for decision making, the VaR has some weaknesses. The VaR measures the tale distribution, but only until a certain level. The VaR does not indicate anything about losses that exceed the α-quantile. Furthermore, the VaR is difficult to optimize when calculated using discrete scenarios, as done in this thesis. The VaR function becomes nonconvex, nonsmooth, and has multiple local minima. However, CVaR is a risk measure that can be minimized using linear programming formulations as proposed by Stavros in [Zen07]. CVaR measures the average amount of losses that exceed the VaR. CVaR is defined by Stavros as the expected value of losses, conditioned on the losses being excess of VaR. The CVaR values in this thesis are calculated on a 99% probability level.

In figure 6.3 the loss functions for the different strategies are drawn. What is seen in the figures is that when the risk profile decreases, then the most common loss of the loss function decreases, and the distribution gets more compact around its mean, making the volatility, VaR and CVaR decrease.

CVaR is in the stochastic programming model defined as

$$\xi = \zeta + \frac{\sum_{l \in \Omega} p^l y^l}{1 - \alpha} \tag{6.10}$$

Where ζ is the VaR and $\alpha = 0.99$, making the probability level at 99%. The CVaR is then indexed as a percentage of the expected income from the no hedge strategy, like the expected income of the different strategies.
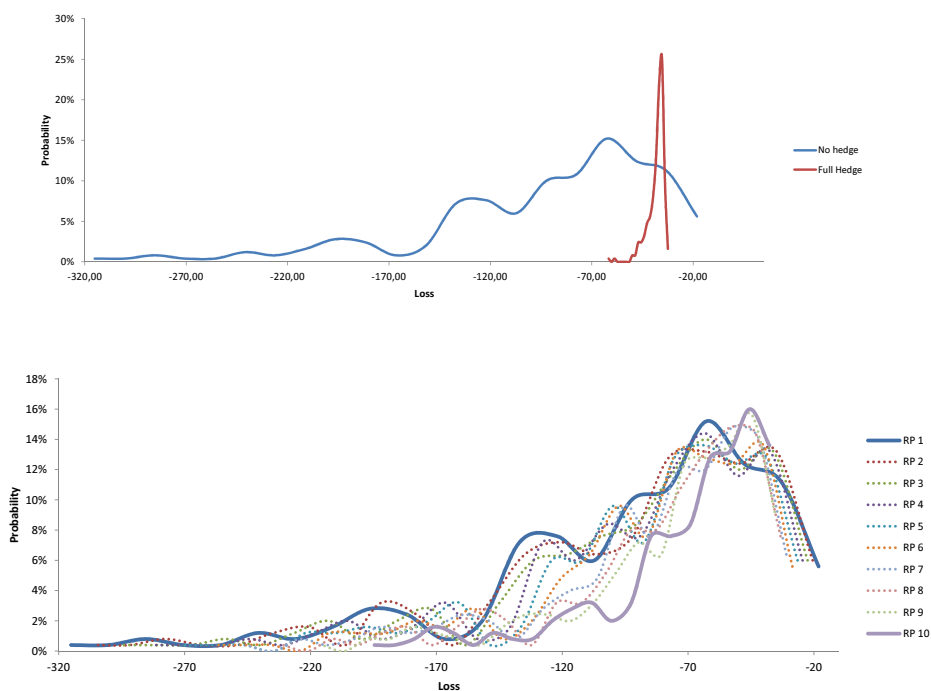
Figure 6.3: The figures illustrate the distributions of the loss functions for the different strategies.

6.2 Performance

It has now been examined how the model performs on one historical period, namely 2006. But one period is not enough to make conclusion on model performance. Therefore, the model has been optimized on different periods, each starting on the first working day in the year and running 18 months ahead. The set-up is the same as described for the 2006 period. The first period is 2006, as just examined, and the last is 2011. This results in 6 different optimizations to compare. The efficient frontiers of the dynamic trading strategies, for each period, can be seen in figure 6.4. The expectations on portfolio performance is visualized through the shape of the efficient frontiers. Obtaining a long frontier with low slope indicates that there is a high gain in expectations of entering into the forward market. Obtaining a short frontier indicates that there is a minor difference in expectations whether to enter into the forward market or not.

Obtaining a long frontier with high increasing slope indicates that one would expect to have a high decrease in income and a low decrease in risk exposure i.e. there is a low or none advantage of entering into the forward market dependent on the level of the slope. The proposed portfolio holdings of forward contracts for each period can be seen in appendix B.
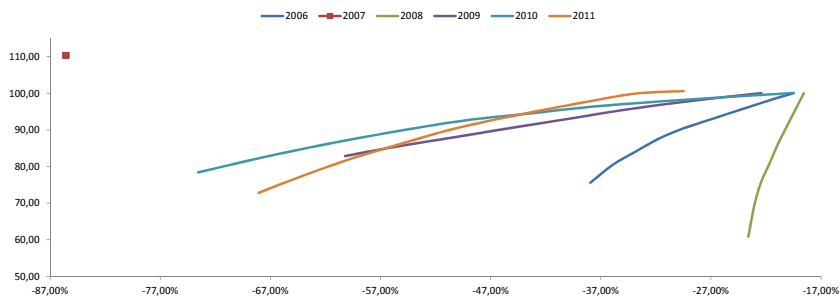
Figure 6.4: The figure illustrate the efficient frontiers of the dynamic trading strategies, on portfolios chosen with initial dates in respectively 2006, 2007, 2008, 2009, 2010 and 2011.

The most striking point when comparing the frontiers of the different periods is that all mentioned shapes are present. The most radical shape is seen in the efficient frontier of 2007. This frontier has vanished into a single point, which means that the optimal portfolio is the same for all risk profiles. When looking at figure 6.5 for 2007 one can see that the expectations in the forward market is very high compared to the expectations obtained with the bootstrap sample. This gives an expected gain in fixing all spot prices for the entire period at the initial date. The model will therefore propose to make a full hedge no matter what risk exposure the company wants, when obtaining an efficient portfolio for the period of 2007. When comparing the expectations of the spot market with the realized spot rates in figure 6.5 for 2007, it can be seen that the spot rates increase dramatically in December. This seems like an unforeseen development in spot prices that never would have been predicted at the beginning of 2007. When looking at the forward prices for 2007, it can be seen that Decembers increase in spot prices is not captured in the expectations of the forward market. When looking at the first 11 months of spot prices in 2007, one can see that spot prices exceed the forward prices in only 2 months, namely in March and May. This indicates that the forward market are in a high level of expectations. When looking at figure 2.2, it can be seen that the volume of traded forward contracts are very low in 2007, therefore liquidity could be a reason of a forward market priced to high.
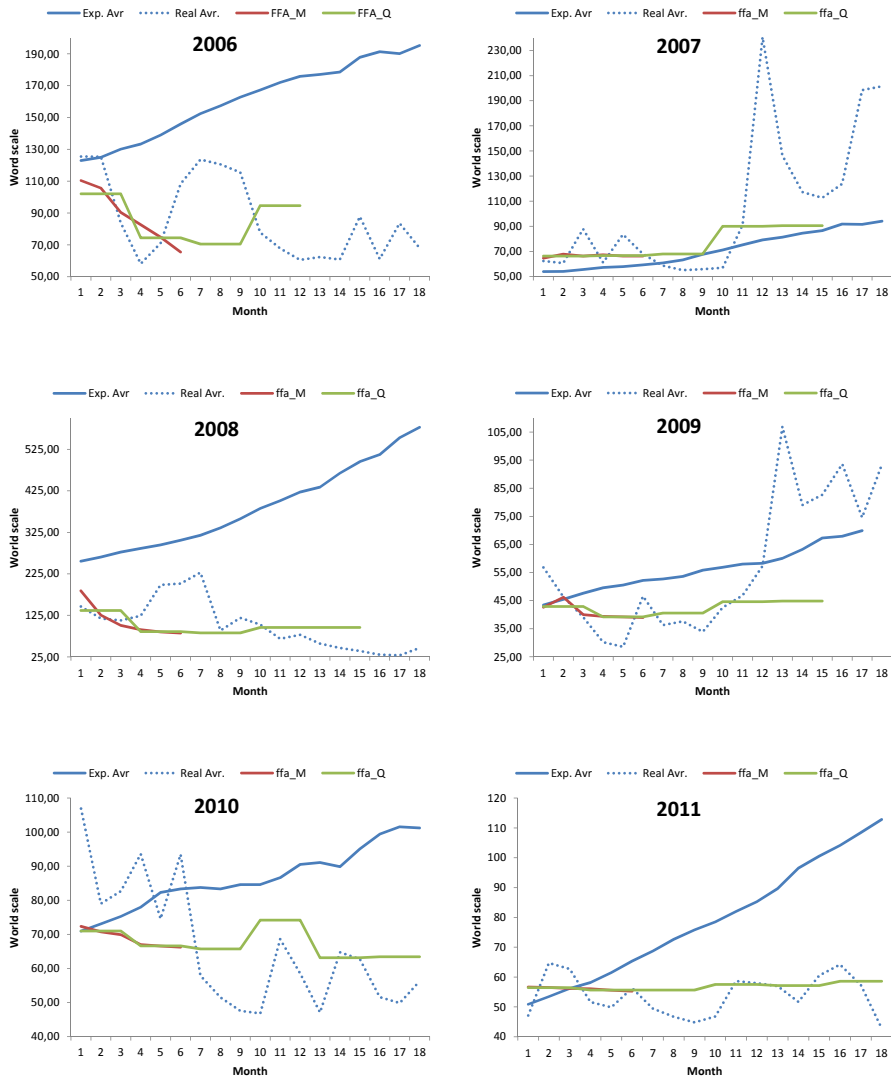
Figure 6.5: The figures illustrates the expected development in spot prices, compared with the forward prices at initial date for each of the 6 periods.

The opposite case of 2007 is seen in the frontiers of 2008 and partly 2006. The frontiers have steep slopes, which indicate that the expected gain of entering the forward market is relatively low. Comparing figure 6.5 for 2006 and 2008 with the frontiers of the same periods provides some answers. It is seen that the expectations in spot prices obtained from the bootstrap samples are very high compared with the low decreasing expectations in the forward market. Expectations of spot prices, from the bootstrap samples of 2006 and 2008, are a high increasing market. The realization of the spot market in the period of 2008 and partly 2006 is a low decreasing market. When looking at figure 6.5, it seems as if the expectations in the forward market are more reliable than the expectations in the bootstrap samples with respect to the realizations of the spot market. When looking at the allocation tables (table 6.1 and B.1), it is seen that the expected income is low with a high downside risk exposure when entering into the forward market for 2006 and 2008. The model therefore proposes some cautious portfolio holdings of forward contracts covering the risk exposures of 2008 and partly 2006. It should be noticed that the model actually allocates forward contracts that are realized with a gain in income for the shipping company. It is only with risk profiles 8,9 and 10 that the model chooses forward contracts, which realize a loss when settled, except for the FFA_M1 allocation in 2006.

For the periods from 2009 to 2011 the frontiers seem more stable. When entering into the forward market in these periods it implies a reasonable expected decrease in downside risk exposure, compared to the decrease in expected income. When comparing the periods in figure 6.5, it shows that the expectations in the spot market obtained from the bootstrap sample has become closer to the expectations in the forward market, making the pay-off between income and down side risk more stable. The frontier in 2011 seems to make a small shift in slope, into a more rapid growing slope, than the other two years. In 2011 is seen some of the same patterns, which shows in 2008. The expectations of spot prices derived from the bootstrap sample are increasing, while the realization of the spot market is slowly decreasing. At the same time, the forward market seems marginally over priced when comparing it with the realizations in figure 6.5.

When gathering the results from all 6 periods, the model seems to perform reasonable. The model performance is limited by the obtained expectations of spot market developments, which decisions are based upon. Because the spot market has been more increasing in the past, the bootstrap procedure produces expectations that are more positive than what in most cases are realized. When comparing allocations from the different periods, it is seen that the allocations proposed for the periods 2006 and 2008 are the ones, which would give the highest realized income, if the portfolio allocations got fixed to the proposals.

6.3   Revisions

Now it has been analysed how the allocation model performs when initializing portfolio allocations with different strategies. Another ting that is important to test when developing an allocation model is performance on changes in the underlying market. When time goes by, and the model is updated with new market informations, how rapid is the model to change, and in what directions? Performance on market movements is typically tested by performing a back test on the model. Back-testing is a procedure making portfolio revisions against market updates. A back-test is performed on the periods examined in the previous chapter with initial portfolios as proposed. The initial time has then been moved one month ahead, making the initial date (t_1) first day in February instead of first day in January, and then optimizing on the remaining period $(t_1, \ldots, t_T)$. The holding variable $x_\kappa^{t_\tau}$, from the first optimization step of the model, has then been fixed and denoted by $\bar{x}_\kappa^{t_\tau}$. The allocation model should now decide, if new contracts should be purchased, which contracts to keep in the portfolio and which contracts to sell, when the expectations of the spot market are updated. The model has therefore been extended as;

$$\max_x \quad (1-\lambda)\frac{1}{N}\left(\sum_{l\in\Omega}\sum_{\kappa\in K, t_\tau\in\mathcal{T}\backslash\{t_0\}} \mu_{\kappa,l}^{t_\tau}x_\kappa^{t_\tau} + \bar{x}_\kappa^{t_\tau}\left(\bar{f}_l^{t_\tau} - f_l^{t_\tau}\right)\right) - \lambda\xi \quad (6.11)$$

The model optimizes on the expected income from entering forward contracts like the initial model, which means that the model allocates new FFA contracts to the portfolio determined with the updated prices. This is done by optimizing $\mu_{\kappa,l}^{t_\tau}x_\kappa^{t_\tau}$, as seen at the new initial date t_1. Then all prior holdings of forward contracts from t_0, are sold at the forward price known at t_1, formulated in the model as; $\bar{x}_\kappa^{t_\tau}(\bar{f}_l^{t_{\tau-1}} - f_l^{t_\tau})$. Updating model formulations in this way it ensures that the right forward prices are used when making allocation decisions. If the model chooses to sell all holdings of a contract type κ, then the new holding parameter will be updated to 0, making;

$$\mu_{\kappa,l}^{t_\tau}x_\kappa^{t_\tau} + \bar{x}_\kappa^{t_\tau}\left(\bar{f}_l^{t_\tau} - f_l^{t_\tau}\right) = \bar{x}_\kappa^{t_\tau}\left(\bar{f}_l^{t_\tau} - f_l^{t_\tau}\right)$$
$$= \bar{x}_\kappa^{t_\tau}\left(\left(\bar{f}_l^{t_\tau} - a_l^{t_\tau}\right) + \left(a_l^{t_\tau} - f_l^{t_\tau}\right)\right)$$

meaning that the company owns a forward contract with a cash flow determined from the forward price $\bar{f}_l^{t_\tau}$ settled at t_τ, and known at t_0. Furthermore the company has sold a forward contract with the upper site cash flow, receiving the spot price and paying the fixed price $f_l^{t_\tau}$ settled at t_τ, and known at t_1. When the contracts are settled it is the difference between the forward prices that are settled; the spot price vanishes in the settlements because the company takes different positions in the two contracts, meaning that they have not fixed the future spot price any more, at t_τ. Conversely, if the model chooses to keep all
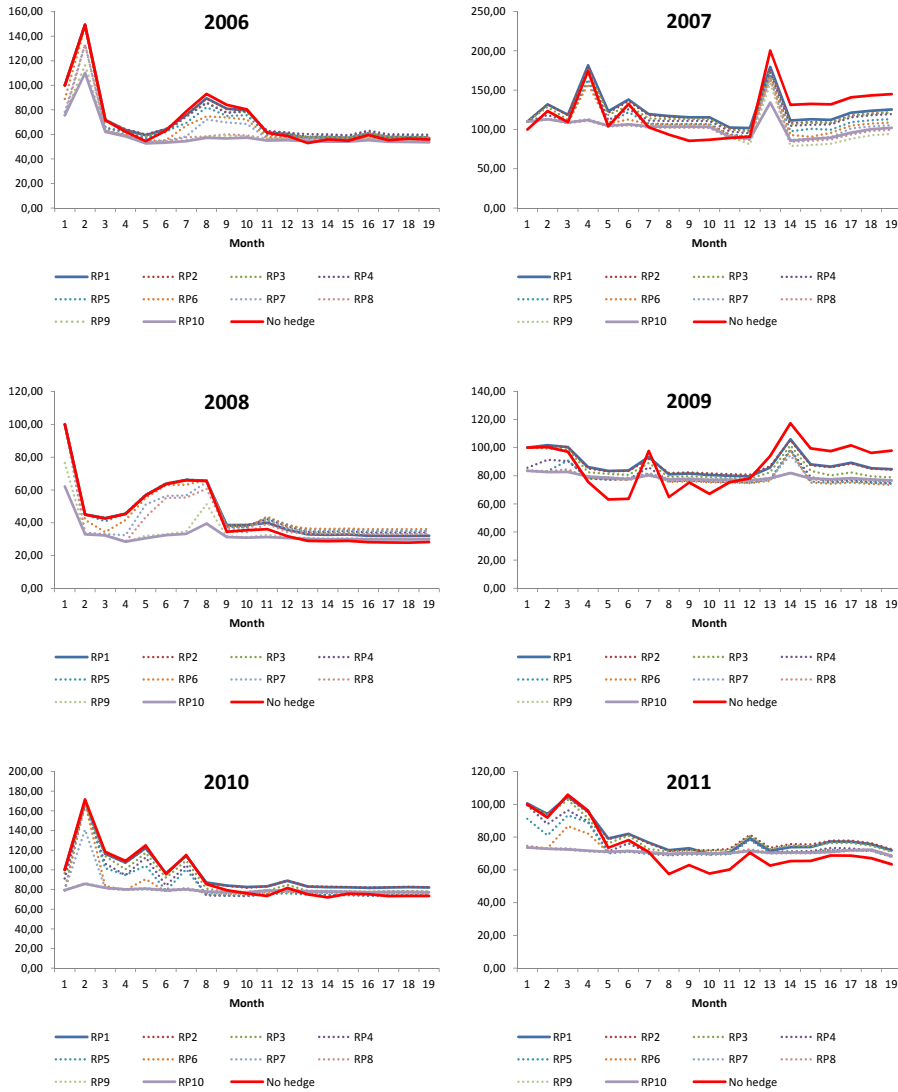
Figure 6.6: The figures illustrate the expected income of portfolios as a function of revision time steps, with 10 different risk profiles, and initial dates in each year.
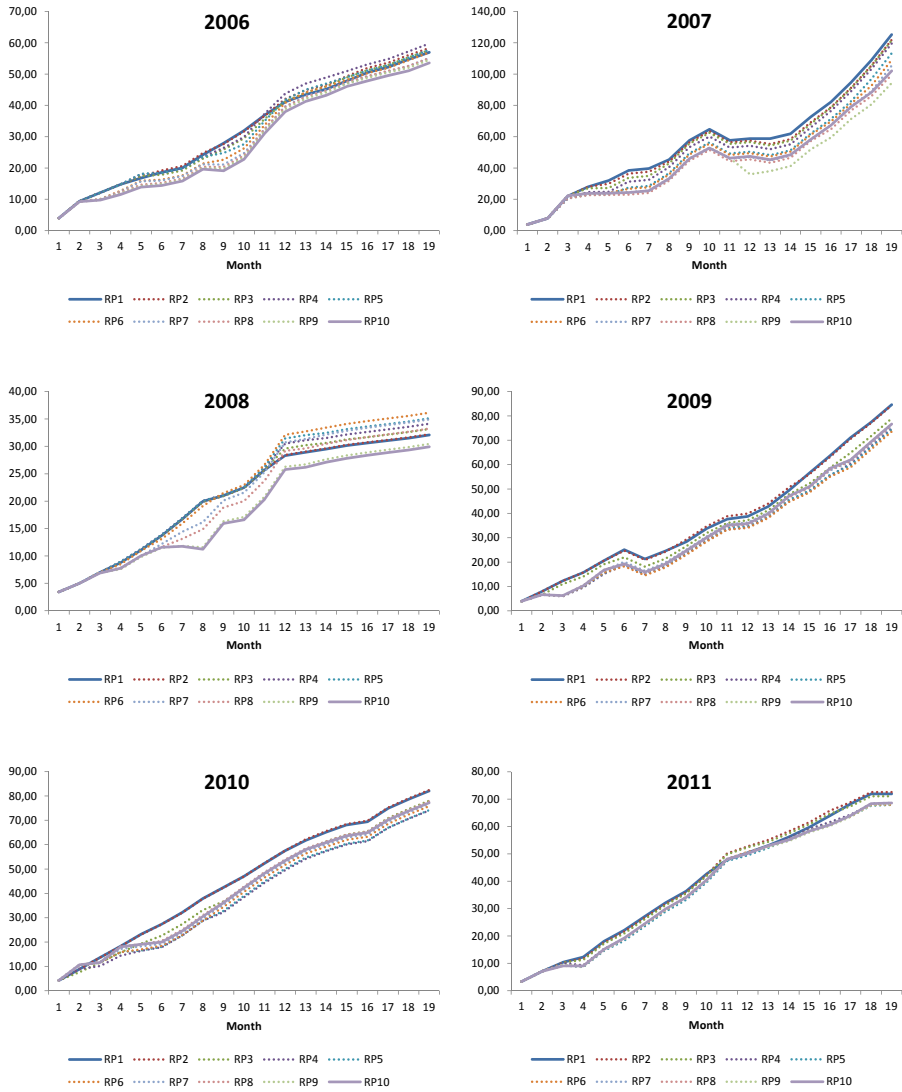
Figure 6.7: The figures illustrate the actualized accumulated income of port-
folios as a function of the revision time steps, with 10 different risk
profiles, and initial dates in each year.
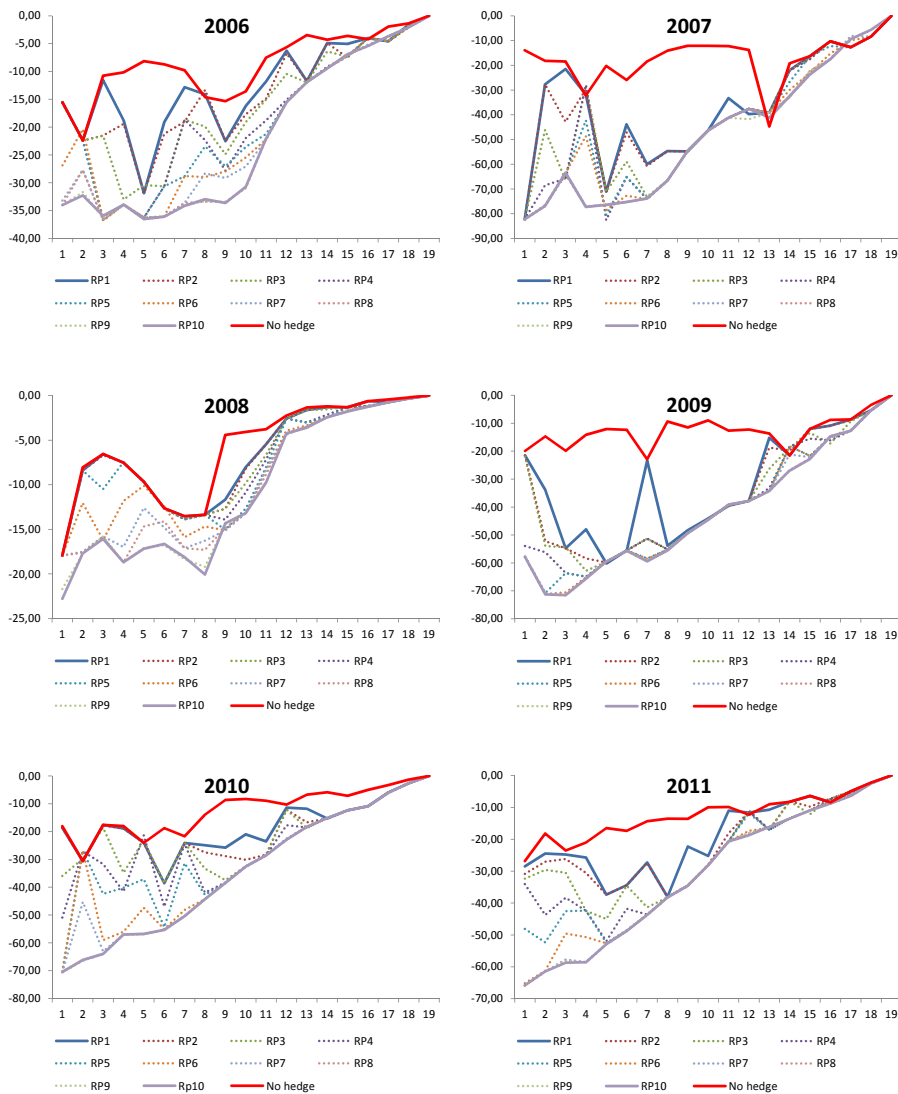
Figure 6.8: The figures illustrate the CVaR of portfolios as a function of the
revision time steps, with 10 different risk profiles, and initial dates
in each year.

holdings of a contract type κ, then the new holding parameter will be updated to the same as the old one $\bar{x}_\kappa^{t_\tau}$, making;

$$\mu_{\kappa,l}^{t_\tau} x_\kappa^{t_\tau} + \bar{x}_\kappa^{t_\tau} \left(\bar{f}_l^{t_\tau} - f_l^{t_\tau} \right) = x_\kappa^{t_\tau} \left(f_l^{t_\tau} - a_l^{t_\tau} \right) + \bar{x}_\kappa^{t_\tau} \left(\bar{f}_l^{t_\tau} - f_l^{t_\tau} \right)$$
$$= x_\kappa^{t_\tau} \left(\bar{f}_l^{t_\tau} - a_l^{t_\tau} \right)$$

meaning that the company owns a forward contract with a cash flow determined from the forward price $\bar{f}_l^{t_\tau}$ at t_τ, known at t_0. The only difference between the prior and the new optimizations is that the expectations of the spot market $a_l^{t_\tau}$ are updated.

When the optimization period has been moved one time step ahead, then one month has been realized. The portfolio performance is then measured against the realization in the spot market, by updating the settlements of forward contracts that have been allocated into the portfolio the month before. This means that a realization parameter gets updated with the settlements of FFA_M0 and FFA_Q0 contracts, if any exists in the portfolio the month before. Furthermore, the realization parameter gets updated, if any forward contracts gets sold the month before, because the settlement price will get fixed. The procedure is then repeated for each month in the optimization period, making it run for 18 time steps. At each time step, the model is making revisions on whether the portfolio allocation should be changed or not with respect to changes in spot market and forward market expectations. Figure 6.6 shows the expected average portfolio income for each month, when making revisions for each period. The figures show how much the model expects of income from each portfolio when running 10 different risk profiles for the dynamic strategy. The shown values are the sum of expectations on portfolio holdings, and previous realized portfolio holdings. The income is compared with the expectations of the income from the No hedge strategy. Index 100 therefore means that one would expect the same income as not entering into the forward market. Appendix Ccontains tables of revision holdings for each of the periods.

It is expected that the risk averse profile will become a linear horizontal line in figure 6.6. The risk averse profile chooses to allocate forward contracts, such that price movements in the spot market will have a minimal impact on portfolio performance. Therefore, portfolio performance should steadily develop. When choosing the risk profile into allowing a higher risk exposure, then the income line will become more volatile. Furthermore, the line will be expected, in average, to be placed above the income line of the risk averse profile. Figure 6.6 for 2006, shows that the first 5 months of expected income seems too volatile, in the risk averse profile, than what would be expected. The same volatility in expected income is seen in the first 2 month of 2008. The experienced volatility is an impact of the missing FFA contracts, covering the risk exposure at the end periods of 2006 and 2008 (FFA_Q4 and FFA_Q5). The hedging strategies

can therefore not eliminate the risk exposure at the end of the periods, which is why expectations will be exposed to the movements in spot market. When revisions are made from the 5th month in 2006 and the 3rd month in 2008, it is possible to allocate forward contracts in a way to cover up the risk exposure for the entire remaining periods. The volatility is therefore only experienced at the beginning of the back test in these periods.

In figure 6.6 for 2007, it is seen that the income line for the risk averse profile at month 13 has a high gain, relative to what is expected. This gain is an impact of the very high increase in spot prices for December, where the price increases from 91 WS in average for November to 240 WS in average for December. The gain in expected income for the other risk profiles, for month 13 in 2007, is higher than what is experienced in the risk averse profile. This behaviour is expected, because the portfolios from the other risk profiles are more exposed to movements in spot market. In the rest of the periods, the expectations of income lines are fulfilled. The risk averse strategy becomes a straight horizontal line, with limited impact on performance from the spot market. One considerable aspect to notice in figure 6.6 is that the risk neutral profiles outperforms the risk averse profiles in all periods, and the no hedge strategies in most periods. It is only in periods, where huge increases in spot prices are experienced that the no hedge strategy will outperform the risk neutral profile in income. This indicates that down side risk exposure is worth able to include when managing VLCC chartering. It protects the chartering income from decreasing spot market developments, but at a cost. The cost for the protection is that when the spot market increases, then the chartering income will not get as high a gain as when following the spot market completely. When looking at figure 6.6 it seem as if the relative high risk exposed portfolios outperforms the less risk exposed. This is because they seem to get a relative protection from the forward market, while at the same time being fast in changing due to spot market changes, and therefore capturing increasing spot market movements.

Figure 6.7 shows the realized accumulated income from each of the risk profiles for each period. The income is measured in the same way as in figure 6.6, making the accumulated income over 18 months end in the same index as the expected income in figure 6.6. If the accumulated income is a linear increasing line, then the company would realize a steady income over the entire period. All lines will start in the same level, with the income realized when initializing the portfolios in month 1. It is to expect that the accumulated income of the risk neutral profile will make the most volatile line, because the portfolio of this risk profile is more exposed to changes in spot market than the more risk averse profiles. When the spot market changes, then it will be seen immediately in the risk neutral accumulated income. However, the risk averse profile is expected to be more stable with respect to changes in the spot market, and therefore the accumulated income is expected to be a more smoothly increasing line than the

more risk exposed portfolios. Furthermore, it is expected that the accumulated income from the risk averse profile will be levelled below the more risk exposed profiles, which was also the case in figure 6.6.

In figure 6.7, it shows that the risk averse profile is levelled below the other risk profiles in almost every periods, over the entire horizon, which is as expected. For all periods it shows that the first two months of accumulated income is approximately the same for all risk profiles. The first month will always be the same, because there is only the settled spot price as income for this period. The second month gives the opportunity of income from the first settlement of FFA contracts, but the changes are very small, and in most circumstances no contracts are allocated to cover up the risk exposure for the first month. Therefore, it is expected that the accumulated income will be the same for all risk profiles in the first two months, in all periods.

For 2006, it is seen that the realization of the risk averse profile seems to perform worst in month 9, which could be because the spot market starts to decrease after a high increasing period. The expectations of the spot market is increasing, and the forward contracts is therefore too expensive to cover up the risk exposure. The risk neutral profile seems to perform very well in months 8, 9 and 10, indicated by a high increase in accumulated income. When looking at figure 6.6, it shows that the spot market has a peek in the period of months 6, 7, 8 and 9, which is actualized immediately in the risk neutral profile. Because the expectations of the future from the bootstrap sample is an increasing market, and the spot market is decreasing in month 9, the risk averse profile will loose against the risk neutral profile. In month 11 and 12 the risk averse profile gets a gain again, because the spot prices decreases rapidly, and the forward contracts cover up this decrease. The same pattern is seen in the period of 2008. The risk averse profile seems to loose against the risk neutral profile, when the spot market peeks. Then the risk averse profile seems to get a gain again, when the spot market decreases, because the forward contracts cover up the decrease in spot market.

In the period of 2007, it shows that the different risk profiles almost have the same developments in accumulated income. This is seen for the entire period, except for month 4,5 and 6, where the risk averse profile is decreasing in level against the risk neutral profile. The differences in accumulated income are a realization of the spot market that seems to have small peeks in month 3 and 5, which is not foreseen in the forward market and therefore the settled contract for these periods is loosing income. In 2007, is also shown that the gain in accumulated income for the last months seems to be higher in the risk neutral profile, than in the risk averse. This is because the spot market is highly increasing in this period, which is captured faster in the risk neutral profile than in the risk averse. In 2009 and 2010, it is again seen that the developments in

the different risk profiles are very close. It is only single months that differ in the accumulated income for the different risk profiles. For 2009, it is month 3 that makes a significant difference. In figure 6.6, it shows that the spot market is higher than the expectations, which makes the income lower than expected. In 2010, the same is seen in month 6, which is because the spot market has a small peek, therefore making forward contracts settle with a loss for the company. In 2011, almost no differences is seen between the accumulated incomes from the different risk profiles. The spot market shows to be almost constant, with a small decreasing slope, and the forward market seems to have captured this movement by making the income steady.

Figure 6.8 shows the downside risk exposure measured as CVaR on a 99% probability level from each risk profile. This is showing how much the company would expect of average income from the portfolio holdings, over the remaining periods, in the 1% worst cases. The downside risk exposures are then updated at each month when making revisions and contract settlements. The risk exposures are converging to 0 at month 19 because the period ends and then everything from the period at this month is know with certainty. It is expected that the no hedge strategy will be visualized as a line beyond all others. When the level of risk exposure is increased in the trading strategies, then the CVaR lines from the back-test will decrease in level. The RP10 CVaR line will therefore become the bottom line on the entire time horizon. All CVaR lines will be expected in average to be increasing when time increases, and all risk profiles will have CVaR to end up in 0 when it is the last month of the planning horizon.

In 2007 the CVaR line shows the huge increase in spot rates as a sudden decrease in CVaR for the no hedge strategy. The CVaR line for the no hedge strategy is significantly decreasing to a level below the risk averse strategy, but the decrease can be explained by the increase in spot prices, which are not captured in the dynamic strategies. The changes in levels between CVaR lines shows the gain in risk exposures from the different risk profiles. In 2008 it shows that the differences in CVaR levels is very low, indicating that the gain of entering the forward market by FFA's does not give a high gain in risk exposure terms. The figure also shows that 2007 is the period where the highest expected gain in down side risk exposure is experienced. The CVaR lines from the periods of 2009, 2010 and 2011 seems also to show a relative high gain in risk exposures. Furthermore, these periods seems to have a more stable increase in CVaR lines when following the different strategies, with some exceptions. At month 7 in 2009 the CVaR line shows a sudden increase for the risk neutral strategy. The increase in CVaR can be explained by the fact that spot prices decrease and therefore the forward market seems unattractive for the risk neutral strategy. From month 8 to month 12 in 2009, all dynamic strategies vanishes into the same line, indicating that forward market seems overpriced with respect to expectations derived from the bootstrap samples.

6.4   Future expectations
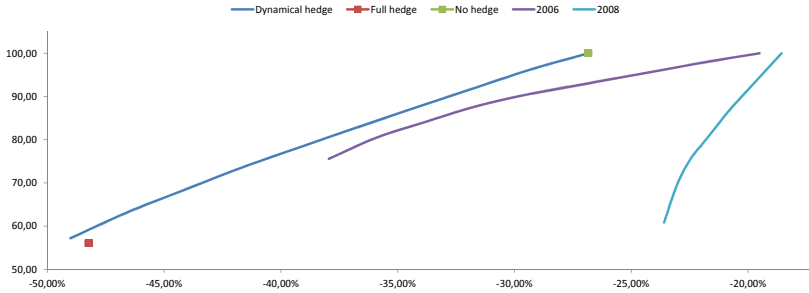
Figure 6.9: The figure illustrates the efficient frontier for the portfolios with different strategies and risk profiles invested 1st of October 2012, compared with the frontiers of 2006 and 2008.
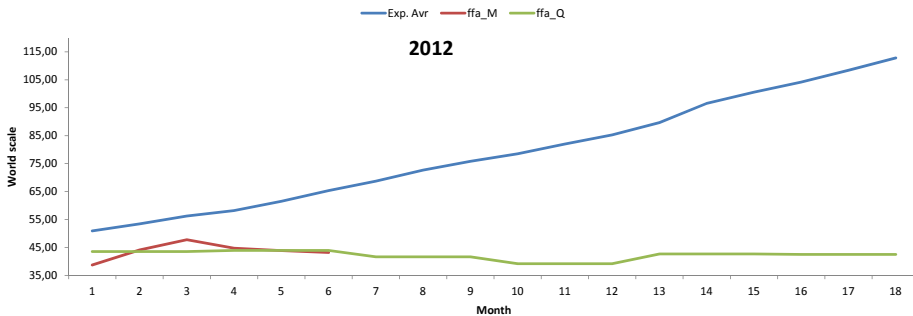
Figure 6.10: The figure illustrates the expectations of 2012 compared with the prices of forward contracts.

One interesting question that comes natural is: what will then happen now and into the unknown future, and how should a shipping company relate to the down side risk exposure for the next 18 months? The allocation model has therefore been optimizing on the period from 1st of October 2012 and 18 months ahead. In figure 6.9, the efficient frontier for the optimization period starting 1st of October 2012 is shown. It can here be seen that the frontier has a relatively high slope, which indicates that the gain in risk exposure of entering the forward market is relatively expensive. Comparing the 2012 frontier with the obtained

frontiers from the other historical periods, it shows that it has a shape between
the frontier from 2006 and 2008, but with a significantly lower down side risk
exposure. In figure 6.10, the expectations of the spot market are seen, obtained
from the bootstrap sample, and the prices of forward contracts at the initial
date. The expectations of the period are high corresponding to the forward
market expectations. Furthermore, the expectations from the bootstrap sample
are an increasing spot market, as seen in all other earlier periods examined. The
expectations of spot market developments obtained from the forward market,
are minor decreasing.

Month	Contract	No hedge strategy	Full hedge strategy
Oct - 12	FFA_M0/FFA_Q0	0/0	1/0
Nov - 12	FFA_M1/FFA_Q0	0/0	1/0
Dec - 12	FFA_M2/FFA_Q0	0/0	1/0
Jan - 13	FFA_M3/FFA_Q1	0/0	1/0
Feb - 13	FFA_M4/FFA_Q1	0/0	1/0
Mar - 13	FFA_M5/FFA_Q1	0/0	1/0
Apr - 13	FFA_Q2	0	1
May - 13	FFA_Q2	0	1
Jun - 13	FFA_Q2	0	1
Jul - 13	FFA_Q3	0	1
Aug - 13	FFA_Q3	0	1
Sep - 13	FFA_Q3	0	1
Oct - 13	FFA_Q4	0	1
Nov - 13	FFA_Q4	0	1
Dec - 13	FFA_Q4	0	1
Jan - 14	FFA_Q5	0	1
Feb - 14	FFA_Q5	0	1
Mar - 14	FFA_Q5	0	1
Expected income		100	56.12
Downside risk		-26.84	-48.23

Table 6.3: The table shows the optimal allocation of FFA contracts, chosen
on the no hedge and full hedge strategies from the allocation model
framework, for the period starting 1st of October 2012 and running
18 months ahead.

When comparing the period of 2012 with the rest of the periods examined
in this chapter, one would expect all trading strategies for 2012 proposed by
the allocation model to outperform the no hedge strategy, both in down side
risk exposure and in expected income. Therefore it would always be suggested
to enter into the forward market to some extent. The risk appetite that the

company shall take, should be determined with respect to what the company can afford of downside risk exposure and regulated to the level that is suitable from a business point of view. From the analysis done in this chapter, and from the model results made on the 2012 period, it would be suggested to keep a high risk profile, only entering the forward market to a limited extent. The limitations in extent of entering the forward market is basically based on the results from the shape of the efficient frontier. When the frontier has such a high increasing slope, it seems that the gain in risk exposure of entering the forward market, is too expensive. When comparing it with the period of 2008, which seems as a good period for comparison because the shape of the efficient frontiers has some equalities, it is seen that keeping a high risk profile, but not too high is most worth able. When looking at the allocation suggestions in table 6.4, it seems most reasonable to enter the forward market in monthly contracts or long term quarterly contracts such as FFA_Q4.

Month	Contract	RP1	RP2	RP3	RP4	RP5	RP6	RP7	RP8	RP9	RP10
Oct - 12	FFA_M0/FFA_Q0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Nov - 12	FFA_M1/FFA_Q0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/0
Dec - 12	FFA_M2/FFA_Q0	0/0	0.36/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Jan - 13	FFA_M3/FFA_Q1	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Feb - 13	FFA_M4/FFA_Q1	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Mar - 13	FFA_M5/FFA_Q1	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Apr - 13	FFA_Q2	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.61	0.64	0.96
May - 13	FFA_Q2	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.61	0.64	0.96
Jun - 13	FFA_Q2	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.61	0.64	0.96
Jul - 13	FFA_Q3	0.00	0.00	0.00	0.00	0.29	0.83	1.00	1.00	1.00	1.00
Aug - 13	FFA_Q3	0.00	0.00	0.00	0.00	0.29	0.83	1.00	1.00	1.00	1.00
Sep - 13	FFA_Q3	0.00	0.00	0.00	0.00	0.29	0.83	1.00	1.00	1.00	1.00
Oct - 13	FFA_Q4	0.00	0.00	0.39	0.81	1.00	1.00	1.00	1.00	1.00	1.00
Nov - 13	FFA_Q4	0.00	0.00	0.39	0.81	1.00	1.00	1.00	1.00	1.00	1.00
Dec - 13	FFA_Q4	0.00	0.00	0.39	0.81	1.00	1.00	1.00	1.00	1.00	1.00
Jan - 14	FFA_Q5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.74	1.00
Feb - 14	FFA_Q5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.74	1.00
Mar - 14	FFA_Q5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.74	1.00
Expected income		100.00	96.26	91.85	87.44	82.93	78.33	73.67	68.49	63.27	57.22
Downside risk		-26.84	-29.30	-31.77	-34.23	-36.69	-39.15	-41.62	-44.08	-46.54	-49.01

Table 6.4: The table shows the optimal allocation of FFA contracts, chosen from the dynamic strategies with the obtained allocation model framework, for the period starting 1st of October 2012 and running for 18 months. The allocation is chosen for 10 different risk profiles with equal distance CVaR.

CHAPTER 7

Conclusion

This thesis sets out to examine the FFA market of dirty tankers on the TD3 index in order to develop a stochastic model framework as an active management support tool, for managing VLCC chartering. Dayli prices of settled spot contracts are examined to develop a stochastic forecasting method, used in the decision framework. The decision framework is based upon a Conditional Value at Risk programming model, proposed by Stavros in [Zen07], optimizing expected income and minimizing downside risk exposure.

The forecasting method has to be used in the decision framework, which is why a model framework has to be chosen to get some reasonable expectations on future spot prices and thereby down side risk exposures. The academic literature is limited when it comes to the development of forecasting methods for freight rates on VLCC chartering. In the literature examined, it has been proposed to use neural networks [MM10] and [JL06]. In the literature neural networks have been compared with the usage of well known time series modelling techniques such as ARMA process. It has been demonstrated that neural networks outperform ARMA process. In the literature examined, it is also stated, that there are not sufficient studies on this subject, and none precise forecasting methods still exist. In the industry there has also been attempts at developing different forecasting methods, such as neural networks and GARCH models. It has here been demonstrated that neural networks are marginally outperforming GARCH models. The main objective of the thesis is not to develop a model framework to

determine expectation of future spot price developments. It has therefore been chosen to work with well-known times series methods, in developing a forecasting method for the decision model. The decision has been based on the fact that no methods exist, which significantly outperform the time series methods, and the usage of the neural network framework on dirty tanker freight rates, is too unexplored. Furthermore, the work of this thesis is limited by limitations of a master thesis, which means that the scope of both looking into new complex forecasting methods and developing an allocation model is too extensive. In the analysis on dayli prices of settled spot contracts, it has been estimated that some autocorrelation exists. Therefore, it has been proposed to use an auto regressive process to capture the autocorrelation. The most adequate process was found to be a pure AR(1)-process. The determination process used has been proposed by Madsen in [Mad07]. In the statistical analysis some variance clustering in the spot rate data set was detected. Therefore, it was tried to fit a GARCH process capturing the variance clustering. It seems that the most adequate GARCH process found, was a (1,2)-process with an auto regressive part, fitting the mean structure. There was found no evidence that the AR-GARCH process was more adequate than the pure auto regressive process. Furthermore, it was concluded that none of the processes were significantly capturing the structure in the model sample in a satisfactory way. It was therefore chosen to generate scenarios with a simple bootstrap procedure, computing the best expectations on future spot rates.

The market of freight derivatives on dirty tankers is an immature market, and so is the academic literature. It has only been possible to find two articles on investigating the market of derivatives on dirty tanker freight rates, [KV06] and [Vas06]. Furthermore, the derivatives market has not yet been widely recognized in the dirty tanker businesses, even though the market contents have a great potential. The pre-knowledge on the derivatives market has therefore been a limitation when processing the thesis.

The reason for a shipping company to enter into the forward market is to give the company a flexible way of controlling their future spot positions and their down side risk exposure. The allocation model framework should therefore allocate FFA contracts to fix future spot positions, if this seems worth able. The decision is made on maximizing the expected income, when managing the future spot positions with forward contracts, and to minimize the downside risk exposure. The analysis is done with 3 different FFA trading strategies, and 10 different risk profiles. This makes it possible to compare how the forward market performs when entering the market on different levels.

The allocation model has been developed and seems to perform reasonably, despite the lack of a significant well performing forecasting method. In the analysis it has been shown that risk averse portfolios, proposed by the allocation model,

are protected against spot market fluctuations. Furthermore, in general, the risk averse portfolios still give a high income when compared with high risk exposed portfolios. It has also been shown that upside movements in the spot market get captured in the risk averse portfolio performance, but delayed in proportion to the less risk averse portfolios. Portfolios from the no hedge strategy, with no FFA contracts allocated, get directly exposed to spot market developments, both downside and upside movements, and therefore in most cases, get out-performed by the dynamic hedge strategies proposed by the allocation model. It is only in periods where the spot market experiences very high and rapid increasing prices, that the no hedge strategy seems to get a significant gain in performance relative to the dynamic strategies.

One considerable thing that has been demonstrated in the analysis of the allo-cations made by the allocation model framework is that the risk neutral profile outperforms the risk averse profiles in all periods, and the no hedge strategy in most periods. This indicates that risk exposure is worth able to include when managing VLCC chartering. But also that high risk profiles seem to marginally outperform lower ones in most circumstances. It seems very often to be long term FFA contracts, covering risk exposures far into the future, that are worth able purchasing, such as FFA_Q2, FFA_Q3 and FFA_Q4. The reason why it seems to be the high risk exposed portfolios that performs best, is because they are protected against decreasing spot rates in a limited extent, and at the same time they can easily adapt to positive changes in the spot market. In that way the risk exposed strategies seem to be protected against small decreases but still captures the most of the increasing spot market movements.

The main conclusion of the thesis is that the developed model framework, of managing future spot positions seems to make reasonable decisions, covering up down side risk exposures while making optimal incomes. When analysing the decisions made by the allocation model, it definitely seems worth able for a tanker company to enter the forward market, and in that way manage future spot positions in a dynamic way. When considering the proposals on allocations, made by the model framework, together with a business knowledge on the spot market, a shipping company could get a beneficial gain in entering the forward market of FFA's. The forward market, though, has some limitations, which is not calculated for in the allocation framework.

The hot issue in the forward market is liquidity. The amount of traded FFA contracts on the dirty tanker indices is too small. In September month 2012 the volume of traded FFA contracts was published to be covering 3625 lots, ie. 3.625 millions mt of crude oil. The amount of FFA contracts traded in September month 2012 has therefore been approximated to cover up 2.3% of the entire fleet of VLCC's, and then no other dirty tanker segments got covered. Therefore market participants working in the forward market and the FFABA,

should try to attract more participants, both taking long and short positions
in the forward contracts. Probably the most difficult participants to get to
enter the forward market will be investors outside the tanker market taking big
amount of floating positions in FFA contracts, covering the risk exposure in the
spot market. Liquidity is also addressed as the most urgent problem for the
FFA market to evolve in [Vas06].

Another issue mentioned in [Vas06] is the way that contracts are priced. Spot
contracts, and therefore also FFA contracts, are prices on the world scale com-
position. WS 100 in one year will be different in dollar terms, than WS 100 in
another year. This is because it is influenced by among other things the bunker
prices, the port dues and the exchange rate of the US currency. Therefore expec-
tations on FFA contracts get non-transparent when purchasing a FFA contract
in one year which is settled in another year.

7.1   Perspective

During the work with the present thesis new ideas arose. Due to time restrictions
on the project, many of these ideas were left untouched. Further more, some of
the work done in the thesis had to be limited due to limitations on the scope.
This section collects some of these ideas, which future work in the topic of
managing VLCC chartering could be built upon.

The most critical part of the developed allocation model is the framework of
computing expectations of the future spot market. In the thesis no satisfac-
tory method has been elaborated capturing patterns in the data sample, to
compute scenarios of the future spot market. In the existing literature on this
topic, no satisfactory alternatives exist, which could fit into the scope of this
thesis. Therefore, the scenarios have been computed with a simple bootstrap
computation in the absence of a better method. The most significant way in
which the framework of the allocation model can be extended to get the most
significant gain in model performance, would probably be to develop a method,
which could compute significant better predictions in future spot rates. From
the analysis done in this thesis, and from knowledge obtained in the literature
and in the industry, it seems like regime shifting processes would be a good
guess of extension. Another framework to consider, which is a very powerful
method in capturing fat tailed distributions, like the one experienced of freight
rates, is Hidden Markov Models. The main objective of this thesis has been to
work out the stochastic programming framework, which is why the development
of a forecasting method has been limited to well known time series processes.
The mentioned methods of regime shifting models or Hidden Markov models

has therefore been chosen not to be developed and tested in this thesis.

Another approach in which to expect a significant gain in performance of the stochastic programming model, is to extend the model into a multi stage programming model. The development of the allocation model in the thesis, is built upon assumptions about reality. For instance, it is assumed that decisions on the amount of forward contracts to allocate for the entire planning horizon, of 18 months, is made at the initial date. The model is then optimizing on the entire horizon, with the decisions made at the initial date. In reality, decisions can be made on a dayli basis over the entire horizon, which makes the assumption a huge simplification of reality. A multi stage programming model is an extension of the one stage model to meet these requirements on when to make decisions. With a multi stage model, one can assume that decisions are taken at several future points in time. The multi stage model would therefore be assumed to have a gain in performance on the decision making process, because it is taken into consideration that the purchase of forward contracts can be done at a future point in time. The time limitations on the working process of the thesis has been a significant factor of why the multi stage model has not been developed and analysed. Furthermore, the problem with using multi stage models is that it needs exponential more computer force to be solved. At each stage of decision making in the multi stage model, there has to be computed N new scenarios, which significantly limits the number of times future decisions can be made. Another issue in developing a multi stage model is that such a model needs a method to compute predictions on future forward prices, which makes the scope evolve into being much more complex than what can be handled in a single master thesis.

APPENDIX A

FFA contracts
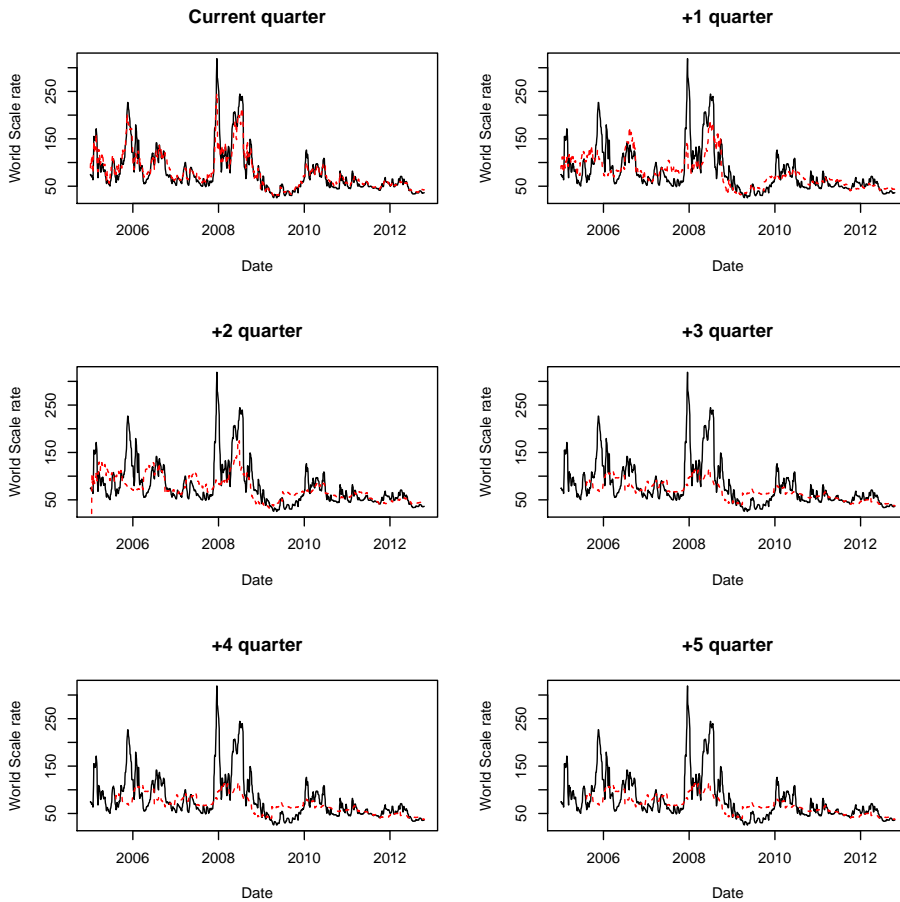
Figure A.1: The figures shows alle FFA contracts prices settled on quarterly basis compared to spot prices at same quote date.
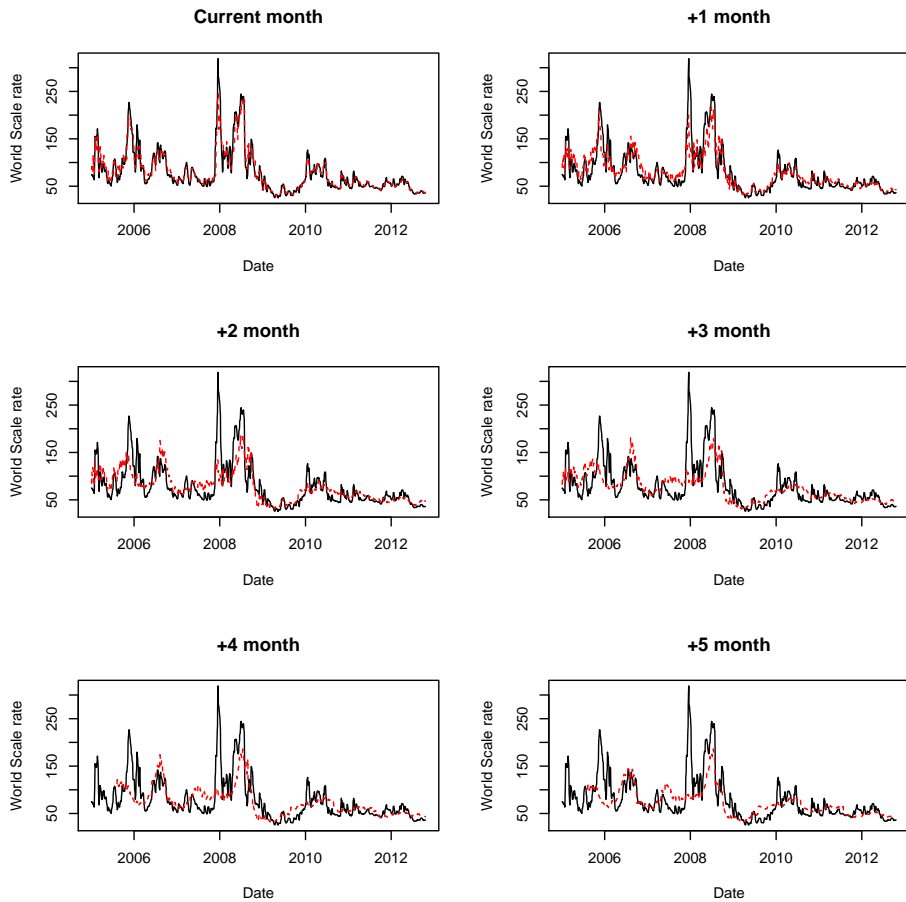
Figure A.2: The figures shows alle FFA contracts prices settled on monthly basis compared to spot prices at same quote date.

Tables of suggested portfolio holdings

Month	Contract	RP 1	RP 2	RP 3	RP 4	RP 5	RP 6	RP 7	RP 8	RP 9	RP 10
Jan - 07	FFA_M0/FFA_Q0	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Feb - 07	FFA_M1/FFA_Q0	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Mar - 07	FFA_M2/FFA_Q0	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Apr - 07	FFA_M3/FFA_Q1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
May - 07	FFA_M4/FFA_Q1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Jun - 07	FFA_M5/FFA_Q1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Jul - 07	FFA_Q2	1	1	1	1	1	1	1	1	1	1
Aug - 07	FFA_Q2	1	1	1	1	1	1	1	1	1	1
Sep - 07	FFA_Q2	1	1	1	1	1	1	1	1	1	1
Oct - 07	FFA_Q3	1	1	1	1	1	1	1	1	1	1
Nov - 07	FFA_Q3	1	1	1	1	1	1	1	1	1	1
Dec - 07	FFA_Q3	1	1	1	1	1	1	1	1	1	1
Jan - 08	FFA_Q4	1	1	1	1	1	1	1	1	1	1
Feb - 08	FFA_Q4	1	1	1	1	1	1	1	1	1	1
Mar - 08	FFA_Q4	1	1	1	1	1	1	1	1	1	1
Apr - 08	FFA_Q5	-	-	-	-	-	-	-	-	-	-
May - 08	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Jun - 08	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Expected income		110.39	110.39	110.39	110.39	110.39	110.39	110.39	110.39	110.39	110.39
Downside risk		-85.57	-85.57	-85.57	-85.57	-85.57	-85.57	-85.57	-85.57	-85.57	-85.57

Table B.1: The table shows the holdings of FFA contracts in the portfolio from the dynamical hedge strategies from period 2007. The contracts FFA_Q5 is not present at the initial date and can therefore not be allocated into the portfolio.

Month	Contract	RP 1	RP 2	RP 3	RP 4	RP 5	RP 6	RP 7	RP 8	RP 9	RP 10
Jan - 08	FFA_M0/FFA_Q0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Feb - 08	FFA_M1/FFA_Q0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Mar - 08	FFA_M2/FFA_Q0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Apr - 08	FFA_M3/FFA_Q1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
May - 08	FFA_M4/FFA_Q1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Jun - 08	FFA_M5/FFA_Q1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Jul - 08	FFA_Q2	0	0	0	0	0	0	0	0	0.18	1
Aug - 08	FFA_Q2	0	0	0	0	0	0	0	0	0.18	1
Sep - 08	FFA_Q2	0	0	0	0	0	0	0	0	0.18	1
Oct - 08	FFA_Q3	0	0.26	0.51	0.77	1	1	1	1	1	1
Nov - 08	FFA_Q3	0	0.26	0.51	0.77	1	1	1	1	1	1
Dec - 08	FFA_Q3	0	0.26	0.51	0.77	1	1	1	1	1	1
Jan - 09	FFA_Q4	0	0	0	0	0.02	0.26	0.51	0.75	1	1
Feb - 09	FFA_Q4	0	0	0	0	0.02	0.26	0.51	0.75	1	1
Mar - 09	FFA_Q4	0	0	0	0	0.02	0.26	0.51	0.75	1	1
Apr - 09	FFA_Q5	-	-	-	-	-	-	-	-	-	-
May - 09	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Jun - 09	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Expected income		100	96.71	93.43	90.14	86.81	83.03	79.25	75.41	69.62	60.85
Downside risk		-18.57	-19.13	-19.69	-20.25	-20.80	-21.36	-21.92	-22.48	-23.04	-23.60

Table B.2: The table shows the holdings of FFA contracts in the portfolio from the dynamical hedge strategies from period 2008. The contracts FFA_Q5 is not present at the initial date and can therefore not be allocated into the portfolio.

Month	Contract	RP 1	RP 2	RP 3	RP 4	RP 5	RP 6	RP 7	RP 8	RP 9	RP 10
Jan - 09	FFA_M0/FFA_Q0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Feb - 09	FFA_M1/FFA_Q0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Mar - 09	FFA_M2/FFA_Q0	0/0	0/0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Apr - 09	FFA_M3/FFA_Q1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/1
May - 09	FFA_M4/FFA_Q1	0/0	0/0	0/0	0/0	0.28/0	0.78/0	1/0	1/0	1/0	0/1
Jun - 09	FFA_M5/FFA_Q1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/1
Jul - 09	FFA_Q2	0	0	0	0	0	0	0.16	0.45	0.98	1
Aug - 09	FFA_Q2	0	0	0	0	0	0	0.16	0.45	0.98	1
Sep - 09	FFA_Q2	0	0	0	0	0	0	0.16	0.45	0.98	1
Oct - 09	FFA_Q3	0	0.35	0.75	1	1	1	1	1	1	1
Nov - 09	FFA_Q3	0	0.35	0.75	1	1	1	1	1	1	1
Dec - 09	FFA_Q3	0	0.35	0.75	1	1	1	1	1	1	1
Jan - 10	FFA_Q4	0	0	0	0.01	0.33	0.61	0.83	1	1	1
Feb - 10	FFA_Q4	0	0	0	0.01	0.33	0.61	0.83	1	1	1
Mar - 10	FFA_Q4	0	0	0	0.01	0.33	0.61	0.83	1	1	1
Apr - 10	FFA_Q5	-	-	-	-	-	-	-	-	-	-
May - 10	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Jun - 10	FFA_Q5	-	-	-	-	-	-	-	-	-	-
Expected income		100.1	98.68	97.15	95.41	93.38	91.35	89.32	87.27	85.21	82.88
Downside risk		-22.41	-26.61	-30.81	-35.01	-39.22	-43.42	-47.62	-51.82	-56.02	-60.22

Table B.3: The table shows the holdings of FFA contracts in the portfolio from the dynamical hedge strategies from period 2009. The contracts FFA_Q5 is not present at the initial date and can therefore not be allocated into the portfolio.

Month	Contract	RP 1	RP 2	RP 3	RP 4	RP 5	RP 6	RP 7	RP 8	RP 9	RP 10
Jan - 10	FFA_M0/FFA_Q0	1/0	0/1	0/1	1/0	1/0	1/0	1/0	0/1	1/0	0/0.17
Feb - 10	FFA_M1/FFA_Q0	0/0	0/1	0/1	1/0	1/0	1/0	1/0	0/1	1/0	0.83/0.17
Mar - 10	FFA_M2/FFA_Q0	0/0	0/1	0/1	1/0	1/0	1/0	1/0	0/1	1/0	0.83/0.17
Apr - 10	FFA_M3/FFA_Q1	0/0	0/0	0/0	0.99/0	1/0	1/0	0/1	0/1	0/1	0.02/0.98
May - 10	FFA_M4/FFA_Q1	0/0	0/0	0/0	0/0	0/0	0.43/0	0/1	0/1	0/1	0/0.98
Jun - 10	FFA_M5/FFA_Q1	0/0	0/0	0/0	0/0	0/0	0/0	0/1	0/1	0/1	0.02/0.98
Jul - 10	FFA_Q2	0	0	0	0	0.56	1	1	1	1	1
Aug - 10	FFA_Q2	0	0	0	0	0.56	1	1	1	1	1
Sep - 10	FFA_Q2	0	0	0	0	0.56	1	1	1	1	1
Oct - 10	FFA_Q3	0	0.25	0.72	1	1	1	1	1	1	1
Nov - 10	FFA_Q3	0	0.25	0.72	1	1	1	1	1	1	1
Dec - 10	FFA_Q3	0	0.25	0.72	1	1	1	1	1	1	1
Jan - 11	FFA_Q4	0	0	0	0	0	0	0.23	0.82	1	0.96
Feb - 11	FFA_Q4	0	0	0	0	0	0	0.23	0.82	1	0.96
Mar - 11	FFA_Q4	0	0	0	0	0	0	0.23	0.82	1	0.96
Apr - 11	FFA_Q5	0	0	0	0	0	0	0	0.82	0.39	1
May - 11	FFA_Q5	0	0	0	0	0	0	0	0	0.39	1
Jun - 11	FFA_Q5	0	0	0	0	0	0	0	0	0.39	1
Expected income		100.1	98.98	97.80	96.42	94.48	92.51	89.61	86.34	82.58	78.42
Downside risk		-19.48	-25.49	-31.50	-37.51	-43.52	-49.53	-55.54	-61.54	-67.55	-73.56

Table B.4: The table shows the holdings of FFA contracts in the portfolio from the dynamical hedge strategies from period 2010.

Month	Contract	RP 1	RP 2	RP 3	RP 4	RP 5	RP 6	RP 7	RP 8	RP 9	RP 10
Jan - 11	FFA_M0/FFA_Q0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Feb - 11	FFA_M1/FFA_Q0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Mar - 11	FFA_M2/FFA_Q0	0/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Apr - 11	FFA_M3/FFA_Q1	0/0	0.82/0.18	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0.01/0.99
May - 11	FFA_M4/FFA_Q1	0/0	0/0.18	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/0.99
Jun - 11	FFA_M5/FFA_Q1	0/0	0/0.18	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/0.99
Jul - 11	FFA_Q2	0	0	0.45	1	0.82	1	1	1	1	0.96
Aug - 11	FFA_Q2	0	0	0.45	1	0.82	1	1	1	1	0.96
Sep - 11	FFA_Q2	0	0	0.45	1	0.82	1	1	1	1	0.96
Oct - 11	FFA_Q3	0	0	0	0.11	0.74	1	1	1	1	1
Nov - 11	FFA_Q3	0	0	0	0.11	0.74	1	1	1	1	1
Dec - 11	FFA_Q3	0	0	0	0.11	0.74	1	1	1	1	1
Jan - 12	FFA_Q4	0	0	0	0	0	0.13	0.60	1	1	1
Feb - 12	FFA_Q4	0	0	0	0	0	0.13	0.60	1	1	1
Mar - 12	FFA_Q4	0	0	0	0	0	0.13	0.60	1	1	1
Apr - 12	FFA_Q5	0	0	0	0	0	0	0	0.07	0.51	1
May - 12	FFA_Q5	0	0	0	0	0	0	0	0.07	0.51	1
Jun - 12	FFA_Q5	0	0	0	0	0	0	0	0.07	0.51	1
Expected income		100.6	99.93	97.79	95.38	92.79	89.85	86.13	82.28	77.77	72.82
Downside risk		-29.48	-33.77	-38.06	-42.34	-46.63	-50.92	-55.21	-59.50	-63.79	-68.07

Table B.5: The table shows the holdings of FFA contracts in the portfolio from the dynamical hedge strategies from period 2011.

Tables of suggested revision holdings

RP1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	0,0																	
3	0,0	0,0																
3	0,0	0,0	1,0															
4	0,0	0,0	0,0	0,0														
5	0,0	0,0	0,0	0,0	1,0													
6	0,0	0,0	0,0	0,0	1,0	1,0												
7	0,0	0,0	0,0	0,0	1,0	1,0	0,0											
8	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0										
9	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0									
10	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	1,0	0,0								
11	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,0	1,0	0,0	0,7							
12	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	1,0	0,0	0,7	0,0						
13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0					
14	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0				
15	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,3			
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	0,0		
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	0,0

Table C.1: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2006 with a risk neutral profile.

RP10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0,4																	
2	1,0	0,0																
3	1,0	0,0	1,0															
4	1,0	1,0	0,8	1,0														
5	1,0	1,0	0,8	1,0	1,0													
6	1,0	0,7	1,0	1,0	1,0	1,0												
7	1,0	1,0	1,0	1,0	1,0	1,0	0,0											
8	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0										
9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,0									
10	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0								
11	1,0	1,0	1,0	1,0	1,0	1,0	0,8	1,0	1,0	1,0	0,7							
12	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,1						
13	0,0	0,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0					
14	0,0	0,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0				
15	0,0	0,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3			
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,9	0,0		
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3

Table C.2: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2006 with a risk averse profile.

RP1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	0,0																	
3	1,0	0,0																
3	1,0	0,0	0,3															
4	1,0	0,0	1,0	0,0														
5	1,0	0,0	0,0	0,0	0,7													
6	1,0	0,0	0,0	0,0	0,7	0,0												
7	1,0	0,0	0,0	0,0	1,0	1,0	1,0											
8	1,0	0,0	0,0	0,0	1,0	1,0	1,0	0,7										
9	1,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,3									
10	1,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0								
11	1,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0							
12	1,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3						
13	1,0	0,0	0,0	0,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0					
14	1,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	1,0				
15	1,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0			
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0		
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0

Table C.3: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2007 with a risk neutral profile.

RP10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	1,0																	
3	1,0	1,0																
3	1,0	1,0	0,3															
4	1,0	1,0	0,8	0,0														
5	1,0	1,0	1,0	0,7	0,7													
6	1,0	1,0	1,0	1,0	0,7	0,0												
7	1,0	1,0	1,0	1,0	0,7	0,7	1,0											
8	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7										
9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,3									
10	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9								
11	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0							
12	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3						
13	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0					
14	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,7				
15	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,7	0,3			
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,9	0,7		
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,1	1,0	0,9	0,9	0,0	
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0

Table C.4: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2007 with a risk averse profile.

RP1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	0,0																	
3	0,0	1,0																
3	0,0	0,0	0,0															
4	0,0	0,0	0,0	0,0														
5	0,0	0,0	0,0	0,0	0,0													
6	0,0	0,0	0,0	0,0	0,0	0,0												
7	0,0	0,0	0,0	0,0	0,0	0,0	0,0											
8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0										
9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3									
10	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0								
11	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0							
12	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	0,3						
13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0					
14	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	1,0				
15	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0			
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0		
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,3

Table C.5: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2008 with a risk neutral profile.

RP10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	0,0																	
3	0,0	0,7																
3	0,0	0,7	0,3															
4	0,0	1,0	0,9	0,9														
5	0,0	1,0	1,0	0,7	0,0													
6	0,0	1,0	1,0	1,0	1,0	0,0												
7	1,0	1,0	1,0	0,8	0,7	0,0	1,0											
8	1,0	1,0	1,0	1,0	0,9	1,0	0,8	0,0										
9	1,0	1,0	1,0	1,0	0,9	1,0	1,0	0,0	0,3									
10	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0								
11	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0							
12	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3						
13	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8	1,0	1,0	1,0	0,9	1,0					
14	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8	1,0	0,9	1,0	1,0	1,0	0,5				
15	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8	1,0	1,0	1,0	1,0	1,0	1,0	0,2			
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,7	0,8		
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3

Table C.6: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2008 with a risk averse profile.

RP1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	0,0																	
3	1,0	1,0																
3	0,0	0,0	0,0															
4	0,0	0,0	0,0	0,0														
5	0,0	0,0	0,0	0,0	1,0													
6	0,0	0,0	0,0	0,0	1,0	0,3												
7	0,0	0,0	0,0	0,0	1,0	1,0	0,0											
8	0,0	0,0	0,0	0,0	1,0	1,0	0,0	1,0										
9	0,0	0,0	0,0	0,0	1,0	1,0	0,0	1,0	0,0									
10	0,0	0,0	0,0	0,0	1,0	1,0	0,0	1,0	0,0	1,0								
11	0,0	0,0	0,0	0,0	1,0	1,0	0,0	1,0	1,0	1,0	0,7							
12	0,0	0,0	0,0	0,0	1,0	1,0	0,0	1,0	1,0	1,0	0,7	0,3						
13	0,0	1,0	1,0	1,0	1,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0					
14	0,0	1,0	1,0	1,0	1,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0				
15	0,0	1,0	1,0	1,0	1,0	1,0	0,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0	0,0			
16	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	1,0		
17	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	
18	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,3

Table C.7: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2009 with a risk neutral profile.

RP10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	1,0																	
3	1,0	0,5																
3	1,0	1,0	0,2															
4	1,0	1,0	1,0	0,9														
5	1,0	1,0	0,6	0,8	0,7													
6	1,0	1,0	1,0	1,0	0,7	0,2												
7	1,0	1,0	1,0	1,0	0,9	1,0	0,0											
8	1,0	1,0	1,0	1,0	1,0	1,0	0,7	1,0										
9	1,0	0,9	1,0	0,8	1,0	0,9	1,0	1,0	0,0									
10	1,0	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,6								
11	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7							
12	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,3						
13	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8					
14	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0				
15	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	0,9	1,0	1,0	1,0	1,0	1,0	0,3			
16	0,0	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0		
17	0,0	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,9	0,7	1,0	
18	0,0	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3

Table C.8: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2009 with a risk averse profile.

RP1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	1,0																	
3	0,0	0,0																
3	0,0	0,0	0,0															
4	0,0	0,0	0,0	1,0														
5	0,0	0,0	0,0	0,0	0,0													
6	0,0	0,0	0,0	0,0	0,0	0,3												
7	0,0	0,0	0,0	0,0	0,0	1,0	0,0											
8	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,7										
9	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,7	0,3									
10	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	1,0	1,0								
11	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	1,0	1,0	0,7							
12	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	1,0	1,0	0,7	0,0						
13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	1,0					
14	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,0	1,0	1,0				
15	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	0,0	1,0	1,0	0,3			
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	1,0	1,0	1,0		
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,7	
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,7	0,3

Table C.9: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2010 with a risk neutral profile.

RP10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	0,2																	
3	1,0	0,0																
3	1,0	1,0	0,3															
4	1,0	1,0	1,0	1,0														
5	1,0	0,8	0,5	0,7	0,5													
6	1,0	1,0	1,0	1,0	0,8	0,3												
7	1,0	1,0	1,0	0,8	1,0	1,0	0,0											
8	1,0	1,0	1,0	1,0	1,0	0,9	1,0	0,7										
9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3									
10	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0								
11	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7							
12	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,3						
13	0,6	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0					
14	0,6	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0				
15	0,6	1,0	1,0	0,7	1,0	1,0	1,0	1,0	0,9	0,9	1,0	1,0	0,9	1,0	0,3			
16	0,3	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9		
17	0,3	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	
18	0,3	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3

Table C.10: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2010 with a risk averse profile.

RP1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	1,0																	
3	1,0	1,0																
4	0,0	1,0	0,3															
5	0,0	1,0	1,0	1,0														
6	0,0	1,0	0,0	1,0	0,7													
7	0,0	0,0	0,0	1,0	0,7	0,3												
8	0,0	0,0	0,0	0,0	1,0	1,0	0,0											
9	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0										
10	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	0,3									
11	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,0								
12	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0							
13	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0						
14	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	0,0	0,0	1,0					
15	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	1,0	0,0	0,0	1,0	0,0				
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0			
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0		
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	

Table C.11: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2011 with a risk neutral profile.

RP10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	1,0																	
3	1,0	0,7																
3	1,0	0,7	0,3															
4	1,0	1,0	1,0	1,0														
5	1,0	1,0	1,0	1,0	0,7													
6	1,0	1,0	0,9	1,0	0,7	0,3												
7	1,0	1,0	1,0	1,0	1,0	1,0	0,8											
8	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,7										
9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3									
10	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8								
11	1,0	1,0	1,0	1,0	1,0	0,9	1,0	1,0	1,0	1,0	0,7							
12	1,0	1,0	1,0	1,0	1,0	0,9	1,0	1,0	1,0	1,0	0,7	0,3						
13	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,5	1,0					
14	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,1				
15	0,7	1,0	1,0	0,7	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9	0,3			
16	0,3	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	0,9	1,0		
17	0,3	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9	0,4	
18	0,3	0,7	1,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,0

Table C.12: The table shows the holdings of FFA contracts as a proportion of spot contracts to hedge, suggested by the revised allocation model. The optimization is done for 2011 with a risk averse profile.

APPENDIX D

Code for making statistical analysis

D.1 GAMS-code

```
$TITLE Optimal freight rate allocation
$EOLCOM //
option iterlim=999999999,solprint=OFF,limrow=100,limcol=0;
option reslim=600, optcr=0.0000000000001;
option decimals=8;

//-------------------------------
//
// Read data
//
//-------------------------------

$ONECHO > gdxxrw.in
i = data\wsRates_GAMS_dayli.xls
o = data\gdx\wsRates_GAMS_dayli.gdx
dset date rng=Ark1!a2 rdim=1
dset asset rng=Ark1!b1 cdim=1
par  rates rng=Ark1!a1 cdim=1 rdim=1
$OFFECHO
```

```
$CALL gdxxrw @gdxxrw.in trace=0

//Define and read the sets used in the script
SETS
  date 'dayli quote dates covering the range from 2000.01.04 -
      2012.10.19'
  asset 'spot and current months FFA contracts'
;

ALIAS(a,asset);
ALIAS(d,date);

$GDXIN data\gdx\wsRates_GAMS_dayli
$LOAD date asset

//Define and read the parameters used in the script
PARAMETERS
  rates(d,a) 'dayli rates in the time horizon'
;

$LOAD rates
$GDXIN

//-----------------------------
//
// Make simple bootstrap sample
//
//-----------------------------

SETS
  scen      '250 scenarios in each node level' /1*250/
  nodeLevel 'node level in scenario tree'      /1*19/

  scenDay   'working days in a month'          /1*20/
  loopParam1 'loop parameter 1 on months'      /1*20/
  loopParam2 'loop parameter 2 on node level'  /1*19/
  loopParam3 'loop parameter 3 on backtest level' /1*18/
  nodeAssets 'statement in each node'          /month_avr, month_beg,
      ffa_m, real_avr/
  backtestPar'Parameter for backtest'          /1*18/
;

ALIAS(s,scen);
ALIAS(sd,scenDay);
ALIAS(nl,nodeLevel);
ALIAS(lp1,loopParam1);
ALIAS(lp2,loopParam2);
```

```
ALIAS(lp3,loopParam3);
ALIAS(n,nodeAssets);
ALIAS(bt,backtestPar);

PARAMETERS
  dayDevel(d)            'Dayli developments for each date'

  randIndex(s,sd,nl,bt)     'random generated index numbers for choosing
        rates randomly'
  dayliScenDevelop(s,sd,nl,bt)'Dayli developmemts in scenarios'
  dayliScenarios(s,nl,sd,bt) 'Scenario on dayli basis'
  monthScenarios(bt,s,nl,n) 'scenarios aggregated on monthly basis'

  startRate(s,bt)
  scenStartIndex(bt)     'Parameter holding start indeces'
  scenStartIndex2(nl)    'Parameter holding start indeces'
  getDateIndex(d)        'Determines the index for a given date'
;

//Get indices for the first day of each month
getDateIndex(d) = ord(d);

scenStartIndex('1') = getDateIndex('01-03-2006');
scenStartIndex(bt)$(ord(bt)>1 and ord(bt)<13) =
    scenStartIndex('1')+20*(ord(bt)-1);
scenStartIndex('13') = getDateIndex('02-01-2007');
scenStartIndex(bt)$(ord(bt)>13 and ord(bt)<25) =
    scenStartIndex('13')+20*(ord(bt)-13);
scenStartIndex('25') = getDateIndex('02-01-2008');
scenStartIndex(bt)$(ord(bt)>25 and ord(bt)<37) =
    scenStartIndex('25')+20*(ord(bt)-25);
scenStartIndex('37') = getDateIndex('02-01-2009');
scenStartIndex(bt)$(ord(bt)>37 and ord(bt)<49) =
    scenStartIndex('37')+20*(ord(bt)-37);
scenStartIndex('49') = getDateIndex('04-01-2010');
scenStartIndex(bt)$(ord(bt)>49 and ord(bt)<61) =
    scenStartIndex('49')+20*(ord(bt)-49);
scenStartIndex('61') = getDateIndex('04-01-2011');
scenStartIndex(bt)$(ord(bt)>61) = scenStartIndex('61')+20*(ord(bt)-61);

scenStartIndex2(nl) = sum(bt,scenStartIndex(bt)$(ord(bt) = ord(nl)));
scenStartIndex2('73') = getDateIndex('03-01-2012');

//Compute set of dayli development of spot rates instead of rates
dayDevel(d)$(ord(d) > 1) = rates(d,'spot_ws')/rates(d-1,'spot_ws');
```

```
//Randomly pick 20 days for each node level between the first half of
    hist data
//execseed                      = gmillisec(jnow);
randIndex(s,sd,nl,bt)$(ord(bt)=1) = uniformint(2,scenStartIndex(bt));
randIndex(s,sd,nl,bt)$(ord(bt)>1) =
    uniformint(2+(scenStartIndex(bt)-scenStartIndex(bt-1)),scenStartIndex(bt));
dayliScenDevelop(s,sd,nl,bt)  = sum(d,dayDevel(d)$(ord(d) =
    randIndex(s,sd,nl,bt)));

//Compute dayli scenarios of rates
dayliScenarios(s,nl,sd,bt) = dayliScenDevelop(s,sd,nl,bt);
dayliScenarios(s,nl,sd,bt)$(ord(sd) = 1 and ord(nl) = 1) =
    sum(d,rates(d,'spot_ws')$(ord(d) = scenStartIndex(bt)));

loop(lp2,
  loop(lp1$(ord(lp1) > 1),
    dayliScenarios(s,nl,sd,bt)$(ord(sd) = ord(lp1) and ord(nl) =
        ord(lp2)) =
        dayliScenarios(s,nl,sd,bt)*dayliScenarios(s,nl,sd-1,bt);
  );

  startRate(s,bt) = sum((sd,nl),dayliScenarios(s,nl,sd,bt)$(ord(sd) =
      card(sd) and ord(nl) = ord(lp2)));

  if(ord(lp2)<card(lp2),
    dayliScenarios(s,nl,sd,bt)$(ord(sd) = 1 and ord(nl) = ord(lp2)+1) =
        startRate(s,bt)*dayliScenarios(s,nl,sd,bt);
  );
);

//Compute beginning of month
monthScenarios(bt,s,nl,'month_beg') =
    sum(sd,dayliScenarios(s,nl,sd,bt)$(ord(sd) = 1));

//Compute monthly average
monthScenarios(bt,s,nl,'month_avr') =
    sum(sd,dayliScenarios(s,nl-1,sd,bt)/card(sd));

//Write results to file
EXECUTE 'gdxxrw.exe data\gdx\wsRates_GAMS_dayli.gdx
    O=portfolioAllocation\bootstrap_2011Sample.xls par=rates
    rng=histRates!a1';

EXECUTE_UNLOAD 'data\gdx\bootstrap_FullSample_randIndex.gdx', randIndex;
//EXECUTE 'gdxxrw.exe data\gdx\bootstrap_2011sample_randIndex.gdx
    O=portfolioAllocation\bootstrap_2011sample.xls par=randIndex
    rng=randIndex!a1';
```

```
EXECUTE_UNLOAD 'data\gdx\bootstrap_Fullsample_dayScen.gdx',
    dayliScenDevelop;
//EXECUTE 'gdxxrw.exe data\gdx\bootstrap_2011sample_dayScen.gdx
    O=portfolioAllocation\bootstrap_2011sample.xls par=dayliScenDevelop
    rng=dayliScenarioDevelopments!a1';

EXECUTE_UNLOAD 'data\gdx\bootstrap_FullSample_day.gdx', dayliScenarios;
//EXECUTE 'gdxxrw.exe data\gdx\bootstrap_2011Sample_day.gdx
    O=portfolioAllocation\bootstrap_2011Sample.xls par=dayliScenarios
    rng=dayliScenarios!a1';

EXECUTE_UNLOAD 'data\gdx\bootstrap_FullSample_month.gdx', monthScenarios;
EXECUTE 'gdxxrw.exe data\gdx\bootstrap_FullSample_month.gdx
    O=portfolioAllocation\bootstrap_FullSample.xls par=monthScenarios
    rng=monthlyScenarios!a1';
```

D.2   R-code

```
##------------------------------------------------------------##
##                                                          ##
##           Script reading historical sample           ##
##                                                          ##
##------------------------------------------------------------##

setwd("C://Users//Jonas//Documents//DTU//Master Thesis")

# READ DATA
data <- read.csv2('working_dir//DATA//wsRates_dayli.csv',header=TRUE)

date <- as.Date(data$date)
spot.td1 <- as.numeric(data$spot_wsTD1)
spot.td2 <- as.numeric(data$spot_wsTD2)
spot.td3 <- as.numeric(data$spot_wsTD3)
spot.td4 <- as.numeric(data$spot_wsTD4)
spot.td5 <- as.numeric(data$spot_wsTD5)
spot.td7 <- as.numeric(data$spot_wsTD7)

spot <- spot.td3

n <- length(spot)
dev <- log(spot[-1]/spot[-n])
```

```
##FFA contract prices.
date.ffa      <- date[c(1254:n)]
spot.td3.ffa <- data$spot_wsTD3[c(1254:n)]
ffa.curm.all <- data$ffa_CURM
ffa.curm     <- data$ffa_CURM[c(1254:n)]
ffa.1m       <- data$ffa_1M[c(1254:n)]
ffa.2m       <- data$ffa_2M[c(1254:n)]
ffa.3m       <- data$ffa_3M[c(1254:n)]
ffa.4m       <- data$ffa_4M[c(1254:n)]
ffa.5m       <- data$ffa_5M[c(1254:n)]
ffa.curq     <- data$ffa_CURQ[c(1254:n)]
ffa.1q       <- data$ffa_1Q[c(1254:n)]
ffa.2q       <- data$ffa_2Q[c(1254:n)]
ffa.3q       <- data$ffa_3Q[c(1254:n)]
ffa.4q       <- data$ffa_4Q[c(1254:n)]
ffa.5q       <- data$ffa_5Q[c(1254:n)]


##------------------------------------------------------------##
##                                                          ##
##           Script reading bootstrap sample               ##
##                                                          ##
##------------------------------------------------------------##
setwd("C://Users//Jonas//Documents//DTU//Master Thesis")

install.packages("reshape2")
install.packages("Model_dir//gdxrrw_0.2.0.zip", repos = NULL)

library("reshape2")
library("gdxrrw")

igdx(gamsSysDir="C://GAMS//win64//23.9")

##Dayli rates
gdxFile <-
    "Model_dir//Data//gdx//Backtest//bootstrap_FullSample_dayScen.gdx"
bootRate <- rgdx.param(gdxFile,"dayliScenDevelop",squeeze = FALSE)

names(bootRate) <- c("scenarios","dateIndex","month","p","rate")

rate.temp   <- subset(bootRate,p == 1 & month %in% c(1:18))
rate <- data.frame(rate.temp$scenarios, rate.temp$month,
    rate.temp$dateIndex, rate.temp$rate)
names(rate) <- c("scenarios","month","dayIndex","rate")

##Order data set properly
rate <- rate[with(rate, order(scenarios, month, dayIndex)), ]
```

```r
rate$rate <- log(rate$rate)

##
## Script for making plots of data
##

##Reading data scripts and setting work directory
setwd("C://Users//Jonas//Documents//DTU//Master Thesis")
source("Model_dir//portfolioAllocation//Rscript//ReadBootstrap.R")
source("Model_dir//portfolioAllocation//Rscript//ReadSample.R")

model.sample <- dev[c(1:1502)]
test.sample <- dev[-c(1:1502)]

##Make table of sample
rec <-
    data.frame(c("ffa_cm","ffa_1m","ffa_2m","ffa_3m","ffa_4m","ffa_5m","ffa_cq","ffa_1q","
                c(sum(!is.na(ffa.curm)),
                  sum(!is.na(ffa.1m)),
                  sum(!is.na(ffa.2m)),
                  sum(!is.na(ffa.3m)),
                  sum(!is.na(ffa.4m)),
                  sum(!is.na(ffa.5m)),
                  sum(!is.na(ffa.curq)),
                  sum(!is.na(ffa.1q)),
                  sum(!is.na(ffa.2q)),
                  sum(!is.na(ffa.3q)),
                  sum(!is.na(ffa.4q)),
                  sum(!is.na(ffa.5q))),
                c(sum(is.na(ffa.curm)),
                  sum(is.na(ffa.1m)),
                  sum(is.na(ffa.2m)),
                  sum(is.na(ffa.3m)),
                  sum(is.na(ffa.4m)),
                  sum(is.na(ffa.5m)),
                  sum(is.na(ffa.curq)),
                  sum(is.na(ffa.1q)),
                  sum(is.na(ffa.2q)),
                  sum(is.na(ffa.3q)),
                  sum(is.na(ffa.4q)),
                  sum(is.na(ffa.5q))),
                c(round(sum(is.na(ffa.curm))/1950,2),
                  round(sum(is.na(ffa.1m))/1950,2),
                  round(sum(is.na(ffa.2m))/1950,2),
                  round(sum(is.na(ffa.3m))/1950,2),
                  round(sum(is.na(ffa.4m))/1950,2),
```

```
                round(sum(is.na(ffa.5m))/1950,2),
                round(sum(is.na(ffa.curq))/1950,2),
                round(sum(is.na(ffa.1q))/1950,2),
                round(sum(is.na(ffa.2q))/1950,2),
                round(sum(is.na(ffa.3q))/1950,2),
                round(sum(is.na(ffa.4q))/1950,2),
                round(sum(is.na(ffa.5q))/1950,2))
)

names(rec) <- c("FFA Contract","Number of records","Number of
    NA's","Fraction")

rec.table <- xtable(rec,
                caption="The table shows the number of records on FFA
                    contract prices",
                label="ffaRecords",
                align=c("l","l",rep("c",3)))

print(rec.table)


##
##Deffining functions for plotting
##
plotBoot <- function(X,x1,max.y,min.y){
  n <- length(X[,1])
  m <- length(X[1,])

  plot(c(max.y,min.y,rep(0,n-1)),
      type="n",
      xlab="month",
      ylab="price of spot contracts")
  legend("topleft",
        cex = 1,
        bty = "n",
        legend = c("95% quantile",
                   "mean of bootstrap samples",
                   "5% quantile"),
        col = 2,
        lwd = 3,
        lty = c(3,1,3)
  )

  for(i in 1:m){
    lines(c(x1,X[,i]), col="grey")
  }
```

```r
  #MEAN
  E <- numeric(n)
  q.05 <- numeric(n)
  q.95 <- numeric(n)
  for(j in 1:n){
    E[j]    <- mean(X[j,])
    q.05[j] <- quantile(X[j,],probs=0.05)
    q.95[j] <- quantile(X[j,],probs=0.95)
  }

  lines(c(x1,E), col=2, lwd = 3)
  lines(c(x1,q.05), col=2, lty=3, lwd=3)
  lines(c(x1,q.95), col=2, lty=3, lwd=3)
}

##
##Plotting data
##

##
##Historical prices of data set
##Chapter 3
##

pdf("Thesis (Tex)//figures//td3.pdf", width=10, height=4)
  plot(date,
       spot.td3,
       type="l",
       ylab = "World Scale rate",
       xlab = "Date")
dev.off()

##Comparisons of different indices
pdf("Thesis (Tex)//figures//scatter.pdf", width=10, height=4)
  pairs(~spot.td1+spot.td2+spot.td3+spot.td4,bty="7")
dev.off()

##Development of historical prices
pdf("Thesis (Tex)//figures//td3_r.pdf", width=10, height=4)
  plot(date[-1],
       dev,
       type="l",
       ylab = "Development of World Scale rate (r)",
       xlab = "Date")
dev.off()
```

```
##
##Plotting bootstrap scenarios
##Chapter 5
##

##Compute mean and confidence interval
T <- 18*20
N <- 250

exp(scenarios.boot[,1])

scenarios.boot <- matrix(ncol=N,nrow=T)
for(i in 1:N){
  scenarios.boot[,i] <- subset(rate,scenarios == i)$rate
}

mean.boot   <- numeric(360)
sd.boot     <- numeric(360)
conf.l.boot <- numeric(360)
conf.h.boot <- numeric(360)

for(i in 1:T){
  mean.boot[i]   <- mean(scenarios.boot[i,])
  sd.boot[i]     <- sd(scenarios.boot[i,])
  conf.l.boot[i] <- mean.boot[i]+quantile(scenarios.boot[i,], probs =
      0.025)
  conf.h.boot[i] <- mean.boot[i]+quantile(scenarios.boot[i,], probs =
      0.975)
}



pdf("Thesis (Tex)//figures//bootRate1.pdf", width = 10, height = 4)
  max <- max(rate$rate)+0.2
  min <- min(rate$rate)

  plot(c(rep(max,T/2),rep(min,(T/2)+1)),type="n",xlab="days",ylab="rate")

  for(i in 1:N){
    lines(scenarios.boot[,i], col="grey")
  }

  lines(mean.boot,col=2,lwd=2)
  lines(conf.l.boot,col=2,lty=3)
  lines(conf.h.boot,col=2,lty=3)

  legend("topleft",
```

```r
        cex = 1,
        bty = "n",
        legend = c("Mean of bootstrap samples","95% confidence
            interval"),
        col = c(2,2),
        lwd = c(2,1),
        lty = c(1,3)
  )
  legend("topright",
      cex = 1,
      bty = "n",
      legend = c("Bootstrap scenarios"),
      col = c("grey"),
      lwd = c(1),
      lty = c(1)
  )
dev.off()

pdf("Thesis (Tex)//figures//bootRate2.pdf", width = 10, height = 4)
  max <- max(conf.h.boot)+0.06
  min <- min(conf.l.boot)

  plot(c(rep(max,T/2),rep(min,T/2)),type="n",xlab="days",ylab="rate")
  lines(test.sample[1:T])
  lines(mean.boot,col=2,lwd=2)
  lines(conf.h.boot,col=2,lty=3)
  lines(conf.l.boot,col=2,lty=3)
  legend("topleft",
      cex = 1,
      bty = "n",
      legend = c("Mean of bootstrap samples","Confidence interval"),
      col = c(2,2),
      lwd = c(2,1),
      lty = c(1,3)
  )
  legend("topright",
      cex = 1,
      bty = "n",
      legend = c("Test sample"),
      col = c(1),
      lwd = c(1),
      lty = c(1)
  )
dev.off()

pdf("Thesis (Tex)//figures//td3_acf.pdf", width=10, height=4)
  acf(model.sample,main="")
```

```
dev.off()

pdf("Thesis (Tex)//figures//td3_pacf.pdf", width=10, height=4)
  pacf(model.sample,main="")
dev.off()



pdf("Thesis (Tex)//figures//td3_hist.pdf", width=10, height=4)
  hist(model.sample, breaks=200, probability=TRUE,
      main="",xlab="Rate",xlim=c(-0.2,0.2))
  curve(dnorm(x, mean=mean(model.sample), sd=sd(model.sample)), col = 2,
      lty = 2, lwd = 2, add = TRUE)
dev.off()

pdf("Thesis (Tex)//figures//td3_qqplot.pdf", width=10, height=4)
  qqplot(model.sample, qnorm(ppoints(model.sample),
      mean=mean(model.sample), sd=sd(model.sample)),xlab="Theoretical
      quantiles",ylab="Sample quantiles")
  abline(0,1, col = 2, lty = 2)
dev.off()


##Compute prices
price.boot  <- matrix(ncol=N,nrow=(T+1))
price.boot[1,] <- 121.61
for(i in 1:T){
  price.boot[(i+1),] <- price.boot[i,]*exp(scenarios.boot[i,])
}

price.mean.boot <- numeric(T+1)
price.conf.h.boot <- numeric(T+1)
price.conf.l.boot <- numeric(T+1)

price.mean.boot[1] <- price.conf.h.boot[1] <- price.conf.l.boot[1] <-
    121.61
for(i in 1:T){
  price.mean.boot[i+1] <- mean(price.boot[i,])
  price.conf.h.boot[i+1] <- quantile(price.boot[i,],probs=0.975)
  price.conf.l.boot[i+1] <- quantile(price.boot[i,],probs=0.025)
}


pdf("Thesis (Tex)//figures//compare_boot2.pdf", width=10, height=4)
  plot(c(price.conf.h.boot[c(2:351)],0),
      type="n",
      xlab="days",
      ylab="spot price")
```

```r
  for(i in 1:250){
    lines(price.boot[,i],col="grey")
  }
  lines(spot[c(1502:1862)],lwd=2)
  lines(price.mean.boot,col=2,lwd=2)
  lines(price.conf.h.boot,col=2,lty=3,lwd=2)
  lines(price.conf.l.boot,col=2,lty=3,lwd=2)
  legend("topleft",
      cex = 1,
      bty = "n",
      legend = c("Mean of bootstrap samples","Test sample","95%
          quantile","Bootstrap samples"),
      col = c(2,1,2,"grey"),
      lwd = c(2,2,2,1),
      lty = c(1,1,3,1)
  )
dev.off()


##Test for normality
shapiro.test(model.sample)
##Test for stationaritet
install.packages(tseries)
library(tseries)
kpss.test(model.sample,null="Trend")


##-------------------------------------------------------------##
##                                                             ##
##                                                             ##
##            Script for computing arma model.                ##
##                                                             ##
##                                                             ##
##-------------------------------------------------------------##


##Reading data scripts and setting work directory
setwd("C://Users//Jonas//Documents//DTU//Master Thesis")
source("Model_dir//portfolioAllocation//Rscript//ReadSample.R")

model.sample <- dev[c(1:1502)]
test.sample <- dev[-c(1:1502)]


##------------------------------------
##
## Fit AR(p) models and find best fit
##
##------------------------------------
```

```r
##
##Choose model order
##

ar.mod9 <- arima(model.sample, order=c(9,0,0), include.mean=FALSE)
ar.mod8 <- arima(model.sample, order=c(8,0,0), include.mean=FALSE)
ar.mod7 <- arima(model.sample, order=c(7,0,0), include.mean=FALSE)
ar.mod6 <- arima(model.sample, order=c(6,0,0), include.mean=FALSE)
ar.mod5 <- arima(model.sample, order=c(5,0,0), include.mean=FALSE)
ar.mod4 <- arima(model.sample, order=c(4,0,0), include.mean=FALSE)
ar.mod3 <- arima(model.sample, order=c(3,0,0), include.mean=FALSE)
ar.mod2 <- arima(model.sample, order=c(2,0,0), include.mean=FALSE)
ar.mod1 <- arima(model.sample, order=c(1,0,0), include.mean=FALSE)


loss <- numeric(9)
loss[1] <- sum(ar.mod1$residuals^2)
loss[2] <- sum(ar.mod2$residuals^2)
loss[3] <- sum(ar.mod3$residuals^2)
loss[4] <- sum(ar.mod4$residuals^2)
loss[5] <- sum(ar.mod5$residuals^2)
loss[6] <- sum(ar.mod6$residuals^2)
loss[7] <- sum(ar.mod7$residuals^2)
loss[8] <- sum(ar.mod8$residuals^2)
loss[9] <- sum(ar.mod9$residuals^2)

pdf("Thesis (Tex)//figures//lossFunction.pdf", width=10, height=4)
  plot(loss,
       type="l",
       xlab="Number of parameters",
       ylab="Loss function")
dev.off()

ar.mod <- ar.mod6

##
##Plot residuals to test normal assumption!!
##
pdf("Thesis (Tex)//figures//residuals.pdf", width = 10, height = 4)
  plot(ar.mod$residuals,xlab="days",ylab="residuals")
dev.off()

pdf("Thesis (Tex)//figures//residQQplot.pdf", width = 10, height = 4)
  qqplot(qnorm(ppoints(ar.mod$residuals), mean=mean(ar.mod$residuals),
       sd = sd(ar.mod$residuals)),
         ar.mod$residuals,
         ylab = "Sample quantiles",
```

```
        xlab = "Theoretical quantiles")
  abline(a=0, b=1, col=2, lty=2)
dev.off()

pdf("Thesis (Tex)//figures//residHist.pdf", width=10, height=4)
  hist(ar.mod$resid, breaks=200, probability=TRUE, xlab="residuals",
       xlim=c(-0.2,0.2), main="")
  curve(dnorm(x, mean=0, sd=sd(ar.mod$resid)), col = 2, lty = 2, lwd =
       2, add = TRUE)
dev.off()

pdf("Thesis (Tex)//figures//residAcf.pdf", width = 10, height = 4)
  acf(ar.mod$resid, main="")
dev.off()

library(MASS)
pdf("preAnalysis//arma//mod1Freq.pdf")
  cpgram(ar.mod$residuals, main="")
dev.off()

##
## Theoretic test on normal assumption
##

#Fortegnstest - 0.5
m <- length(ar.mod$residuals)
binom.test(sum(1*(ar.mod$residuals[2:m]*ar.mod$residuals[1:(m-1)] <
    0)),m-1)

##
## Test for model reduktion
##

##H0: mod.ar6 = mod.ar5
test1 <- (loss[5] - loss[6])/(loss[6]/(m - 6))
test1.pvalue <- 1-pf(test1, 1,(m-6))
test1.pvalue
##p-value = 0,02791 < 0,05
##Significant changes and H0 are rejected on 5% significanse niveau.

##H0: mod.ar6 = mod.ar4
test2 <- ((loss[4] - loss[6])/(6 - 4))/(loss[6]/(m - 6))
test2.pvalue <- 2-pf(test1, (6-4),(m-6))
test2.pvalue
##p-value = 0,0606 > 0,05
##insignificant changes and H0 are accepted on 5% significanse niveau.
```

```
##H0: mod.ar4 = mod.ar3
test3 <- ((loss[3] - loss[4])/(4 - 3))/(loss[4]/(m - 4))
test3.pvalue <- 1-pf(test3, (4-3),(m-4))
test3.pvalue
##p-value = 0,7850 > 0,05
##insignificant changes and H0 are accepted on 5% significanse niveau.


##H0: mod.ar3 = mod.ar2
test4 <- ((loss[2] - loss[3])/(3 - 2))/(loss[3]/(m - 3))
test4.pvalue <- 1-pf(test4, 1,(m-3))
test4.pvalue
##p-value = 0,6155 > 0,05
##insignificant changes and H0 are accepted on 5% significanse niveau.


##H0: mod.ar3 = mod.ar2
test6 <- ((loss[1] - loss[2])/(2 - 1))/(loss[2]/(m - 2))
test6.pvalue <- 1-pf(test6, 1,(m-2))
test6.pvalue
##p-value = 0,1916 > 0,05
##insignificant changes and H0 are accepted on 5% significanse niveau.


ar.mod <- ar.mod1

pdf("Thesis (Tex)//figures//residAcf1.pdf", width = 10, height = 4)
  acf(ar.mod$resid, main="")
dev.off()


##
##Compute and analyse scenarios
##
ar.mod <- ar.mod1

T  <- 18*20
N  <- 250

scenarios <- matrix(ncol=N,nrow=T)
for(j in 1:N){
  scenarios[,j] <- arima.sim(list(ar = ar.mod$coef), sd =
      sqrt(ar.mod$sigma2), n = T)
}

##Compute mean and confidence interval
mean <- numeric(360)
sd <- numeric(360)
conf.l <- numeric(360)
conf.h <- numeric(360)
```

```r
for(l in 1:360){
  mean[l]   <- mean(scenarios[l,])
  sd[l]     <- sd(scenarios[l,])
  conf.l[l] <- mean[l]+qnorm(0.025, mean=0, sd=1)*sd[l]
  conf.h[l] <- mean[l]+qnorm(0.975, mean=0, sd=1)*sd[l]
}

pdf("Thesis (Tex)//figures//AR1Rate.pdf", width = 10, height = 4)
  plot(test.sample[1:T],type="n",xlab="days",ylab="rate")
  lines(test.sample[1:T])
  lines(mean,col=2,lwd=2)
  lines(conf.h,col=2,lty=3)
  lines(conf.l,col=2,lty=3)
  legend("topright",
         cex = 1,
         bty = "n",
         legend = c("Mean of AR(1) samples","Confidence interval","Test
              sample"),
         col = c(2,2,1),
         lwd = c(2,1,1),
         lty = c(1,3,1)
  )
dev.off()

lines(model.sample,col=3)

pdf("Thesis (Tex)//figures//AR1Rate2.pdf", width = 10, height = 4)
  max <- max(rate$rate)+0.4
  min <- min(rate$rate)

  plot(c(rep(max,180),rep(min,181)),type="n",xlab="days",ylab="rate")

  for(i in 1:150){
    lines(subset(rate, scenarios == i)$rate)
  }
  for(i in 1:250){
    lines(scenarios[,i],col="grey")
  }
  lines(mean,col=2,lwd=2)
  lines(conf.l,col=2,lty=3)
  lines(conf.h,col=2,lty=3)
  legend("topleft",
         cex = 1,
         bty = "n",
         legend = c("AR(1)-sample","Mean of AR(1)-sample"),
         col = c("grey",2),
         lwd = 1,
```

```r
        lty = c(1,1)
    )
  legend("topright",
         cex = 1,
         bty = "n",
         legend = c("95% confidence interval","Bootstrap sample"),
         col = c(2,1),
         lwd = 1,
         lty = c(3,1)
  )
dev.off()


pdf("Thesis (Tex)//figures//compareVariance.pdf", width = 10, height = 4)
  plot(sd.boot^2,type="l",ylab="Variance",xlab="days")
  lines(sd^2,lwd=2,col=2)
  legend("topleft",
         cex=1,
         bty="n",
         legend=c("Variance of bootstrap sample","Variance of
             AR(1)-sample"),
         col=c(1,2),
         lwd=c(1,2)
  )
dev.off()

#plot sammen med prisen fra bootstrap
pdf("Thesis (Tex)//figures//AR1Price.pdf", width = 10, height = 4)
  price.ar  <- matrix(ncol=N,nrow=(T+1))
  price.ar[1,] <- 121.61
  for(i in 1:T){
    price.ar[(i+1),] <- price.ar[i,]*exp(scenarios[i,])
  }

  price.mean.ar <- numeric(T+1)
  price.conf.h.ar <- numeric(T+1)
  price.conf.l.ar <- numeric(T+1)

  price.mean.ar[1] <- price.conf.h.ar[1] <- price.conf.l.ar[1] <- 121.61
  for(i in 1:T){
    price.mean.ar[i+1] <- mean(price.ar[i,])
    price.conf.h.ar[i+1] <- quantile(price.ar[i,],probs=0.975)
    price.conf.l.ar[i+1] <- quantile(price.ar[i,],probs=0.025)
  }

  plot(price.conf.h.ar,type="n",xlab="days",ylab="expected price of spot
       contracts")
```

```
  for(i in 1:N){
    lines(price.ar[,i],col="grey")
  }
  lines(price.conf.h.ar,col=2,lwd=2,lty=3)
  lines(price.conf.l.ar,col=2,lwd=2,lty=3)
  lines(price.mean.ar,col=2,lwd=2)

  lines(price.mean.boot,col=3,lwd=2)

  lines(spot[c(1502:1862)],type="l",lwd=2)
  legend("topleft",
         bty = "n",
         cex = 1,
         legend = c("Mean of AR(1)-sample","Test sample","95%
             quantile","AR(1)-samples","Mean of bootstrapsamples"),
         col = c(2,1,2,"grey",3),
         lwd = c(2,2,2,1,2),
         lty = c(1,1,3,1,1))
dev.off()



a.ga <- c(scenarios.garch > 0)
sum(as.numeric(a.ga))/length(scenarios.garch)

a.ar <- c(scenarios > 0)
sum(as.numeric(a.ar))/length(scenarios)

a.boot <- c(scenarios.boot > 0)
sum(as.numeric(a.boot))/length(scenarios.boot)

a.boot <- c(test.sample > 0)
sum(as.numeric(a.boot))/length(test.sample)



m <- length(test.sample)
binom.test(sum(1*(test.sample[2:m]*test.sample[1:(m-1)] < 0)),m-1)

m <- length(scenarios.boot)
binom.test(sum(1*(scenarios.boot[2:m]*scenarios.boot[1:(m-1)] < 0)),m-1)

m <- length(scenarios)
binom.test(sum(1*(scenarios[2:m]*scenarios[1:(m-1)] < 0)),m-1)

m <- length(scenarios.garch)
```

```r
binom.test(sum(1*(scenarios.garch[2:m]*scenarios.garch[1:(m-1)] <
    0)),m-1)


##------------------------------------------------------------##
##                                                          ##
##                                                          ##
##          Script for computing arma model.               ##
##                                                          ##
##                                                          ##
##------------------------------------------------------------##

##Reading data scripts and setting work directory
setwd("C://Users//Jonas//Documents//DTU//Master Thesis")
source("Model_dir//portfolioAllocation//Rscript//ReadSample.R")

model.sample <- dev[c(1:1502)]
test.sample <- dev[-c(1:1502)]

library(fGarch)
library (xtable)


##
##Modelling
##

garch.mod7 = garchFit (formula = ~ arma (1,0)+garch (1,2),
                    data = model.sample,
                    trace = FALSE,
                    algorithm = "lbfgsb" ,
                    hessian = "rcd",
                    skew = 1.5,
                    shape = 15,
                    include.mean=FALSE)

garch.mod8 = garchFit (formula = ~ arma (1,0)+garch (1,1),
                    data = model.sample,
                    trace = FALSE,
                    algorithm = "lbfgsb" ,
                    hessian = "rcd",
                    skew = 1.5,
                    shape = 15,
                    include.mean=FALSE)

garch.mod9 = garchFit (formula = ~ arma (1,0)+garch (1,0),
                    data = model.sample,
                    trace = FALSE,
```

```
                              algorithm = "lbfgsb" ,
                              hessian = "rcd",
                              skew = 1.5,
                              shape = 15,
                              include.mean=FALSE)

garch.mod10 = garchFit (formula = ~ garch (1,2),
                              data = model.sample,
                              trace = FALSE,
                              algorithm = "lbfgsb" ,
                              hessian = "rcd",
                              skew = 1.5,
                              shape = 15,
                              include.mean=FALSE)

garch.mod11 = garchFit (formula = ~ garch (1,1),
                              data = model.sample,
                              trace = FALSE,
                              algorithm = "lbfgsb" ,
                              hessian = "rcd",
                              skew = 1.5,
                              shape = 15,
                              include.mean=FALSE)

garch.mod12 = garchFit (formula = ~ garch (1,0),
                              data = model.sample,
                              trace = FALSE,
                              algorithm = "lbfgsb" ,
                              hessian = "rcd",
                              skew = 1.5,
                              shape = 15,
                              include.mean=FALSE)

AICS <- c(-3.417026,
          -3.408866,
          -3.323323,
          -3.213462,
          -3.215546,
          -3.136795)


garch.mod <- garch.mod7


garch.table <- xtable(garch.mod@fit$matcoef,
                      caption="The table shows the estimates of the most
                          adequate ARMA-GARCH (1,0)x(1,2) process.",
```

```
                    label="garchMod",
                    digits = 2,
                    align=c('l','l',rep("r",3)))

print(garch.table)


##
##Plot residuals to test normal assumption!!
##
pdf("Thesis (Tex)//figures//residualsGarch.pdf", width = 10, height = 4)
  plot(garch.mod@residuals,type="l",xlab="days",ylab="residuals")
dev.off()

pdf("Thesis (Tex)//figures//residQQplotGarch.pdf", width = 10, height =
    4)
  qqplot(qnorm(ppoints(garch.mod@residuals),
      mean=mean(garch.mod@residuals), sd = sd(garch.mod@residuals)),
        garch.mod@residuals,
        ylab = "Sample quantiles",
        xlab = "Theoretical quantiles")
  abline(a=0, b=1, col=2, lty=2)
dev.off()

pdf("Thesis (Tex)//figures//residHistGarch.pdf", width=10, height=4)
  hist(garch.mod@residuals, breaks=200, probability=TRUE,
      xlab="residuals", xlim=c(-0.2,0.2), main="")
  curve(dnorm(x, mean=0, sd=sd(garch.mod@residuals)), col = 2, lty = 2,
      lwd = 2, add = TRUE)
dev.off()



##Compute arma-garch scenarios
T  <- 18*20
N  <- 250

ar1   <- garch.mod@fit$par[1]
omega <- garch.mod@fit$par[2]
a1    <- garch.mod@fit$par[3]
b1    <- garch.mod@fit$par[4]
b2    <- garch.mod@fit$par[5]


scenarios.garch <- matrix(ncol=N,nrow=T)
for(j in 1:N){
  T1 <- T #Time plus burning period of 100 steps
  e <- numeric(T1)
```

```r
  x <- numeric(T1)
  sigma2 <- numeric(T1)

  sigma2[1] <- omega
  e[1]      <- rnorm(n=1,mean=0,sd=sqrt(sigma2[1]))

  sigma2[2] <- omega + a1*e[1]^2+b1*sigma2[1]
  e[2]      <- rnorm(n=1,mean=0,sd=sqrt(sigma2[2]))

  x[c(1:2)] <- e[c(1:2)]
  for(t in 3:T1){
    sigma2[t] <- omega + a1*e[t-1]^2+b1*sigma2[t-1]+b2*sigma2[t-2]
    e[t]      <- rnorm(n=1,mean=0,sd=sqrt(sigma2[t]))
    x[t]      <- mu+ar1*x[t-1]+e[t]
  }

  scenarios.garch[,j] <- x[c(1:T1)]
}

##Compute mean and confidence interval
garch.mean <- numeric(360)
garch.sd <- numeric(360)
garch.conf.l <- numeric(360)
garch.conf.h <- numeric(360)

for(l in 1:T){
  garch.mean[l]  <- mean(scenarios[l,])
  garch.sd[l]    <- sd(scenarios[l,])
  garch.conf.l[l] <- mean[l]+qnorm(0.025, mean=0, sd=1)*sd[l]
  garch.conf.h[l] <- mean[l]+qnorm(0.975, mean=0, sd=1)*sd[l]
}


pdf("Thesis (Tex)//figures//garch1Rate.pdf", width = 10, height = 4)
  plot(c(rep(-0.2,350),0.2),type="n",xlab="days",ylab="rate")
  lines(test.sample)
  lines(garch.mean,col=2,lwd=2)
  lines(garch.conf.l,col=2,lty=3)
  lines(garch.conf.h,col=2,lty=3)
  legend("topright",
      cex = 1,
      bty = "n",
      legend = c("Mean of ARMA-GARCH samples","Confidence
          interval","Test sample"),
      col = c(2,2,1),
      lwd = c(2,1,1),
      lty = c(1,3,1)
```

```r
  )
dev.off()


#plot sammen med prisen fra bootstrap
price.garch  <- matrix(ncol=N,nrow=(T+1))
price.garch[1,] <- 121.61
for(i in 1:T){
  price.garch[(i+1),] <- price.garch[i,]*exp(scenarios.garch[i,])
}


price.mean.garch <- numeric(T+1)
price.conf.h.garch <- numeric(T+1)
price.conf.l.garch <- numeric(T+1)


price.mean.garch[1] <- price.conf.h.garch[1] <- price.conf.l.garch[1] <-
     121.61
for(i in 1:T){
  price.mean.garch[i+1] <- mean(price.garch[i,])
  price.conf.h.garch[i+1] <- quantile(price.garch[i,],probs=0.975)
  price.conf.l.garch[i+1] <- quantile(price.garch[i,],probs=0.025)
}

pdf("Thesis (Tex)//figures//garchPrice.pdf", width = 10, height = 4)
  plot(price.conf.h.garch,type="n")
  for(i in 1:N){
    lines(price.garch[,i],col="grey")
  }
  lines(price.conf.h.garch,col=2,lty=3,lwd=2)
  lines(price.conf.l.garch,col=2,lty=3,lwd=2)
  lines(price.mean.garch,col=2,lwd=2)

  lines(price.mean.boot,col=3,lwd=2)
  lines(price.mean.ar,col=4,lwd=2)

  lines(spot[c(1502:1862)],lwd=2)
  legend("topleft",
         bty = "n",
         cex = 1,
         legend = c("Mean of ARMA-GARCH samples","Test sample","95%
              quantile","ARMA-GARCH samples","Mean of AR1-samples","Mean
              of bootstrapsamples"),
         col = c(2,1,2,"grey",4,3),
         lwd = c(2,2,2,1,2,2),
         lty = c(1,1,3,1,1,1))
dev.off()
```

APPENDIX E

Code for making optimal asset allocation

E.1 GAMS-code

```
$TITLE Optimal freight rate allocation
$EOLCOM //
option iterlim=999999999,solprint=OFF,limrow=100,limcol=0;
option reslim=600, optcr=0.0000000000001;
option decimals=8;


//------------------------------
//
// Read data
//
//------------------------------


$ONECHO > gdxxrw.in
i = data\wsRates_GAMS_dayli.xls
o = data\gdx\wsRates_GAMS_dayli.gdx
dset date rng=Ark1!a2 rdim=1
dset asset rng=Ark1!b1 cdim=1
par  rates rng=Ark1!a1 cdim=1 rdim=1
$OFFECHO
```

```
$CALL gdxxrw @gdxxrw.in trace=0

//Define and read the sets used in the script
SETS
  date 'dayli quote dates covering the range from 2000.01.04 -
      2012.10.19'
  asset 'spot and current months FFA contracts'
;

ALIAS(a,asset);
ALIAS(d,date);

$GDXIN data\gdx\wsRates_GAMS_dayli
$LOAD date asset

//Define and read the parameters used in the script
PARAMETERS
  rates(d,a) 'dayli rates in the time horizon'
;

$LOAD rates
$GDXIN

//-----------------------------
//
// Make simple bootstrap sample
//
//-----------------------------

SETS
  scen      '250 scenarios in each node level' /1*250/
  nodeLevel 'node level in scenario tree'      /1*73/

  scenDay   'working days in a month'          /1*20/
  loopParam1 'loop parameter 1 on months'      /1*20/
  loopParam2 'loop parameter 2 on node level' /1*73/
  loopParam3 'loop parameter 3 on backtest level' /1*72/
  nodeAssets 'statement in each node'          /month_avr, month_beg,
      ffa_m, real_avr/
  backtestPar'Parameter for backtest'          /1*72/
;

ALIAS(s,scen);
ALIAS(sd,scenDay);
ALIAS(nl,nodeLevel);
ALIAS(lp1,loopParam1);
ALIAS(lp2,loopParam2);
```

```
ALIAS(lp3,loopParam3);
ALIAS(n,nodeAssets);
ALIAS(bt,backtestPar);

PARAMETERS
  dayDevel(d)            'Dayli developments for each date'

  randIndex(s,sd,nl,bt)    'random generated index numbers for choosing
      rates randomly'
  dayliScenDevelop(s,sd,nl,bt)'Dayli developmemts in scenarios'
  dayliScenarios(s,nl,sd,bt) 'Scenario on dayli basis'
  monthScenarios(bt,s,nl,n) 'scenarios aggregated on monthly basis'

  startRate(s,bt)
  scenStartIndex(bt)     'Parameter holding start indeces'
  scenStartIndex2(nl)    'Parameter holding start indeces'
  getDateIndex(d)        'Determines the index for a given date'
;

//Get indices for the first day of each month
getDateIndex(d) = ord(d);

scenStartIndex('1') = getDateIndex('03-01-2006');
scenStartIndex(bt)$(ord(bt)>1 and ord(bt)<13) =
    scenStartIndex('1')+20*(ord(bt)-1);
scenStartIndex('13') = getDateIndex('02-01-2007');
scenStartIndex(bt)$(ord(bt)>13 and ord(bt)<25) =
    scenStartIndex('13')+20*(ord(bt)-13);
scenStartIndex('25') = getDateIndex('02-01-2008');
scenStartIndex(bt)$(ord(bt)>25 and ord(bt)<37) =
    scenStartIndex('25')+20*(ord(bt)-25);
scenStartIndex('37') = getDateIndex('02-01-2009');
scenStartIndex(bt)$(ord(bt)>37 and ord(bt)<49) =
    scenStartIndex('37')+20*(ord(bt)-37);
scenStartIndex('49') = getDateIndex('04-01-2010');
scenStartIndex(bt)$(ord(bt)>49 and ord(bt)<61) =
    scenStartIndex('49')+20*(ord(bt)-49);
scenStartIndex('61') = getDateIndex('04-01-2011');
scenStartIndex(bt)$(ord(bt)>61) = scenStartIndex('61')+20*(ord(bt)-61);

scenStartIndex2(nl) = sum(bt,scenStartIndex(bt)$(ord(bt) = ord(nl)));
scenStartIndex2('73') = getDateIndex('03-01-2012');

//Compute set of dayli development of spot rates instead of rates
dayDevel(d)$(ord(d) > 1) = rates(d,'spot_ws')/rates(d-1,'spot_ws');
```

```
//Randomly pick 20 days for each node level between the first half of
    hist data
//execseed                          = gmillisec(jnow);
randIndex(s,sd,nl,bt)$(ord(bt)=1) = uniformint(2,scenStartIndex(bt));
randIndex(s,sd,nl,bt)$(ord(bt)>1) =
    uniformint(2+(scenStartIndex(bt)-scenStartIndex(bt-1)),scenStartIndex(bt));
dayliScenDevelop(s,sd,nl,bt)  = sum(d,dayDevel(d)$(ord(d) =
    randIndex(s,sd,nl,bt)));

//Compute dayli scenarios of rates
dayliScenarios(s,nl,sd,bt) = dayliScenDevelop(s,sd,nl,bt);
dayliScenarios(s,nl,sd,bt)$(ord(sd) = 1 and ord(nl) = 1) =
    sum(d,rates(d,'spot_ws')$(ord(d) = scenStartIndex(bt)));

loop(lp2,
  loop(lp1$(ord(lp1) > 1),
    dayliScenarios(s,nl,sd,bt)$(ord(sd) = ord(lp1) and ord(nl) =
        ord(lp2)) =
        dayliScenarios(s,nl,sd,bt)*dayliScenarios(s,nl,sd-1,bt);
  );

  startRate(s,bt) = sum((sd,nl),dayliScenarios(s,nl,sd,bt)$(ord(sd) =
      card(sd) and ord(nl) = ord(lp2)));

  if(ord(lp2)<card(lp2),
    dayliScenarios(s,nl,sd,bt)$(ord(sd) = 1 and ord(nl) = ord(lp2)+1) =
        startRate(s,bt)*dayliScenarios(s,nl,sd,bt);
  );
);

//Compute beginning of month
monthScenarios(bt,s,nl,'month_beg') =
    sum(sd,dayliScenarios(s,nl,sd,bt)$(ord(sd) = 1));

//Compute monthly average
monthScenarios(bt,s,nl,'month_avr') =
    sum(sd,dayliScenarios(s,nl-1,sd,bt)/card(sd));

monthScenarios(bt,s,nl,'real_avr')$(ord(nl)>1) =
    sum(d,rates(d,'spot_ws')$(ord(d) >= (scenStartIndex2(nl-1)) and
        ord(d) <
        scenStartIndex2(nl)))/(scenStartIndex2(nl)-scenStartIndex2(nl-1));

//monthly ffa's
//monthScenarios(bt,s,nl,'ffa_M')$(ord(nl) = ord(bt) + 1) =
    sum(d,rates(d,'ffa_CURM')$(ord(d) = scenStartIndex(bt)));
```

```
//monthScenarios(bt,s,nl,'ffa_M')$(ord(nl) = ord(bt) + 2) =
    sum(d,rates(d,'ffa_1M')$(ord(d) = scenStartIndex(bt)));
//monthScenarios(bt,s,nl,'ffa_M')$(ord(nl) = ord(bt) + 3) =
    sum(d,rates(d,'ffa_2M')$(ord(d) = scenStartIndex(bt)));
//monthScenarios(bt,s,nl,'ffa_M')$(ord(nl) = ord(bt) + 4) =
    sum(d,rates(d,'ffa_3M')$(ord(d) = scenStartIndex(bt)));
//monthScenarios(bt,s,nl,'ffa_M')$(ord(nl) = ord(bt) + 5) =
    sum(d,rates(d,'ffa_4M')$(ord(d) = scenStartIndex(bt)));
//monthScenarios(bt,s,nl,'ffa_M')$(ord(nl) = ord(bt) + 6) =
    sum(d,rates(d,'ffa_5M')$(ord(d) = scenStartIndex(bt)));


//Write results to file
//EXECUTE 'gdxxrw.exe data\gdx\wsRates_GAMS_dayli.gdx
    O=portfolioAllocation\bootstrap_2011Sample.xls par=rates
    rng=histRates!a1';

//EXECUTE_UNLOAD 'data\gdx\bootstrap_FullSample_randIndex.gdx',
    randIndex;
//EXECUTE 'gdxxrw.exe data\gdx\bootstrap_2011sample_randIndex.gdx
    O=portfolioAllocation\bootstrap_2011sample.xls par=randIndex
    rng=randIndex!a1';

//EXECUTE_UNLOAD 'data\gdx\bootstrap_Fullsample_dayScen.gdx',
    dayliScenDevelop;
//EXECUTE 'gdxxrw.exe data\gdx\bootstrap_2011sample_dayScen.gdx
    O=portfolioAllocation\bootstrap_2011sample.xls par=dayliScenDevelop
    rng=dayliScenarioDevelopments!a1';

//EXECUTE_UNLOAD 'data\gdx\bootstrap_FullSample_day.gdx', dayliScenarios;
//EXECUTE 'gdxxrw.exe data\gdx\bootstrap_2011Sample_day.gdx
    O=portfolioAllocation\bootstrap_2011Sample.xls par=dayliScenarios
    rng=dayliScenarios!a1';

EXECUTE_UNLOAD 'data\gdx\bootstrap_FullSample_month.gdx', monthScenarios;
EXECUTE 'gdxxrw.exe data\gdx\bootstrap_FullSample_month.gdx
    O=portfolioAllocation\bootstrap_FullSample.xls par=monthScenarios
    rng=monthlyScenarios!a1';




$TITLE Optimal freight rate allocation
$eolcom //
OPTION iterlim=999999999,solprint=OFF,limrow=100,limcol=0;
OPTION reslim=600, optcr=0.0000000000001;
OPTION decimals=8;

//============================//
```

```
//
// Load historical sample
//
//============================//

$ONECHO > gdxxrw.in
i = data\wsRates_GAMS_dayli.xls
o = data\gdx\wsRates_GAMS_dayli.gdx
dset date rng=Ark1!a2 rdim=1
dset asset rng=Ark1!b1 cdim=1
par  rates rng=Ark1!a1 cdim=1 rdim=1
$OFFECHO
$CALL gdxxrw @gdxxrw.in trace=0

SETS
  date 'dayli quote dates covering the range from 2000.01.04 -
      2012.10.19'
  asset 'spot and FFA contracts'
;

ALIAS(a,asset);
ALIAS(d,date);

$GDXIN data\gdx\wsRates_GAMS_dayli
$LOAD date asset

PARAMETERS
  rates(d,a) 'dayli rates in the time horizon'
;

$LOAD rates
$GDXIN


//============================//
//
// Load bootstrap samples
//
//============================//
$CALL gdxxrw.EXE Data/gdx/bootstrapScenariosRate.gdx

SETS
  scen       '250 scenarios in each node level' /1*250/
  nodeLevel 'node level in scenario tree'  /1*19/
  scenAssets 'the assets used in scenarios' /spot_ws, ffa_m0, ffa_m1,
      ffa_m2, ffa_m3, ffa_m4, ffa_m5/
  nodeAssets 'statement in each node'        /month_avr, month_beg,
      ffa_M, ffa_Q, real_avr/
```

```
    backtestPar'Parameter for backtest'        /1/
;

ALIAS(s,scen);
ALIAS(nl,nodeLevel);
ALIAS(sa,scenAssets);
ALIAS(n,nodeAssets);
ALIAS(p,backtestPar);

PARAMETERS
  monthScenarios(p,s,nl,n)
;

// Read bootstrap data
$GDXIN Data\gdx\Backtest\bootstrap_FullSample_month.gdx
$LOAD monthScenarios
$GDXIN

//Get indices for the first day of each month
PARAMETERS
  startRate(s,p)
  scenStartIndex(p)     'Parameter holding start indeces'
  scenStartIndex2(nl)   'Parameter holding start indeces'
  getDateIndex(d)       'Determines the index for a given date'
  realAverage(p)
;
getDateIndex(d) = ord(d);

scenStartIndex('1') = getDateIndex('03-01-2006');
scenStartIndex('2') = getDateIndex('01-02-2006');
scenStartIndex('3') = getDateIndex('01-03-2006');
scenStartIndex('4') = getDateIndex('03-04-2006');
scenStartIndex('5') = getDateIndex('02-05-2006');
scenStartIndex('6') = getDateIndex('01-06-2006');
scenStartIndex('7') = getDateIndex('03-07-2006');
scenStartIndex('8') = getDateIndex('01-08-2006');
scenStartIndex('9') = getDateIndex('01-09-2006');
scenStartIndex('10') = getDateIndex('02-10-2006');
scenStartIndex('11') = getDateIndex('01-11-2006');
scenStartIndex('12') = getDateIndex('01-12-2006');

scenStartIndex('13') = getDateIndex('02-01-2007');
scenStartIndex('14') = getDateIndex('01-02-2007');
scenStartIndex('15') = getDateIndex('01-03-2007');
scenStartIndex('16') = getDateIndex('02-04-2007');
scenStartIndex('17') = getDateIndex('01-05-2007');
scenStartIndex('18') = getDateIndex('01-06-2007');
```

```matlab
scenStartIndex('19') = getDateIndex('02-07-2007');
scenStartIndex('20') = getDateIndex('01-08-2007');
scenStartIndex('21') = getDateIndex('03-09-2007');
scenStartIndex('22') = getDateIndex('01-10-2007');
scenStartIndex('23') = getDateIndex('01-11-2007');
scenStartIndex('24') = getDateIndex('03-12-2007');

scenStartIndex('25') = getDateIndex('02-01-2008');
scenStartIndex('26') = getDateIndex('01-02-2008');
scenStartIndex('27') = getDateIndex('03-03-2008');
scenStartIndex('28') = getDateIndex('01-04-2008');
scenStartIndex('29') = getDateIndex('01-05-2008');
scenStartIndex('30') = getDateIndex('02-06-2008');
scenStartIndex('31') = getDateIndex('01-07-2008');
scenStartIndex('32') = getDateIndex('01-08-2008');
scenStartIndex('33') = getDateIndex('01-09-2008');
scenStartIndex('34') = getDateIndex('01-10-2008');
scenStartIndex('35') = getDateIndex('03-11-2008');
scenStartIndex('36') = getDateIndex('01-12-2008');

scenStartIndex('37') = getDateIndex('02-01-2009');
scenStartIndex('38') = getDateIndex('02-02-2009');
scenStartIndex('39') = getDateIndex('02-03-2009');
scenStartIndex('40') = getDateIndex('01-04-2009');
scenStartIndex('41') = getDateIndex('01-05-2009');
scenStartIndex('42') = getDateIndex('01-06-2009');
scenStartIndex('43') = getDateIndex('01-07-2009');
scenStartIndex('44') = getDateIndex('03-08-2009');
scenStartIndex('45') = getDateIndex('01-09-2009');
scenStartIndex('46') = getDateIndex('01-10-2009');
scenStartIndex('47') = getDateIndex('02-11-2009');
scenStartIndex('48') = getDateIndex('01-12-2009');

scenStartIndex('49') = getDateIndex('04-01-2010');
scenStartIndex('50') = getDateIndex('01-02-2010');
scenStartIndex('51') = getDateIndex('01-03-2010');
scenStartIndex('52') = getDateIndex('01-04-2010');
scenStartIndex('53') = getDateIndex('04-05-2010');
scenStartIndex('54') = getDateIndex('01-06-2010');
scenStartIndex('55') = getDateIndex('01-07-2010');
scenStartIndex('56') = getDateIndex('02-08-2010');
scenStartIndex('57') = getDateIndex('01-09-2010');
scenStartIndex('58') = getDateIndex('01-10-2010');
scenStartIndex('59') = getDateIndex('01-11-2010');
scenStartIndex('60') = getDateIndex('01-12-2010');

scenStartIndex('61') = getDateIndex('04-01-2011');
```

```
scenStartIndex('62') = getDateIndex('01-02-2011');
scenStartIndex('63') = getDateIndex('01-03-2011');
scenStartIndex('64') = getDateIndex('01-04-2011');
scenStartIndex('65') = getDateIndex('03-05-2011');
scenStartIndex('66') = getDateIndex('01-06-2011');
scenStartIndex('67') = getDateIndex('01-07-2011');
scenStartIndex('68') = getDateIndex('01-08-2011');
scenStartIndex('69') = getDateIndex('01-09-2011');
scenStartIndex('70') = getDateIndex('03-10-2011');
scenStartIndex('71') = getDateIndex('01-11-2011');
scenStartIndex('72') = getDateIndex('01-12-2011');

scenStartIndex('73') = getDateIndex('03-01-2012');
scenStartIndex('74') = getDateIndex('01-02-2012');
scenStartIndex('75') = getDateIndex('01-03-2012');
scenStartIndex('76') = getDateIndex('02-04-2012');
scenStartIndex('77') = getDateIndex('01-05-2012');
scenStartIndex('78') = getDateIndex('01-06-2012');
scenStartIndex('79') = getDateIndex('02-07-2012');
scenStartIndex('80') = getDateIndex('01-08-2012');
scenStartIndex('81') = getDateIndex('03-09-2012');

scenStartIndex2(nl) = sum(p,scenStartIndex(p)$(ord(p) = ord(nl)));
scenStartIndex2('82') = getDateIndex('01-10-2012');

//Insert historically prices
monthScenarios(p,s,nl,'real_avr')$(ord(nl) > 1) =
    sum(d,rates(d,'spot_ws')$(ord(d) >= (scenStartIndex2(nl-1)) and
    ord(d) <
    scenStartIndex2(nl)))/(scenStartIndex2(nl)-scenStartIndex2(nl-1));
realAverage(p)$(ord(p)>1) = sum(d,rates(d,'spot_ws')$(ord(d) >=
    (scenStartIndex(p-1)) and ord(d) <
    scenStartIndex(p)))/(scenStartIndex(p)-scenStartIndex(p-1));

//Insert monthly ffa's
monthScenarios(p,s,nl,'ffa_M')$(ord(nl) = 2) =
    sum(d,rates(d,'ffa_CURM')$(ord(d) = scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_M')$(ord(nl) = 3) =
    sum(d,rates(d,'ffa_1M')$(ord(d) = scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_M')$(ord(nl) = 4) =
    sum(d,rates(d,'ffa_2M')$(ord(d) = scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_M')$(ord(nl) = 5) =
    sum(d,rates(d,'ffa_3M')$(ord(d) = scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_M')$(ord(nl) = 6) =
    sum(d,rates(d,'ffa_4M')$(ord(d) = scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_M')$(ord(nl) = 7) =
    sum(d,rates(d,'ffa_5M')$(ord(d) = scenStartIndex(p)));
```

```
monthScenarios(p,s,nl,'ffa_Q')$(ord(nl) < (21 - 3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = sum(d,rates(d,'ffa_5Q')$(ord(d) =
    scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_Q')$(ord(nl) < (18 - 3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = sum(d,rates(d,'ffa_4Q')$(ord(d) =
    scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_Q')$(ord(nl) < (15 - 3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = sum(d,rates(d,'ffa_3Q')$(ord(d) =
    scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_Q')$(ord(nl) < (12 - 3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = sum(d,rates(d,'ffa_2Q')$(ord(d) =
    scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_Q')$(ord(nl) < (9 - 3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = sum(d,rates(d,'ffa_1Q')$(ord(d) =
    scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_Q')$(ord(nl) < (6 - 3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = sum(d,rates(d,'ffa_CURQ')$(ord(d) =
    scenStartIndex(p)));
monthScenarios(p,s,nl,'ffa_Q')$(ord(nl) = 1) = 0;

EXECUTE_UNLOAD 'data\gdx\bootstrap_FullSample_month.gdx', monthScenarios;
EXECUTE_UNLOAD 'data\gdx\realAverage.gdx', realAverage;

$TITLE Optimal freight rate allocation
$eolcom //
OPTION iterlim=999999999,solprint=OFF,limrow=100,limcol=0;
OPTION reslim=600, optcr=0.0000000000001;
OPTION decimals=8;

scalar
 strategy    'Trading strategy'
 orderofp    'Revision month'
 riskProfile 'Risk profile for revision model'
 begMonth    'Index of month where strategy should start'
 revision
;
//revision = 1 - Make revision on dynamical hedge
//strategy = 1 - Dynamical hedge
//strategy = 2 - No hedge
//strategy = 3 - Full hedge
strategy    = 3;
riskProfile = 1;
revision = 0;

//begMonth = 1 (19)- 2006
//begMonth = 13(31)- 2007
```

```
//begMonth = 25(43)- 2008
//begMonth = 37(55)- 2009
//begMonth = 49(67)- 2010
//begMonth = 61(79)- 2011
begMonth  = 25;
orderofp  = 1;

//
//Load data
//

SETS
  scen       '250 scenarios in each node level' /1*250/
  nodeLevel  'node level in scenario tree'  /1*19/
  scenAssets 'the assets used in scenarios' /spot_ws, ffa_m0, ffa_m1,
      ffa_m2, ffa_m3, ffa_m4, ffa_m5, ffa_q0, ffa_q1, ffa_q2, ffa_q3,
      ffa_q4, ffa_q5/
  nodeAssets 'statement in each node'        /month_avr, month_beg,
      ffa_M, ffa_Q/
  backtestPar 'Parameter for backtest'       /25*43/
;

ALIAS(s,scen);
ALIAS(nl,nodeLevel);
ALIAS(sa,scenAssets);
ALIAS(n,nodeAssets);
ALIAS(p,backtestPar);

PARAMETERS
  monthScenarios(p,s,nl,n)
;

// Read bootstrap data
$GDXIN Data\gdx\bootstrap_FullSample_month.gdx
//$GDXIN Data\gdx\bootstrap_2012.gdx
$LOAD monthScenarios
$GDXIN

PARAMETERS
  realAverage(p) 'Average of realizations'
;

$GDXIN Data\gdx\realAverage.gdx
$LOAD realAverage
$GDXIN
```

```
//Define paramters and variables for modelling purpose (CVaR).
SCALAR
  alpha       'Confidence level'
  cvarlim     'Step for CVaR'
  lambda      'Risk attitude'
;

alpha    = 0.99;
cvarlim  = 1000000;

PARAMETERS
  pr(s,p)          'Scenario probability'
  Mu(s,p)          'Income for physical spot contracts in each senario'
  muBeg(p)         'True income for spot contracts in month p'

  price_FFA(s,sa,p,nl) 'Denoting the price at each forward contract at
      time p'
  price_spot(s,sa,p,nl)'Denoting the expected spot price at time p for
      scenario s which ffa sa are settled on'

  truePrice(p)     'The average of actualized price of spot contracts
      used for settle forward contracts from historical data'
  trueFFA(sa,p,nl) 'The accumulated forward prices'
  trueIncome(p)    'The actualized income from historical data'
  trueFFApayoff(sa,p)'The true payoff from purchased contracts'

  payoff(p,sa)     'Measuring the payoff of entering into forward
      contracts'
  Muavr(p)
;

pr(s,p) = 1 / CARD(s);
Mu(s,p) = sum(nl,monthScenarios(p,s,nl,'month_beg')$(ord(nl) <=
    card(nl)-ord(p)+1 and ord(nl) > 1));
muBeg(p) = sum(s,monthScenarios(p,s,'1','month_beg'))/card(s);

Muavr(p) = sum(s,Mu(s,p))/card(s);

display Muavr, realAverage;


//update forward prices
price_FFA(s,'ffa_m0',p,nl)$(ord(nl) = 2) =
    monthScenarios(p,s,nl,'ffa_M');
price_FFA(s,'ffa_m1',p,nl)$(ord(nl) = 3) =
    monthScenarios(p,s,nl,'ffa_M');
```

```
price_FFA(s,'ffa_m2',p,nl)$(ord(nl) = 4) =
    monthScenarios(p,s,nl,'ffa_M');
price_FFA(s,'ffa_m3',p,nl)$(ord(nl) = 5) =
    monthScenarios(p,s,nl,'ffa_M');
price_FFA(s,'ffa_m4',p,nl)$(ord(nl) = 6) =
    monthScenarios(p,s,nl,'ffa_M');
price_FFA(s,'ffa_m5',p,nl)$(ord(nl) = 7) =
    monthScenarios(p,s,nl,'ffa_M');

price_FFA(s,'ffa_q0',p,nl)$(ord(nl)>=2 and ord(nl)<(6-3*(mod(ord(p),3)
    eq 0)-mod(ord(p),3)))                             =
    monthScenarios(p,s,nl,'ffa_Q');
price_FFA(s,'ffa_q1',p,nl)$(ord(nl)>=(6 -3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(9 -3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'ffa_Q');
price_FFA(s,'ffa_q2',p,nl)$(ord(nl)>=(9 -3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(12-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'ffa_Q');
price_FFA(s,'ffa_q3',p,nl)$(ord(nl)>=(12-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(15-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'ffa_Q');
price_FFA(s,'ffa_q4',p,nl)$(ord(nl)>=(15-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(18-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'ffa_Q');
price_FFA(s,'ffa_q5',p,nl)$(ord(nl)>=(18-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(21-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'ffa_Q');

//Update prices outside the optimization region to 0.
price_FFA(s,sa,p,nl)$(ord(nl) > card(nl)-ord(p)+1) = 0;

//Update expected spot price, setting price 9999 out of contract regions
price_spot(s,sa,p,nl) = 9999;

price_spot(s,'ffa_m0',p,nl)$(ord(nl) = 2) =
    monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_m1',p,nl)$(ord(nl) = 3) =
    monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_m2',p,nl)$(ord(nl) = 4) =
    monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_m3',p,nl)$(ord(nl) = 5) =
    monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_m4',p,nl)$(ord(nl) = 6) =
    monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_m5',p,nl)$(ord(nl) = 7) =
    monthScenarios(p,s,nl,'month_avr');
```

```
price_spot(s,'ffa_q0',p,nl)$(ord(nl)>=2 and ord(nl)<(6-3*(mod(ord(p),3)
    eq 0)-mod(ord(p),3)))                              =
    monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_q1',p,nl)$(ord(nl)>=(6 -3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(9 -3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_q2',p,nl)$(ord(nl)>=(9 -3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(12-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_q3',p,nl)$(ord(nl)>=(12-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(15-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_q4',p,nl)$(ord(nl)>=(15-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(18-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'month_avr');
price_spot(s,'ffa_q5',p,nl)$(ord(nl)>=(18-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3)) and ord(nl)<(21-3*(mod(ord(p),3) eq
    0)-mod(ord(p),3))) = monthScenarios(p,s,nl,'month_avr');

//Update actualized spot prices and forward prices
truePrice(p) = realAverage(p+1);
trueFFA('ffa_m0',p,'2') = sum(s,price_FFA(s,'ffa_m0',p,'2'))/card(s);
trueFFA('ffa_q0',p,'2') = sum(s,price_FFA(s,'ffa_q0',p,'2'))/card(s);

payoff(p,sa)$(ord(sa)>2 and ord(sa)<8)                    =
    sum((s,nl),price_FFA(s,sa,p,nl)-price_FFA(s,sa-1,p+1,nl-1))/card(s);
payoff(p,sa)$(ord(sa)>8 and ord(sa)<13)                   =
    sum((s,nl),price_FFA(s,sa,p,nl)-price_FFA(s,sa,p+1,nl-1))/(3*card(s));
payoff(p,sa)$(mod(ord(p),3)=0 and ord(sa)>8 and ord(sa)<13) =
    sum((s,nl),price_FFA(s,sa,p,nl)-price_FFA(s,sa-1,p+1,nl-1))/(3*card(s));


parameter
  test(nl,n)
;

test(nl,n) = sum((s,p),monthScenarios(p,s,nl,n)$(ord(p)=1))/card(s);

display price_FFA, price_spot, test;
$stop;

POSITIVE VARIABLES
  xt(sa,p,nl)    'Holdings of contracts on a per node level basis'
  VaRDev(s)      'Measures of the deviations from the VaR'
  buy(sa,p)      'Amount we buy of ffas a at time p'
  sell(sa,nl,p)  'Amount we sell of ffas a at time p'
;
```

```
VARIABLES
  Income(s)       'Measuring income'

  Losses(s)       'Measures of the losses'
  VaR             'Value-at-Risk'
  CVaR            'Objective function value - Conditional-Value-at-Risk'
  profit          'profit'
  CVaRreturn      'Return in the CVaR model'
;

FREE VARIABLES
  scenportmean(s) 'return for each scenario'
;

EQUATIONS
  IncomeDef1(s,p)    'Income for each scenario'
  IncomeDef2(s,p)    'Income for each scenario in revision model'
  LossDef(s,p)       'Equations defining the losses'
  VaRDevCon(s)       'Equations defining the VaR deviation constraints'
  ObjDefCVaR(p)      'Objective function definition for CVaR minimization'
  CVaRdefinition     'Limit on CVaR'
  ObfFun(p)          'objective function for CVaR model'
  Return(p)          'Return for the CVaR model'
  FFAIncome          'Income from FFA contracts'

  TotP(p,sa,nl)      'Total budget in physical market'
  TotF1(p,nl)        'Total budget in forward contracts pr node level in
      No Hedging strategy'
  TotF2(p,nl)        'Total budget in forward contracts pr node level in
      Full Hedging strategy'
  TotF3(p,nl)        'Total budget in forward contracts pr node level in
      Dynamical Hedging strategy'

  x_q0(sa,p,nl)      'Ensuring quarterly contracts are purchased for
      entire period'
  x_q1(sa,p,nl)      'Ensuring quarterly contracts are purchased for
      entire period'
  x_q2(sa,p,nl)      'Ensuring quarterly contracts are purchased for
      entire period'
  x_q3(sa,p,nl)      'Ensuring quarterly contracts are purchased for
      entire period'
  x_q4(sa,p,nl)      'Ensuring quarterly contracts are purchased for
      entire period'
  x_q5(sa,p,nl)      'Ensuring quarterly contracts are purchased for
      entire period'
```

```
  scenarioreturn(s,p) 'Definition of return for each scenario'
;

//
//Formulation of CVaR Model
//
IncomeDef1(s,p)$(ord(p)=orderofp).. Income(s) =E=
    sum((sa,nl),xt(sa,p,nl)*(price_FFA(s,sa,p,nl)-price_spot(s,sa,p,nl)))
    + Mu(s,p);
IncomeDef2(s,p)$(ord(p)=orderofp).. Income(s) =E=
    sum((sa,nl),xt(sa,p,nl)*(price_FFA(s,sa,p,nl)-price_spot(s,sa,p,nl))
    + xt(sa,p-1,nl)*payoff(p-1,sa)) + Mu(s,p);

LossDef(s,p)$(ord(p)=orderofp).. Losses(s)    =E= -Income(s);
VaRDevCon(s) ..                   VaRDev(s)    =G= Losses(s) - VaR;
ObjDefCVaR(p)$(ord(p)=orderofp).. CVaR         =E= VaR + SUM(s, pr(s,p) *
    VaRDev(s)) / (1 - alpha);
CVaRdefinition..                  cvarlim      =g= CVaR;

TotP(p,sa,nl)$(ord(p)=orderofp).. xt('spot_ws',p,nl) =E= 0;
TotF1(p,nl)$(ord(p)=orderofp and ord(nl)>1)..
    sum(sa,xt(sa,p,nl)$(ord(sa)>1)) =E= 0;
TotF2(p,nl)$(ord(p)=orderofp and ord(nl)>1)..
    sum(sa,xt(sa,p,nl)$(ord(sa)>1)) =E= 1;
TotF3(p,nl)$(ord(p)=orderofp and ord(nl)>1)..
    sum(sa,xt(sa,p,nl)$(ord(sa)>1)) =l= 1;

//Ensuring quarterly contracts to be fixed over entire period
x_q0(sa,p,nl)$(ord(p)=orderofp and ord(sa)=8 and ord(nl)>1 and
    ord(nl)<(6-3*(mod(ord(p),3) eq 0)-mod(ord(p),3)))..
                                xt(sa,p,nl) =E= xt(sa,p,'2');
x_q1(sa,p,nl)$(ord(p)=orderofp and ord(sa)=9 and ord(nl)>=(6
    -3*(mod(ord(p),3) eq 0)-mod(ord(p),3)) and ord(nl)<(9
    -3*(mod(ord(p),3) eq 0)-mod(ord(p),3))).. xt(sa,p,nl) =E=
    xt(sa,p,'5');
x_q2(sa,p,nl)$(ord(p)=orderofp and ord(sa)=10 and ord(nl)>=(9
    -3*(mod(ord(p),3) eq 0)-mod(ord(p),3)) and
    ord(nl)<(12-3*(mod(ord(p),3) eq 0)-mod(ord(p),3))).. xt(sa,p,nl)
    =E= xt(sa,p,'8');
x_q3(sa,p,nl)$(ord(p)=orderofp and ord(sa)=11 and
    ord(nl)>=(12-3*(mod(ord(p),3) eq 0)-mod(ord(p),3)) and
    ord(nl)<(15-3*(mod(ord(p),3) eq 0)-mod(ord(p),3))).. xt(sa,p,nl)
    =E= xt(sa,p,'11');
x_q4(sa,p,nl)$(ord(p)=orderofp and ord(sa)=12 and
    ord(nl)>=(15-3*(mod(ord(p),3) eq 0)-mod(ord(p),3)) and
    ord(nl)<(18-3*(mod(ord(p),3) eq 0)-mod(ord(p),3))).. xt(sa,p,nl)
    =E= xt(sa,p,'14');
```

```
x_q5(sa,p,nl)$(ord(p)=orderofp and ord(sa)=13 and
    ord(nl)>=(18-3*(mod(ord(p),3) eq 0)-mod(ord(p),3)) and
    ord(nl)<(21-3*(mod(ord(p),3) eq 0)-mod(ord(p),3))).. xt(sa,p,nl)
    =E= xt(sa,p,'17');

return(p)$(ord(p)=orderofp)..         cvarreturn      =E=
    sum(s,Income(s))/card(s);
ObfFun(p)$(ord(p)=orderofp)..         profit          =E= (1 - lambda) *
    cvarreturn - lambda * CVaR;
scenarioreturn(s,p)$(ord(p)=orderofp).. scenportmean(s) =l= Income(s);

//Model for MEAN/CVAR
MODEL CVaRModNoHedging
  /IncomeDef1,LossDef,VarDevCon,ObjDefCVaR,CVaRdefinition,TotP,TotF1,
   x_q0,x_q1,x_q2,x_q3,x_q4,x_q5,ObfFun,Return,scenarioreturn/;
MODEL CVaRModFuHedging
  /IncomeDef1,LossDef,VarDevCon,ObjDefCVaR,CVaRdefinition,TotP,TotF2,
   x_q0,x_q1,x_q2,x_q3,x_q4,x_q5,ObfFun,Return,scenarioreturn/;
MODEL CVaRModDyHedging
  /IncomeDef1,LossDef,VarDevCon,ObjDefCVaR,CVaRdefinition,TotP,TotF3,
   x_q0,x_q1,x_q2,x_q3,x_q4,x_q5,ObfFun,Return,scenarioreturn/;

//Model for revision MEAN/CVAR
MODEL RevisionCVaRModNo
  /IncomeDef2,LossDef,VarDevCon,ObjDefCVaR,CVaRdefinition,TotP,TotF1,
   x_q0,x_q1,x_q2,x_q3,x_q4,x_q5,ObfFun,Return,scenarioreturn/;
MODEL RevisionCVaRModFu
  /IncomeDef2,LossDef,VarDevCon,ObjDefCVaR,CVaRdefinition,TotP,TotF2,
   x_q0,x_q1,x_q2,x_q3,x_q4,x_q5,ObfFun,Return,scenarioreturn/;
MODEL RevisionCVaRModDy
  /IncomeDef2,LossDef,VarDevCon,ObjDefCVaR,CVaRdefinition,TotP,TotF3,
   x_q0,x_q1,x_q2,x_q3,x_q4,x_q5,ObfFun,Return,scenarioreturn/;

SET
  frontierpoints /1*10/
;

alias(frontierpoints,fp);

PARAMETERS
  SolverStatus(fp,*)
  SummaryReport(*,*,*)
  SummaryReportscenarios(*,*)
;

PARAMETERS
  maxCvar                      'maximum CVaR'
```

```
  minCvar                    'minimum CVaR'
  Runningcvar(fp)            'running CVaR for frontier points 1-10'
  runningcvarreturn(fp)      'running std deviation for fp'
  runningallocationcvar(fp,sa,nl)'running asset allocation for all 10
      solutions'
  MaxVar                     'maximum std deviation'
  MinVar                     'minimum std deviation'
  Runningscenarioreturn(fp,s) 'running return for all 10 solutions and
      all scenarios'
  PortReturn
  runningLambda(fp)
;

//---------------------------------------------------
//
// Solve CVaR Dynamic Hedge with 10 different rik attitudes
//
//---------------------------------------------------
if(strategy = 1 and revision = 0,
//---------------
//Maximize return
//---------------
lambda = 0.001;

Solve CVaRModDyHedging maximizing profit using lp;

MaxCvaR                    = cvar.l;
RunningCvaR('1')           = cvar.l;
Runningcvarreturn('1')     = cvarreturn.l + muBeg('1');
RunningAllocationcvar('1',sa,nl)= sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
Runningscenarioreturn('1',s) = scenportmean.l(s) + muBeg('1');

//-------------
//Minimize risk
//-------------
lambda = 0.999;

Solve CVaRModDyHedging maximizing profit using lp;

MinCvaR                    = cvar.l;
RunningCvaR('10')          = cvar.l;
Runningcvarreturn('10')    = CvarReturn.l + muBeg('1');
RunningAllocationcvar('10',sa,nl)=
    sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
Runningscenarioreturn('10',s) = scenportmean.l(s) + muBeg('1');

//----------------------
```

```
//Find equidistant CVaR
//---------------------
CVaRlim = MaxCvaR;

Loop(fp$(ord(fp)>1 and ord(fp)<card(fp)),
  cvarlim = cvarlim-(MaxCvaR-MinCvar)/(card(fp)-1);

  lambda = 0.001;

  solve CVaRModDyHedging maximizing profit using LP;

  RunningAllocationcvar(fp,sa,nl) =
      sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
  Runningcvarreturn(fp)       = CvarReturn.l + muBeg('1');
  RunningCvaR(fp)             = cvar.l;
  Runningscenarioreturn(fp,s) = scenportmean.l(s) + muBeg('1');
);

SummaryReport(nl,sa,fp)     = RunningAllocationcvar(fp,sa,nl);
SummaryReport('','CVaR',fp) = RunningCvaR(fp);
SummaryReport('','Income',fp) = Runningcvarreturn(fp);
SummaryReport('',s,fp)      = Runningscenarioreturn(fp,s);

//Write results to excell files
EXECUTE_UNLOAD 'data\gdx\CVaRSummaryDyHedge.gdx', SummaryReport;
EXECUTE 'gdxxrw.exe data\gdx\CVaRSummaryDyHedge.gdx
    O=portfolioAllocation\bootstrap.xls par=SummaryReport
    rng=DyHedge!a1';
);


//----------------------------------------------------
//
// Solve CVaR No Hedge with 10 different rik attitudes
//
//----------------------------------------------------
if(strategy = 2 and revision = 0,
//--------------
//Maximize return
//--------------
lambda = 0.001;

Solve CVaRModNoHedging maximizing profit using lp;

MaxCvaR                  = cvar.l;
RunningCvaR('1')         = cvar.l;
Runningcvarreturn('1')   = cvarreturn.l + muBeg('1');
RunningAllocationcvar('1',sa,nl)= sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
```

```
Runningscenarioreturn('1',s) = scenportmean.l(s) + muBeg('1');


//-------------
//Minimize risk
//-------------
lambda=0.999;

Solve CVaRModNoHedging maximizing profit using lp;

MinCvaR                       = cvar.l;
RunningCvaR('10')             = cvar.l;
Runningcvarreturn('10')       = CvarReturn.l + muBeg('1');
RunningAllocationcvar('10',sa,nl)=
    sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
Runningscenarioreturn('10',s) = scenportmean.l(s) + muBeg('1');


//---------------------
//Find equidistant CVaR
//---------------------
CVaRlim = MaxCvaR;

Loop(fp$(ord(fp)>1 and ord(fp)<card(fp)),
  cvarlim = cvarlim-(MaxCvaR-MinCvar)/(card(fp)-1);

  lambda=0.001;

  solve CVaRModNoHedging maximizing profit using LP;

  RunningAllocationcvar(fp,sa,nl) =
      sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
  Runningcvarreturn(fp)       = CvarReturn.l + muBeg('1');
  RunningCvaR(fp)             = cvar.l;
  Runningscenarioreturn(fp,s) = scenportmean.l(s) + muBeg('1');
);

SummaryReport(nl,sa,fp)     = RunningAllocationcvar(fp,sa,nl);
SummaryReport('','CVaR',fp) = RunningCvaR(fp);
SummaryReport('','Income',fp) = Runningcvarreturn(fp);
SummaryReport('',s,fp)      = Runningscenarioreturn(fp,s);

//Write results to excell files
EXECUTE_UNLOAD 'data\gdx\CVaRSummaryNoHedge.gdx', SummaryReport;
EXECUTE 'gdxxrw.exe data\gdx\CVaRSummaryNoHedge.gdx
    O=portfolioAllocation\bootstrap.xls par=SummaryReport
    rng=NoHedge!a1';
);
```

```
//------------------------------------------------------
//
// Solve CVaR Full Hedge with 10 different rik attitudes
//
//------------------------------------------------------
if(strategy = 3 and revision = 0,
//---------------
//Maximize return
//---------------
lambda = 0.001;

Solve CVaRModFuHedging maximizing profit using lp;

MaxCvaR                    = cvar.l;
RunningCvaR('1')           = cvar.l;
Runningcvarreturn('1')      = cvarreturn.l + muBeg('1');
RunningAllocationcvar('1',sa,nl)= sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
Runningscenarioreturn('1',s) = scenportmean.l(s) + muBeg('1');

//-------------
//Minimize risk
//-------------
lambda=0.999;

Solve CVaRModFuHedging maximizing profit using lp;

MinCvaR                    = cvar.l;
RunningCvaR('10')          = cvar.l;
Runningcvarreturn('10')     = CvarReturn.l + muBeg('1');
RunningAllocationcvar('10',sa,nl)=
    sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
Runningscenarioreturn('10',s) = scenportmean.l(s) + muBeg('1');

//----------------------
//Find equidistant CVaR
//----------------------
CVaRlim = MaxCvaR;

Loop(fp$(ord(fp)>1 and ord(fp)<card(fp)),

  cvarlim = cvarlim-(MaxCvaR-MinCvar)/(card(fp)-1);
  lambda = 0.001;

  solve CVaRModFuHedging maximizing profit using LP;

  RunningAllocationcvar(fp,sa,nl) =
      sum(p,xt.l(sa,p,nl)$(ord(p)=orderofp));
```

```
  Runningcvarreturn(fp)        = CvarReturn.l + muBeg('1');
  RunningCvaR(fp)              = cvar.l;
  Runningscenarioreturn(fp,s)  = scenportmean.l(s) + muBeg('1');
);

SummaryReport(nl,sa,fp)     = RunningAllocationcvar(fp,sa,nl);
SummaryReport('','CVaR',fp) = RunningCvaR(fp);
SummaryReport('','Income',fp) = Runningcvarreturn(fp);
SummaryReport('',s,fp)      = Runningscenarioreturn(fp,s);

//Write results to excell files
EXECUTE_UNLOAD 'data\gdx\CVaRSummaryFuHedge.gdx', SummaryReport;
EXECUTE 'gdxxrw.exe data\gdx\CVaRSummaryFuHedge.gdx
    O=portfolioAllocation\bootstrap.xls par=SummaryReport
    rng=FuHedge!a1';
);


//-------------------------------------------------------------
//
// Make revision model for each month running 18 month ahead
//
//-------------------------------------------------------------
SETS
  loopParameter 'Parameter for looping through all nodelevels' /1*19/
;

ALIAS(lp,loopParameter);

PARAMETERS
  revisionAllocation(p,sa,nl) 'Holding allocations for revision model'
  revisionCvarReturn(p)     'Holding cvar return for revision model'
  revisionCvar(p)           'Holding cvar values for revision model'
  revisionScenarioReturn(p,s) 'Holding scen return for revision model'
  revisionRealReturn(p)     'Holding real return for revision model'
  revisionsummaryreport(*,*,p)'Holding summary report for revisions'
;

scalar
  minLambda
  maxLambda
;

if(revision = 1,

  //Update lambda to new risk profile
  minLambda = 0.001;
```

```
maxLambda = 0.999;

lambda = minLambda + (riskProfile-1)*(maxLambda-minLambda)/9;

//----------------------
// Find x for month one
//----------------------

cvarlim                          = 1000000;
trueIncome(p)$(ord(p)=orderofp) = 0;

if(strategy = 1,
    solve CVaRModDyHedging maximizing profit using LP;
  elseif strategy = 2,
    SOLVE CVaRModNoHedging maximixing profit using lp;
  elseif strategy = 3,
    SOLVE CVaRModFuHedging maximixing profit using lp;
  );



trueIncome(p)$(ord(p)=orderofp) = muBeg(p);

revisionCvarReturn(p)$(ord(p)=orderofp)  = CvarReturn.l+trueIncome(p);
revisionCvar(p)$(ord(p)=orderofp)        = cvar.l;
revisionScenarioReturn(p,s)$(ord(p)=orderofp) = scenportmean.l(s);
revisionAllocation(p,sa,nl)$(ord(p)=orderofp) = xt.l(sa,p,nl);

//-----------------------------
//Fix x and solve revision model
//-----------------------------
Loop(lp$(ord(lp)>1),

  xt.fx(sa,p,nl)$(ord(p)=orderofp) = xt.l(sa,p,nl);

  orderofp = orderofp + 1;

  if(strategy = 1,
    SOLVE RevisionCVaRModDy maximizing profit using lp;
  elseif strategy = 2,
    SOLVE RevisionCVaRModNo maximizing profit using lp;
  elseif strategy = 3,
    SOLVE RevisionCVaRModFu maximizing profit using lp;
  );

  //Trueincome actualized next month, accumulated
```

```
   trueFFApayoff(sa,p)$(ord(p)=orderofp and ord(sa)=2) =
       sum(nl,xt.l(sa,p-1,'2')*(trueFFA(sa,p-1,'2')-truePrice(p-1)))/card(nl);

   trueFFApayoff(sa,p)$(ord(p)=orderofp and mod(ord(p)-1,3)=0 and
       ord(sa)=8) =
   sum(nl,xt.l(sa,p-1,'2')*(1*trueFFA(sa,p-1,'2')-truePrice(p-1)))/card(nl);
   trueFFApayoff(sa,p)$(ord(p)=orderofp and mod(ord(p)-1,3)=1 and
       ord(sa)=8) =
   sum(nl,
     xt.l(sa,p-1,'2')*(3*trueFFA(sa,p-1,'2')-(truePrice(p-1)+truePrice(p)+truePrice(p+1)))
   )/card(nl);
   trueFFApayoff(sa,p)$(ord(p)=orderofp and mod(ord(p)-1,3)=2 and
       ord(sa)=8) =
   sum(nl,xt.l(sa,p-1,'2')*(2*trueFFA(sa,p-1,'2')-(truePrice(p-1)+truePrice(p))))/card(nl);

   trueIncome(p)$(ord(p)=orderofp) = trueIncome(p-1) + muBeg(p) +
       sum(sa,trueFFApayoff(sa,p));

   revisionCvarReturn(p)$(ord(p)=orderofp)  = CvarReturn.l +
       trueIncome(p);
   revisionCvar(p)$(ord(p)=orderofp)          = cvar.l;
   revisionScenarioReturn(p,s)$(ord(p)=orderofp) = scenportmean.l(s);
   revisionAllocation(p,sa,nl)$(ord(p)=orderofp) = xt.l(sa,p,nl);

   //Update sold contracts prices.
   trueIncome(p)$(ord(p)=orderofp) = trueIncome(p) +
       sum((nl,sa),xt.l(sa,p-1,nl)*payoff(p-1,sa));
);

revisionsummaryreport('1','CVaR',p) = revisionCvar(p);
revisionsummaryreport('1','Income',p) = revisionCvarReturn(p);
revisionsummaryreport('1',s,p)        = revisionScenarioReturn(p,s);
revisionsummaryreport(nl,sa,p)       = revisionAllocation(p,sa,nl);


if(riskProfile = 1,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk1!a1' ;
elseif riskProfile = 2,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk2!a1' ;
elseif riskProfile = 3,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
```

```
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk3!a1' ;
elseif riskProfile = 4,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk4!a1' ;
elseif riskProfile = 5,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk5!a1';
elseif riskProfile = 6,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk6!a1' ;
elseif riskProfile = 7,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk7!a1' ;
elseif riskProfile = 8,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk8!a1' ;
elseif riskProfile = 9,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk9!a1' ;
elseif riskProfile = 10,
  EXECUTE_UNLOAD 'data\gdx\RevisionSummary.gdx', revisionsummaryreport;
  EXECUTE 'gdxxrw.exe data\gdx\RevisionSummary.gdx
      O=portfolioAllocation\bootstrapRevision.xls
      par=revisionsummaryreport rng=risk10!a1' ;
);
);
```

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