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Real options in the LNG shipping industry



by

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Abstract

The prime focus of this dissertation is to bring forward and explain well founded and intuitive methods for valuing real options in the LNG transportation industry, and by that convince industry participants that such flexibility has a considerable value. The dissertation applies academic theory on realistic cases, and represents a good source of information for participants in the industry seeking to implement such tools in their business management.

The applied valuation methodology is a risk adjusted version of the well-known Black and Scholes model fitted to each specific case. The composition, coherence and application of this framework are thoroughly explained, and the options tentative structure and value basis are visualised in figures.

The option values obtained are sound and are accompanied by sensitivity analyses offering insight into the fundamental value drivers. The sensitivity analyses are also vital for testing the validity of the models and for remedying possible erroneous assumptions.

Owing to a lack of historical data material from the LNG industry, an extensive collection and processing of data was call for. This rendered not only information on essential parameters for option valuations, but also unique time series important for further studies.

Interesting is also how the risk adjustment affects the relationship between certain parameters and the option value. Risk adjusted drift rates were developed to remedy certain risk elements in the underlying asset, and these rates proved in some cases to be negative. This was so because they were partly based on historical new building prices which have experienced a real decline the last seventeen years. The negativity of these rates led to some adverse relationships compared to what is to be expected based on options theory, especially when time was a decisive factor.

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1.0 Introduction

“You can check out any time you like, but you can never leave”

From Hotel California - Henley, Frey and Felder

There is perhaps no other industry that has been witness to such spectacular success and amassment of wealth for some, and utter destruction and loss of stature for others, as the industry of international marine transportation. Although marine transportation of commodities has taken place since man learned to navigate the sea, he is still incapable of taming the various risks of the shipping cycles. Not only does the above quotation refer to the captivating nature of this industry, but also to the devastating destiny of poor decision making - or just bad luck.

The risks and uncertainties facing ship owners and operators span wide, from plunges in the freight and asset market to war and political instability. Daily fluctuations in the commodity and financial markets may affect investment decisions, and furthermore can port congestions and technical failures unexpectedly disrupt operational performance. Such risks combined with highly leveraged financial positions can prove catastrophic. The ever-present possibilities for both unfortunate outcomes and speculative positioning have brought about risk management tools like freight futures, but a variety of maritime real options is still the fundamental method to obtain valuable flexibility.

The LNG shipping industry has been rapidly growing since its start-up in the mid 1960's, and is expected to keep the pace over the next decades due to the ever-increasing demand for clean energy. Although the LNG industry is characterized by monumental investments and long lasting static relations, tendencies of increasing speed and risk willingness are finding its way. The combination of huge investments and more uncertainty makes flexibility become of great value to a risk taker, but also at a possible great cost to the party that offers it.

Such flexibility in the form of real options and their values are the focal point of this dissertation. However, fair compensation and proper valuation of such arrangements are rarities in the LNG industry, much owing to a well established business conduct and uneven negotiating power, but also to a lack of a proper valuation tools and familiarity to options theory.

1.1 The aim of the dissertation

The aim of the dissertation is to present credible option values and reliable valuation tools to convince participants in the LNG industry that options do comprise substantial values and that the insights and rationales ought to be adopted into business management.

Achieving the overall aim of this dissertation relies on solving three other main tasks as shown in figure 1.1. Firstly, the amount of historical and present data from the LNG industry is very limited, which complicates the valuation process. The first task is therefore of high value; to collect relevant data material and further process it. The second task is to develop and present a valuation framework for the three options drawn up in cooperation with Høegh LNG. Important here is to find solutions for coping with the risk related to the different underlying assets in the options. Conventional theory for financial options utilize risk neutral probabilities based on replicating strategies, which open for discounting based on the risk free interest rate. As such replication strategies are difficult to apply to real options, a risk adjusted drift rate will be derived and applied to the calculations. The third task is to produce a sound calculus and a solid sensitivity analysis that both explain option fundamentals in an intuitive way, in addition to proving the strength and validity of the model.

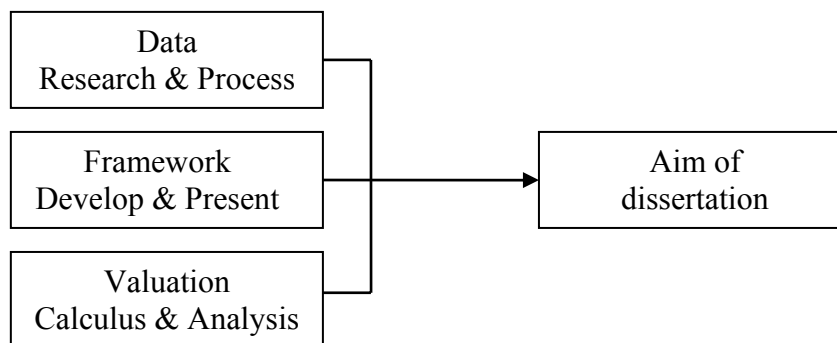


Figure 1.1: Three important tasks to achieve the overall aim of the thesis

1.2 The structure of the dissertation

This dissertation consists of two main parts, one conceptual and one qualitative. The conceptual part is found in chapter 2 and chapter 3, while the rest of the thesis is devoted to the analysis of three real world cases.

Chapter 2 provides necessary insights for understanding both the shipping market and the LNG industry, and the costs, risks and contracts associated to these markets. Chapter 2 also explains how options are utilized within shipping in general and in the LNG industry in particular. Chapter 3 explains the similarities between financial and real options, in addition to the conceptual option valuation framework that will be employed later in the dissertation. A part of chapter 3 also discusses option valuation as a part of capital budgeting tools. Chapter 4 gives an introduction to the valuation of three different options found in chapter 5 to chapter 7. Each option, the framework, and the calculus will be thoroughly presented, in addition to conclusions and a sensitivity analysis of the most determining variables. Since the same valuation tools are employed for all three options, the first option valuation is described more in depth than the remaining two. Main conclusions are drawn in chapter 8, before relevant figures and graphs are presented in the appendices in chapter 9.

2.0 Shipping and the LNG business

The valuations performed in later chapters assume that the reader is acquainted with basic knowledge of the shipping industry. Important concepts regarding shipping in general and LNG shipping in special, will in the following be presented.

2.1 The market for LNG transport

The transport of liquefied natural gas (LNG) is a highly specialized and sophisticated form of bulk shipping. The first commercial LNG trade took place between Algeria and UK in 1964, and the trading volumes have more than doubled the last fifteen years. The quantity traded is expected to grow rapidly over the next few years, and the quantity traded in 2001 is expected to be doubled by 2010 (Drewry, 2006). The current orderbook of LNG carriers reflects the massive demand for LNG with the capacity on order almost equivalent to the current fleet. However, this will not be enough to meet projected demand by the turn of the decade, and the foreseeable future for the market for LNG transport hence appears promising (Drewry, 2006).

Natural gas is produced in both associated and non-associated gas fields, both at land and sea. Before the gas is transported by vessels, an upstream plant cools the gas to -163°C , a temperature at which the gas turns liquid. The LNG is then transported at very low temperatures under atmospheric pressure in dedicated, purpose built vessels. Receiving terminals regasify the LNG before it is further distributed through local gas grids¹.

The hazardous nature of the LNG requires special facilities isolated from the rest of the port, in addition to dedicated ship design, heavily insulated cargo tanks and advanced cargo containment and surveillance systems. The industry is highly affected by monumental fixed investments, both up and down stream the LNG chain. High fixed costs and high exit barriers² naturally call for predictability. This has been achieved through time charter (TC) contracts of fifteen to twenty years duration, where the stable cash flows have enabled the ship owner to prepare ship budgets and perform well-considered capital budgeting.

¹ Natural gas may also be transported through pipelines. However, as distance increases intra regional deep sea shipment of LNG is economically more efficient

² Due to irreversible investments with low alternative value

2.2 Höegh LNG

Höegh LNG is a privately held LNG transportation and services company with headquarters based in Oslo. The company has more than thirty years history and experience dating back to the delivery of the Norman Lady in 1973, the first LNG carrier with spherical Moss-Rosenberg containment tanks. Today Höegh LNG operates a fleet of six LNG carriers of which five are wholly or partly owned. In the competitive market of today, Höegh LNG emphasizes the importance of new solutions that add value to the traditional LNG transportation. An example of this are the two highly technical and innovative Shuttle and Regasification Vessels presently on order to serve the Neptune deep water port project. Onboard regasification solutions, advanced navigation and propulsion systems, submerged turret mooring buoy and sub-sea pipeline grids to shore, opens up for off-shore discharging of natural gas from vessel directly to the market. Such a solution embraces over a large part of the LNG value chain and complies with the request for safer and more remote terminal facilities.

As the LNG industry develops, especially in the western part of the world, Höegh LNG appreciates this important growth potential. Its presence at the Snøhvit-project in northern Norway with two dedicated vessels and twenty year contracts with extension options supports this focus. Examples of such extension options will be valued in chapter 5.

Focal points in the LNG industry of today are massive new building programmes, increased focus on technology, old vessels at the end of their TC contracts, newly explored and developed gas fields, and above all the increasing focus on LNG as a clean energy. As more vessels will enter the growing market in addition to some ship owners taking upon more risk by accepting short term contracts, a change in the industry fundamentals is expected. Höegh LNG realizes the high importance of flexibility in more uncertain markets, and appreciates that various options incorporated in different contracts represent exactly such flexibility. And as the quantitative part of this dissertation will show, such flexibility should not be given away for free.

Through internships I have experienced that Höegh LNG is a dynamic company with long traditions and an interesting business portfolio. Its genuine dedication to the industry and compliance and responsiveness to new ideas make Höegh LNG a rewarding partner for this academic work. The aim of the dissertation and the cases for evaluation were put forward through discussions with experienced staff members of Höegh LNG, who have followed up

on the development in a constructive manner. Due to the close collaboration there was no need for gathering further information from similar companies.

2.3 Shipping costs, risks and contracts

There exist a handful of different shipping contracts governing both the allocation of costs and risks between the charterer, ship owner and operator, in addition to the structure of the revenues. Firstly, different shipping costs will be presented, secondly there will be placed emphasis on various types of risk and finally some contracts and their content will be described. The following explanations are based on Stopford (2004) and Strandenes (2006a). How the different elements relate to the dissertation will be commented in section 2.4.

2.3.1 Shipping costs

Operating costs are the ongoing expenses connected with the day-to-day running of the vessel (excluding fuel), together with an allowance for day-to-day repairs and maintenance. The principal components of operating costs are manning costs, stores, routine maintenance, insurance and administration. The structure and amount of operating costs thus depend on the size and nationality of the crew, maintenance policy, the age and insured value of the vessel, and the efficiency of the administration.

Voyage costs are the variable costs incurred in undertaking a particular voyage. Fuel costs, port dues, tugs and pilotage, and canal dues constitute the main cost elements. Fuel costs are the single most important item in voyage costs, due to both the high fuel consumption and to the volatility of the oil prices. Speed, engine design, propulsion efficiency and ship design are important factors determining the fuel consumption. Port dues vary between locations, and comprise costs related to arrival, stay and departure from a port.

Cargo handling costs incur at loading and discharging of cargo, in addition to allowances for cost of any cargo claims that may arise.

Capital costs comprise interests, dividends and debt repayments. The financing strategy and conditions are based on the company's capital structure and the expected risk-return relationship governing the market. Together with the value of the vessel, debt and interest are important elements in determining the size of the capital costs. Financial gearing must be considered in conjunction with the financial strength of the company, the structure and volatility of the revenues, and the impending balance in the shipping market.

2.3.2 Shipping risks

The most evident risks of the shipping industry are normally divided into the five groups presented in this section. The relevance of each specific risk category for the later quantitative analysis is briefly described. However, it is important bear in mind, that every LNG project is unique, and so is the risk associated to it.

Freight market risk refers to the volatility of the spot freight rate and the time charter rates. The availability of cargo and the possibilities to close contracts are other important elements of this risk. The volatility of the time charter rate is an important parameter in the valuation of the extension option in chapter 5.

Financial market risks comprise interest rate risks that affect the cost of capital, in addition to currency risk. The latter asserts itself only if the freight income is in one currency and the operating costs, debt or equity in another. Although the focus in this dissertation is on the real side of projects, it is important to also keep the financing side in mind to get the full perception of the later presented calculations. The mentioned currency and interest rate risks are elaborated on in the valuation of the new building option in chapter 6.

Political risks encompass regulatory changes, flag rules and market protection. In this dissertation it is assumed that potential changes in regulations, flag rules and political compliance have been thoroughly examined before a project is launched. The relevance of such risk is thus neglected.

Operational risks involve loss of hire due to mechanical breakdown, loss of vessel, damage to third party property, vessel unemployment while awaiting cargo, fuel cost volatility and charter default risk. Operational risk has proved to be both time consuming and costly. However, if a diversified fleet or business portfolio is assumed this could be viewed as unsystematic risk, and adjusting the parameters or models to allow for this is hence not adequate.

Asset market risk considers fluctuations in second hand prices and scrap values. This parameter is one of the most decisive factors in the valuation of the sale of the second hand option in chapter 7.

2.3.3 Shipping contracts

A *voyage charter* refers to the spot freight market, and provides a single transport of a specific cargo between a given number of ports. All relevant terms are described in the charter party, and the ship owner bears all the above mentioned risks and costs, except for the cargo handling cost. The LNG spot market has traditionally been marginal, but the growth has been solid the last years, and in 2006 13,5 percent of the LNG tonnage was on voyage charter basis (Drewry, 2006).

A *bareboat (BB) charter* involves that the ship owner contracts the vessel to an operator. The latter pays the bareboat charter to the ship owner and mans and operates the ship as if he owned it. The BB charter only covers the capital cost. This kind of contract frequently occurs in marine ownership structures, because this arrangement often leads to tax benefits. This contract is not particularly relevant in this dissertation.

A *contract of affreightment* implies that a ship owner undertakes to carry quantities of a specific cargo on a particular route or routes over a given period of time using ships of his choice within specified restrictions. COA's are complex and the allocation of risks and costs are not standardized. Not relevant for this dissertation.

A *time charter (TC) contract* implies that a vessel is hired for a specific period of time, with a predetermined, prepaid daily, monthly or annual fee. A TC contract comprises strictly defined obligations regarding freight rates, operational responsibility, period of hire and insurance. The time charter freight rates are based on capital costs, operating costs and an allowance for a target percentage rate of return on invested capital. The ship owner retains possession of the vessel, and mans and operates it under instructions from the charterer. Ship owner pays the operating costs, whilst the charterer bears the voyage costs. Hence, a TC transfers many of the costs, commercial responsibilities and risks from the ship owner to the charterer. TC contracts are essential in the LNG industry and will be a much discussed topic in this dissertation.

2.4 Costs, risks and contracts - assumptions for the valuation framework

As stated have long term TC contracts in the LNG industry historically been of fifteen to twenty years duration, wherein LNG carriers have been ordered to serve fixed routes for the whole TC period. As previously stated, TC contracts have also been the customary way of dealing with the immense investment in the LNG transportation business. An LNG ship owner utilizing TC contracts bears only the capital and operating costs, and is consequently not exposed to freight market risk as described in the previous sections. The operating costs are to some extent predictable, and most contracts also comprise clauses for escalation of the TC freight rate based on inflation or increase in operating costs. In this dissertation operating costs are regarded as fixed, and for data processing and valuation purposes assumed to be equal to 18'000 USD per day. Capital costs will largely be disregarded in this dissertation, as the emphasis is put on the real, commercial side of the projects, not on internal financial matters.

2.5 Options in shipping

Financial options are used for various purposes including risk management and speculation. Also in shipping is risk management possible through freight options³, while recent stories of staggering sums generated by speculative options within the tanker, rig and bulk industries⁴ are examples of the latter. However, most options employed in the shipping industry have a very different purpose than those mentioned above, especially in the rather conservative LNG industry:

Firstly, options are to a large extent perceived as standardized components of contracts, and the valuation methods applied are correspondingly unsophisticated. Strandenes (2006b: 8) pointed out in her elaboration on maritime options that “these can have substantial value but are often given away”. This underlines the gap between the common practises of the business, and how options are treated in most other industries.

Secondly, options are often used as decoys and sweeteners in the race to win contracts. That is, several ship owners have offered option elements to close contracts and thereby secure revenues from their vessels without receiving compensation for the flexibility offered through the options.

³ More liquid is the market of Forward Freight Agreements, a risk management tool traded over the counter or through a clearing house on an exchange

⁴ Dagens Næringsliv (2006), Dagens Næringsliv (2007a), Dagens Næringsliv (2007b), Dagens Næringsliv (2007c)

The treatment of options and the unfair remuneration for offering such is a key element in this dissertation, and one could expect that this is not only because of the above mentioned business practices, but also as a consequence of market cycles. The latter leads to an often unbalanced negotiation power, something one would expect to change when the market turns. However, receiving proper compensation would prove to be difficult for the ship owner also in a good market (personal correspondence, Birgitte Lind, Höegh LNG), which indicates that the unbalanced negotiating power and market trends are not as significant as one could tend to believe. The unfair remuneration thus rests mainly on mature business practises, in addition to insufficient awareness of option values and an absence of generally accepted option valuation tools.

The business practices and the balance of negotiating power are in this dissertation perceived to be external factors. Whether the LNG ship owner is in a position to demand a reward for including options or not, is hence not the interesting issue. The aim of this dissertation is rather to present a framework and option values comprehensible to industry participants and in that way prove that the options offered *do* comprise substantial values, for which compensations ideally should be paid.

3.0 Theoretical basis and introduction to options theory

In this chapter important insights into financial and real options are presented, in addition to the conceptual option valuation framework that later will be applied to the specific cases. A digression on the implementation of option valuation framework as a capital budgeting tool is added in the last section of this chapter.

3.1 Financial options

A financial option comprises the right, but not an obligation, to buy or sell an underlying financial asset at some time in the future. A call option gives its holder the right to purchase an asset for a specified price, called the exercise price, on or before some specified expiration date. A put option is equivalently a right to sell an asset to the exercise price.

The exercise style of the options governs the time at which exercise can occur. If exercise only can take place at expiry, the option is said to have a European style. If the option holder can exercise at any time before or at expiry, the option is of American style. If exercise only can occur during specified periods before expiry, it is a so-called Bermudan style option. The notations are names only, without any geographical interpretation. This dissertation will from now on solely focus on European options, and the expression “option” refers to European options unless else is stated.

The holder of an option will only exercise as long as it has economic rationale to do so. More precisely, a call option will only be exercised if the market value of the asset at the time of exercise is higher than the predetermined exercise price. Equivalently, a put option will only be exercised if the market value is lower than the exercise price. Thus, an option enables the holder to benefit from upside gains while limiting down side losses to the premium paid for the option, as depicted in figure 3.1:

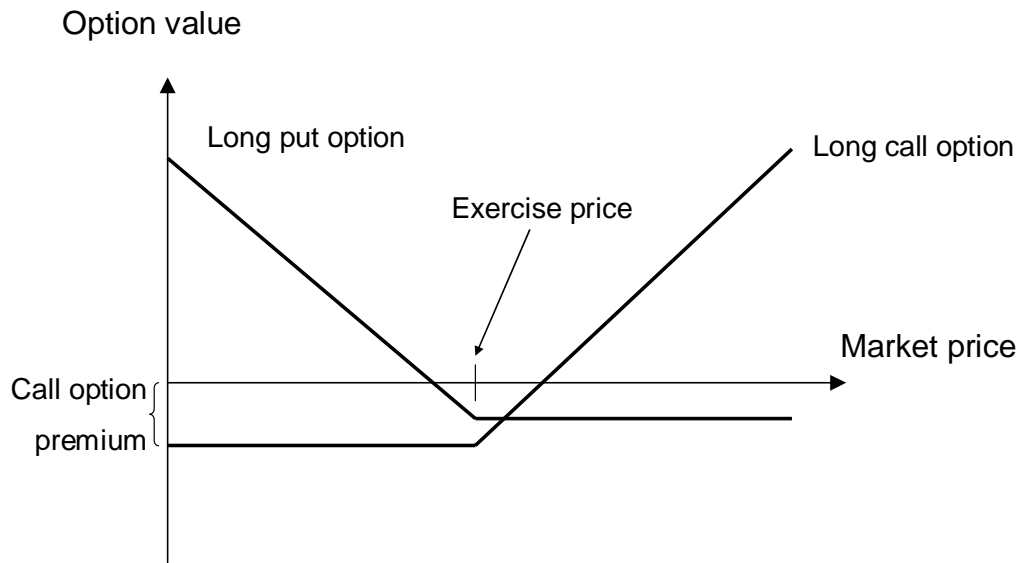


Figure 3.1: Profit from being long in a call or put option

The party that writes and sells the option is said to be “short” in the option, and is committed to comply with the option holder’s actions. It is important to understand that the option writer’s cash flow at time of exercise is the opposite of the option holder’s, which means negative or zero at best. To be willing to write options, the issuer demands an option premium, which the buyer pays to receive the option. The option premium equals the value of the option, which said loosely is the discounted expected payoff from the option. Such option values are the core concept of this dissertation.

The valuation of options comprises some important variables and parameters. The exercise price and the time until exercise characterise the options contract, the stock price, its volatility and dividend yield characterise the underlying stock and the risk free interest rate is used for discounting purposes. When the stock price exceeds the exercise price a call the option is said to be “in-the-money”, when they are equal the option is “at-the-money, and when the stock price is lower than the exercise price the call option is “out-of-the-money”. The more an option is in-the-money the higher is the option value. Higher volatility also leads to increased option value, due to higher probability of the option expiring far in-the-money. Increasing time until exercise usually results in higher option value, both because of discounting reasons and because there is a longer period in which the option can evolve far in-the-money. Dividend payments reduce the call option value because the holder of the option does not receive the dividends.

3.2 Real options

A real option gives the option holder the right but not the obligation to undertake an *action* at a predetermined cost (the exercise price), during a predetermined period or at a specified point in time. More specifically “it gives the manager the right to defer, to expand, to contract or abandon the project once more information becomes available” (Bendal 2002, referred to in Grammenos 2002: 645). Such a feature enabling postponement of managerial decision making represents a valuable flexibility. Although the link between real and financial options may not appear obvious, the tools used for valuing and describing options can successfully be applied to the valuation of real options. However, the value of real options is rarely incorporated into valuation processes and capital budgeting, which again refers to the aim of this dissertation.

Yet it is worthwhile to elaborate a bit on the term “real options”, because it can involve two different meanings. Firstly, it can mean straight options incorporated in a business contract, such as an optional vessel in a new building program or an optional purchase of a vessel at the end of a TC contract. In such real options, the underlying asset is often represented by a rather tangible object. Secondly, it can refer to the real options approach (ROA), which is a capital budgeting tool built on options theory. This is a helpful tool that renders percipient particulars of a project when managerial flexibility and contingent claims are important issues. The emphasis of this dissertation is put on the first category of real options. However, a short description of the ROA is presented in section 3.4, because the insights obtained in this dissertation can make this capital budgeting tool more interesting and accessible to the reader.

3.3 Valuation of financial options

There exist several different techniques for valuing financial options. In the following the two most used option pricing methods will be presented.

3.3.1 The binominal option pricing model

The binominal option pricing model achieves its intelligibility by making a very strong assumption: It allows the price of the underlying asset in each time period only to move up or down by a specified amount. The value of the underlying asset thus follows a binominal distribution. Correspondingly can an option written on this asset only take two values, because its value is dependant on the value of the underlying asset. It can be shown that a portfolio consisting of the underlying asset and bonds mimics this option and replicates the option's payoff at expiry⁵. Since the payoffs from the option and from the replicating portfolio are similar, the value of the option must be equal to the cost of the replicating portfolio. This is due to the law of one price, so called absence of arbitrage opportunities. Another important feature of the replication strategy is the emergence of risk neutral probabilities, which is the probability of an up movement in the asset price such that the expected return on the asset is the risk free rate. The option value is ultimately calculated as present value of the expected risk neutral payoff, discounted by the risk free rate of return.

The assumption regarding the one period binominal price movement is obviously unrealistic. This simplification is remedied by increasing the number of periods before expiry, which leads to a more realistic price path of the underlying asset. The price and option value developments are then best described through a binominal tree, of which figure 3.2 in section 3.4 is an example. In each state of the tree the option pricing based on arbitrage theory and risk free discounting is still valid. However, any change in the value of the underlying asset calls for a rebalancing of the replicating portfolio, and thus an amendment of the option price. This issue will be more described in section 5.4, but the conclusion of this section is that the binominal pricing method is disregarded because the following Black and Scholes model is more convenient for the valuations in this dissertation.

⁵ See McDonald (2003: 307-309) for derivation and formulas of the binominal option pricing method

3.3.2 The Black and Scholes option pricing model ⁶

The Black and Scholes (BS) model, which is used extensively in this dissertation, is founded on the principles of the binominal option pricing model. It can be shown, that for a European option, which underlying stock movements are based on an n -periodic binominal tree, the binominal option pricing formula will approach the BS formula. This is so because as n approaches infinity, the binominal distribution approaches the normal distribution. That the return on the underlying asset is normally distributed is an important assumption in the BS option pricing model.

The B&S model is further founded on the insight from the binominal method that when holding the option and simultaneously being short in a portfolio comprising Δ of the underlying asset (e.g. shares) and a borrowed amount, the net payoff at a future date is known. This is a result of perfect hedging. That there is no risk involved implies that the expected rate of return only can be equal to the risk free rate of return, minus the dividend rate⁷. This is the reason for why the risk free interest is used in the discounting of the B&S model.

For the theoretical option value, the B&S model further employs the value of the underlying asset today (S), the exercise price (K), the volatility of the underlying asset (σ), the risk free interest rate (r), the time to expiration (T) and the dividend payments (δ). The value of a call option is given by the following formula:

$$C(S, K, \sigma, r, T, \delta) = S \times e^{-\delta \times T} \times N(d_1) - K \times e^{-r \times T} \times N(d_2) \quad (3.1)$$

where

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r - \delta + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} \quad (3.2) \quad \text{and} \quad d_2 = d_1 - \sigma\sqrt{T} \quad (3.3)$$

The equivalent formula for valuing a put option can be found based on the put-call parity, but is here given as:

$$P(S, K, \sigma, r, T, \delta) = K \times e^{-r \times T} \times N(-d_2) - S \times e^{-\delta \times T} \times N(-d_1) \quad (3.4)$$

⁶ In 1973 Fisher Black and Myron Scholes published their famous formula together with closely related work by Robert Merton. The formula revolutionized both the theory and practise of finance, for which Merton and Scholes received the Nobel Prize in Economics in 1997. Black was ineligible for the prize, having died in 1995

⁷ The holder of a call option will not receive the dividend stream because he has an option on the stock not the stock itself. Thus the value of a call option must be adjusted for not receiving this dividend stream

The BS formula may appear intimidating, but can be explained at a somewhat intuitive level. The trick is to view the $N(d)$ terms (loosely) as risk adjusted probabilities that the option will expire in-the-money. The value of a call option in equation (3.1) is then left as the difference between the value of the underlying asset minus the present value of the strike price, adjusted for their respective probabilities⁸. Because of the nature of the options valued in this dissertation, only the framework of the call option will be applied in the later valuations. Option valuation is both intriguing and complex, and academic literature is recommended for obtaining a full understanding of the topic.

3.3.3 Assumptions made by the BS model

The following assumptions of the BS formula can appear quite unattainable, and their implications for the option valuation framework are here discussed briefly. Yet, the assumptions are satisfied, although not perfectly, and the BS model is accepted as an adequate valuation tool.

The continuously compounded return on the underlying asset is assumed to be normally distributed and independent over time. The following chapters present three different options with three different underlying assets; the TC freight rates, the new building prices and the second hand vessel values. These variables are perceived to fluctuate rather randomly (private correspondence, Jørn Bakkelund RS Platou), leaving a normally distributed return. Other papers have employed mean reverting processes for the freight rates, like Lorange (1998) and Bjerksund & Ekern (1991). Mjelde & Ingebrigtsen (2006) applied mean reverting processes for the freight rate in the tanker industry, and found a low explanatory factor of only ten percent. As the mentioned variables fluctuate rather randomly and that other possible distributions have proven not too strong, it is assumed that this assumption holds.

The volatility of the continuously compounded return is assumed to be known and constant. The volatilities used in this dissertation are based on historical fluctuations in the respective underlying assets. Allowing for varying volatilities calls for an advanced methodological framework, and there exist no significant basis for predicting such variations. The volatilities utilized are thus assumed to be constant over the duration of the options.

⁸ If the probability of exercise is high, that is when the call option is far in the money, the $N(d)$ -terms will be close to 1. This leaves the call value as $Se^{-\delta t} - Ke^{-rt}$, today's stock value (less the dividend yield) minus the present value of the exercise price

Future dividends are known. The real options in this dissertation do not pay dividends.

The risk free rate is known and constant. By altering the BS formula varying rates of interest could be permitted. However, such alterations are not undertaken, but it is assumed that the risk free interest rates based on appropriate yields in the money market are adequate.

There are no transaction costs or taxes. Real options in the LNG market are not traded commercially and have no transaction costs. Taxes are to be disregarded in this dissertation, although corporate structures and accompanying financial arrangements based on tax savings are employed extensively in the shipping industry.

It is possible to short-sell costlessly and to borrow at the risk free rate. This assumption relates to the replicating strategy. Replicating real options and exploiting arbitrage possibilities in mispriced real options in the shipping industry is beyond the realm of possibility.

3.4 Discounted cash flow versus real options approach

Investments in shipping are huge and the cash flows enormous, but so are also the risks involved. Shipping is an industry which cash flows are exposed to daily changes in international financial markets, to multi-country currency and sovereign risks, to movement in oil prices and above all to risks related to trade cycles. A decision to invest “can be regarded as a large scale capital evaluation problem within the context of a great number of volatile parameters” (Bendal 2002, referred to in Grammenos 2002: 642). Additionally, an investment decision can prove vital to the future success or failure of the firm, especially if it is not easily reversible and commits the firm for a certain long term path. The management thus needs sound and reliable tools to minimize the risk of poor investment decisions.

The most common approach to addressing and valuing projects is calculations based on discounted cash flows (DCF). Positive net present value (NPV) or internal rate of return (IRR) higher than the required rate of return, lead to projects being accepted. The problem is that the traditional NPV method is based on value maximisation under passive or static conditions and on implicit assumptions concerning a predetermined operating strategy in which the project would be initiated immediately and operated continuously at base case until the end of a pre-specified useful life. However, most projects require significant commitments of both capital and managerial input along the way, in addition to offering managerial flexibility when dealing with future contingencies. Embedding an extra flexibility parameter into the traditional NPV calculations would open up for possibilities to adapt or change the investment in response to altered market conditions. As sound decision making would increase the value of the project if commercial possibilities emerged, whilst limiting the downside if the contrary, the value of such flexibility adds to the static NPV.

Bendall (2002, referred to in Grammenos 2002) names this expanded NPV:

$$\text{Value of project with flexibility} = \text{Value of project without flexibility} + \text{Value of flexibility}$$

A project with contingencies and future possibilities of choice are usually illustrated in binominal trees as shown in figure 3.2: At time zero the optimal choices for the expected state at time one is made. However, at time one the prospects of the market may have changed, and the optimal strategy until period two has changed correspondingly. Calculating the NPV of such a project calls for a present value calculation of each possible state, adjusted for their

respective probabilities. The weakness of this traditional static DCF is that it is only correct under the special assumption that risk resolves at a constant rate over time. That means that the discount rate set at the beginning of the project is true for the whole lifetime of the project and for each state of outcome. However, when markets evolve, possibilities appear, or contingencies are involved, the risk of a project is changed. Still it is possible to alter the DCF discount rate to consider the altered associated risk and thereby find the correct expanded NPV, but this is tricky and timely. The real options approach (ROA) on the other hand, is based on risk-neutral probabilities, which remain unchanged even when risk changes dynamically. Such risk-neutral probabilities can either be estimated based on the forward prices of the underlying asset found in the market, or through parameters that are necessary for performing standard DCF analyses of projects with flexibility. Employing ROA thus calculates the expanded NPV much easier than does the intricate DCF approach that allows for flexibility, and that too based on rather easily accessible parameters.

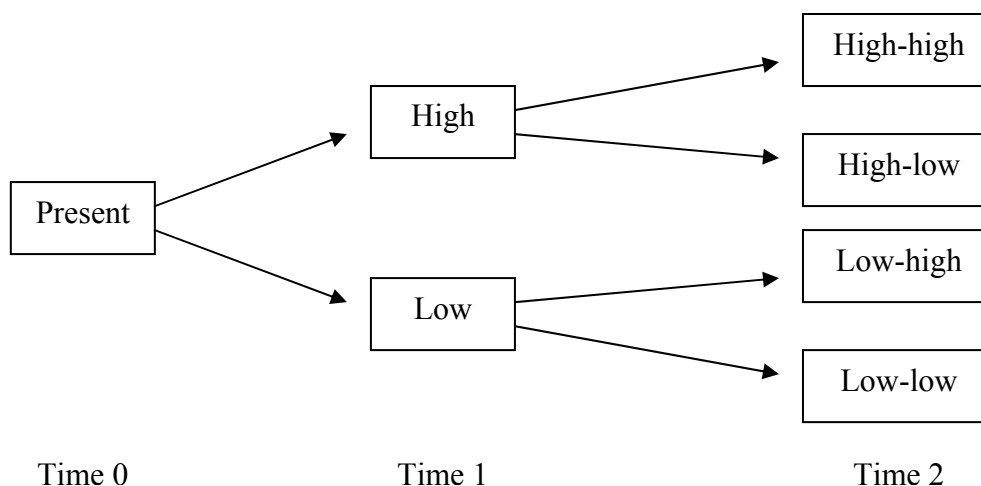


Figure 3.2: *Binominal tree showing the flexibility of managerial decision making*

Surveys of international corporate practice indicate that over 90% of firms use the NPV tool and that for most firms this is the primary method of project evaluation (Kester et al., 1999). And less than a quarter of companies say they use real options methods when making capital budgeting decisions (McDonald, 2006). Since the value of flexibility increases with the size and the risk of the investment, incorporating consecutive managerial decision making into project assessments and capital budgeting would be of high value for the shipping industry. Put shortly, the ROA method is the best and easiest method to calculate project values also incorporating the value of future managerial flexibility. Because of this, it should be used as a capital budgeting approach supplementing the DCF and IRR methods.

4.0 Introduction to the quantitative part of the dissertation

Thus far the dissertation has given an extensive insight into the shipping market and the LNG industry, in addition to discussing the use of options in shipping and option valuation tools and applications. The valuation of maritime real options could have been further developed on a conceptual basis, with further analysis on different valuation methods like binominal pricing or simulation. However, the following valuation of three realistic options from the LNG shipping industry excels this dissertation from not only being a qualitative one, but also to become a quantitative one. Through internships and consultations with participants in the industry, the three most common and supposedly the most valuable options within the LNG transportation industry were selected for appraisal: An option regarding an extension of a TC contract, an option on a new building, and an option on the purchase of an LNG vessel at the end of a TC contract.

4.1 The way to the target

The valuation of the above mentioned options called for a large quantity of data and parameters, together with a comprehensive knowledge about the industry. Ship owning companies, brokers, bankers and academic professionals have provided useful data and information for this purpose. Academic literature, internet resources, Bloomberg's database and the maritime press were also used extensively. The data and information were further processed by the help of spreadsheets, macro programming and graphic methods. The processing capability and data applicability make spreadsheets models reliable, robust and user friendly. Another important reason for utilizing such tools is that Høegh LNG will employ the models made for this dissertation in their future business analysis.

4.2 Comments on data

The LNG transportation industry has distinguished itself from other shipping sectors by the utilization of long term contracts, low liquidity in the asset market and an absence of spot market features in general. As a consequence, very little adequate data on vessel prices, freight rates etc. is available. The only usable historical data obtainable was the quarterly quoted development of the new building prices of LNG carriers from 1990 until the present. Each of the three valued options applies data and information collected from this source, and the respective processing and applications of it are described shortly in each chapter.

It is worthwhile to elaborate a bit on what is the optimal time horizon for the empirical data used for predictive measures. On one hand, the longer the time horizon the more extensive is the amount of data, and one should expect a higher validity of the estimates processed from it. On the other hand, freight rates are correlated to the business cycle, in addition to the fact that structural changes may cause permanent shifts in supply and demand (Mjelde & Ingebrigtsen, 2006). Data sourcing back to the shipping crisis in the 1980's would hence render parameters not applicable for descriptive measures for today's market. Participants in the industry regard the time horizon of the data from 1990 until the present as adequate for describing both the LNG shipping market of today and the expectations for the coming decade. This historical data is therefore assumed adequate.

5.0 Case 1: Extension option

In this chapter the value of a five year extension option will be determined. The framework and calculus can easily be applied to render values also on other option structures for the extension of TC contracts. By valuing such an option, the importance of incorporating it into calculations and negotiations is emphasized, hopefully yielding a clear cut, convincing evidence that should support a ship owner pursuing a higher rate on a contract with a built-in option element. The chapter opens with a presentation of the case before an elaboration on the data and the processing of data is given. The derivation of the valuation framework is then explained, followed by the calculus. Finally a sensitivity analysis on the different option parameters is undertaken. This structure is believed to be intuitive and pedagogic, and the two following chapters also take on this structure.

5.1 Presentation of the case and the problem to be addressed

As TC contracts come to an end, the charterer has in many cases an option to extend the duration of the TC contract for another five to ten years. This extension period normally consist of two options of five year periods, or three options of three year periods. The options have to be exercised two years before the present contract or previous extension option matures. The terms of the option are defined as the initial TC contract is signed, and thus set fifteen to twenty years before the option may be exercised. In the following, a five year option expiring at the end of a twenty years TC contract will be valued.

Because the ship owner has a short position in the option, he is committed to apply to the charterer's exercise decision. The charterer on the other hand possesses the flexibility to choose between alternatives of different economic value, that is he can exercise the option or not. If the sum of the freight rates over a twenty year TC contract with a five year extension option is equal to the sum of an alternative twenty-five years straight TC contract, then the ship owner gives away this flexibility for free. In other words, the value of the former should be higher; the ship owner should receive compensation for providing such flexibility. And because an option normally is paid for when the option is bought, the value of this option should be reflected in the cash flows of the initial contract before the time of exercise. And this is no impossibility because the option value is based on assumptions and parameters stated at the time the initial TC contract is signed.

It is worth mentioning that there exist differing ideas on how one of these parameters, the TC freight rate in the optional period, is to be quantified. However, in many real world cases the TC freight rate in the option period is equal to the freight rate in the twenty year contract before exercise. This is also the assumed relation in this valuation. Interesting is also the fact that when the time of exercise approaches fundamentals of the market might have changed, which often lead to renegotiations of the contractual terms for the options periods. This issue could be elaborated on, but the ultimate design of the contractual elements is here considered irrelevant for the options pricing. This is firstly because the compensation for providing an options element should take place during the time before the initial contract expires, and that the option price is correct due to being based on all relevant and obtainable information. Secondly, this amendment is often very much a result of the strong negotiating power of the charterer, a factor not taken into consideration in this dissertation.

Given that the charterer wishes to get cargo transported at the time of exercise and throughout the whole life of the option, he may as an alternative to extending the contract, utilize another vessel from the market and accept the TC freight rate prevailing in the market for the whole option period. Thus, the charterer only wishes to exercise the option if the contracted TC freight rate in the extension period is lower than the freight rate available in the market at the time of exercise. And because the ship owner has to comply with the charterer's decision, he loses out because he alternatively could have closed contracts to the higher market freight rate. The ship owner's position is hence characterized by the features of being short in a call option:

Payoff to ship owner at exercise = - max (Market TC freight rate - Contracted TC freight rate, 0)

Figure 5.1 depicts this relation graphically. It is evident that the ship owner's pay-off from the option at the time the option is put to life is negative or zero at best. The figure hence emphasises in an intuitive and visual way the ship owner's right to demand compensation for offering such an extension option.

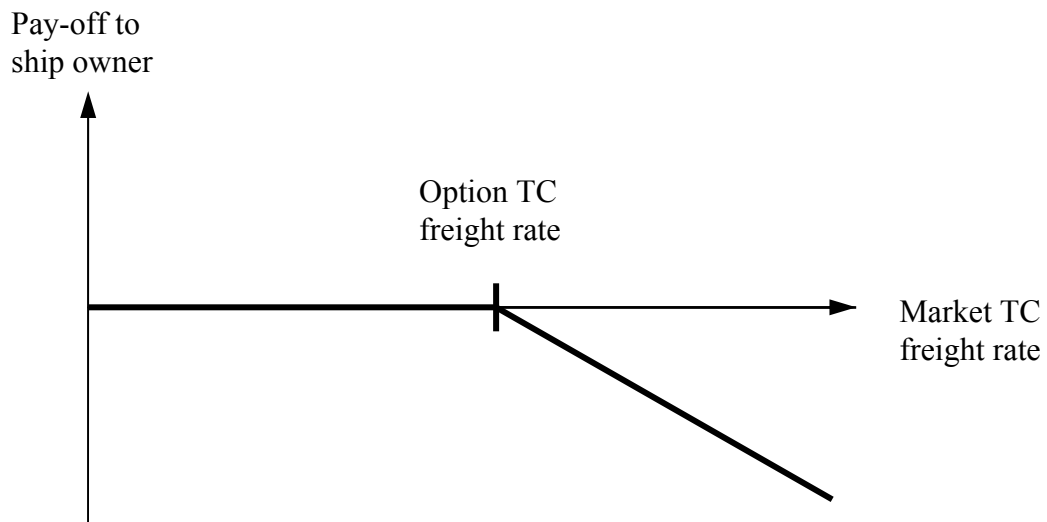


Figure 5.1: Ship owner holds a short position in the call option

5.2 Gathering and processing of data

Important parameters in the option valuation process rest heavily on the price characteristics of the underlying asset. The underlying asset for the valuation of the extension option is the nonexistent spot TC freight rate. Based on company specific capital budgeting parameters and quarterly nominal new building prices of delivered standard LNG vessels from 1990 to 2006 obtained from Fearnley's gas trade division, I developed a fictitious quarterly quoted TC freight rate for a standard LNG carrier⁹. That is, the daily TC freight rate necessary to cover the capital and operational costs plus an allowance for profits. The estimation of this freight rate at one given point in time called for a comprehensive spreadsheet calculation. By employing a Visual Basic macro, the calculation was repeated for every point in time with input data. This rendered a complete quarterly price path for the spot TC freight rate from 1990 to 2006, depicted in figure 5.2. Based on the development of US CPI in this period (US Bureau of Labour Statistics), the nominal spot TC freight rate was converted to real figures. This historical fictitious TC freight rate development gained praise among experienced participants in the industry, and is thus believed to be adequate for later valuations. The historical newbuilding prices and the visual basic macro code are reproduced in appendix A and B respectively.



Figure 5.2: *Processed TC freight rates*

⁹ The standard LNG carrier has grown steadily in size from 125 to 155 thousand cubic meters the last fifteen years. According to Jørn Bakkellund in Fearnley Research, this growth in sizes has had no significant impact on the new building prices

5.3 Framework for valuation

This section is devoted to the explanation and application of the different parameters of the B&S model presented in section 3.3.2. Emphasis is especially put on the exercise price and the today's price of the underlying asset. This section together with the risk adjustment of uncertain parameters presented in section 5.4, put forward a holistic valuation framework for the extension option based on the B&S model. Both sections may appear intricate, but together they adapt a model mainly applied to financial assets also to fit this specific case.

To make the following explanations more comprehensible, figure 5.3 depicts the chronological structure of the TC contract with a built in extension option element. It illustrates the charterer's possibility to extend the initial twenty year TC contract with another five years. This extension option must be exercised two years before the initial TC contract matures, but it is not put to life before this TC contract comes to an end. All terms of both the TC contract and the extension option are agreed upon at time zero.

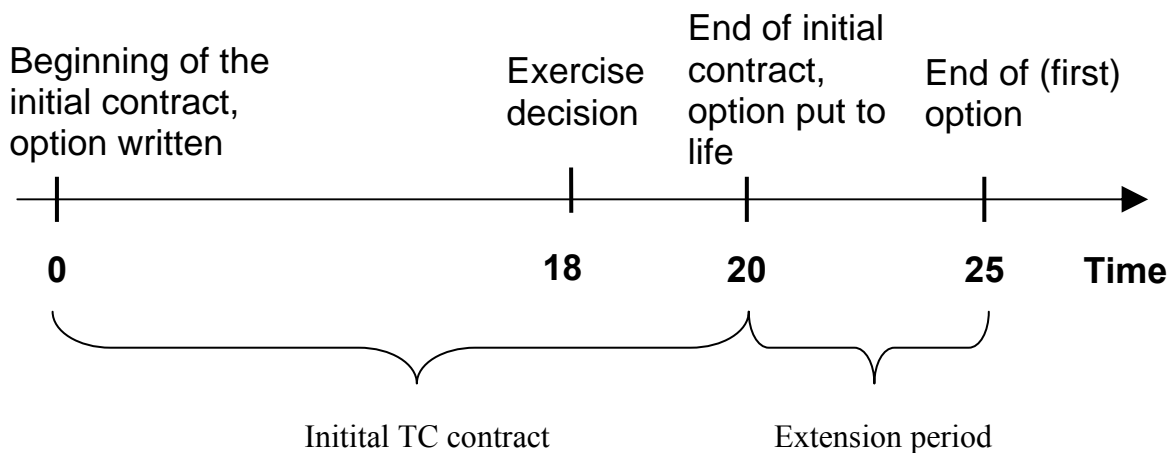


Figure 5.3: *Chronological structure of the extension option*

The daily TC freight rate payable throughout the extension period is decided at time zero and denoted by k . It was stated in section 5.1 that the option would only be exercised if this TC freight rate k was lower than the TC freight rate otherwise obtainable in the market at the time of exercise. This k could thus be perceived as the exercise price of the option, but this is in fact not entirely correct. This is so because the underlying asset obtained when the option is exercised is actually not the single TC freight rate k , but a five year service provided for a daily payment of the TC freight rate k . The correct exercise price is thus the value of this

service, which is the stream of the TC freight rate k over the five years of the option. More specifically, the exercise price denoted K is the value of the stream of the contracted and fixed daily TC freight rate k between the start and the end of the extension period, discounted back to the time the option is exercised.

In the presentation of the B&S model in section 3.3.2 it was described that the today's value of the underlying asset is one of the necessary parameters to perform the option valuation. For stock options this parameter is the current stock price. The right measure in the case of the extension option is the current value of the underlying five year service described above. Such a value is found by the present value of the daily TC freight rate observed in the market today for an equivalent five year period. Denote this daily freight rate x_0 , and the current value of the underlying asset X_0 .

As both the daily freight rates k and x_0 are payable to the ship owner on a monthly basis, annuity formulas are adequate for measuring the values of K and X_0 . The valuations are performed based on equations (5.1) and (5.2) respectively. The second terms in the two equations convert the daily TC freight rates to a monthly basis, by using the factor TC_d , time charter days per year. The two last terms are standard annuity calculations¹⁰. As mentioned above and shown in figure 5.3, the decision on whether or not to exercise is made two years before the initial contract ends, which is two years before the option may be put to life. This time lap is denominated by h , and the first term in equations (5.1) and (5.2) consider further discounting of the annuities to the time of exercise.

$$K = \frac{1}{(1+r)^h} \times \left[k \times \frac{TC_d}{12} \right] \times \frac{1}{r/n} \times \left[1 - \frac{1}{(1+r/n)^m} \right] \quad (5.1)$$

$$X_0 = \frac{1}{(1+r)^h} \times \left[x_0 \times \frac{TC_d}{12} \right] \times \frac{1}{(r-\alpha)/n} \times \left[1 - \frac{(1+\alpha/n)^m}{(1+r/n)^m} \right] \quad (5.2)$$

The daily TC freight rate for the whole extension period k is fixed and agreed upon at time zero. As it can not change during the extension period there is no uncertainty related to this parameter. Because of this the discounting in equation (5.1) employs the risk free rate of

¹⁰ See Bodie, Kane & Marcus (2005) chapter 14 for derivation

return in the valuation of the exercise price K . This is not the case for the calculation of the today's value of the underlying asset X_0 . This is because the daily TC freight rate x_0 observed in the market today has an uncertain five year development. In equation (5.2) the parameter α emerges for the first time in this dissertation. This variable is further explained in the next section, and is a measure of a risk neutral drift in the uncertain development of the TC freight rates.

By now having found valuation tools for the relevant exercise price and the today's value of the underlying asset, the remaining B&S parameters from equation (3.1) at page 22 appear rather intuitive. When valuing a stock option, σ is the volatility of the underlying stock price. σ is in this context the volatility of the underlying TC freight rate derived from the already discussed historical TC freight rates. T is the time until exercise and r the risk free interest rate. For financial options δ is the dividend rate, and the value $e^{-\delta T}$ can in this context be viewed as the difference between the spot freight rate and a forward freight rate at the time the option expires. However, the parameter δ will be altered later in this valuation.

5.4 Risk adjustment of the uncertain TC freight rate development

In section 3.3.2 it was asserted that the B&S model employs discounting based on the risk free rate of return due to the assumption of perfect hedging possibilities. Through such hedging strategies the uncertain development in the value of the underlying asset is neutralized. There is also uncertainty related to the underlying asset of this option, more specifically uncertainty related to the development of the TC freight rate. This was present in the last section in the evaluation of the today's value of the underlying asset K , and is also relevant for the TC freight rate development until the time of exercise. By stating the very realistic assumption that investors are risk averse, investors do demand compensation for carrying the risk related to this uncertainty. The value of the option thus has to be adjusted for this associated risk.

One possibility to deal with this risk is through amendments of the required rate of return on the replicating portfolio consisting of Δ shares and bonds described in section 3.3.2. However, this calls for a measure of delta, which is the amount of the underlying asset in the replicating portfolio, which again is measured as the sensitivity of the option price to a change in the price of the underlying asset. The problem with this method is that when the value of the underlying asset changes, so do the delta and the required rate of return. The option valuation

based on discounting would thus be a very timely and intricate process, because every change in the TC freight rate would call for altered portfolio weights. In addition, Mjelde & Ingebrigtsen (2006) point out that it is intricate to find an adequate measure of delta when dealing with real options, whilst Copeland & Antikarov (2001) describe the difficulty of finding a proper replicating asset for real options. This approach is thus not very applicable for this case.

A better alternative is to perform the risk adjustments on certain parameters in the B&S formula. The process presented in “Options, Futures, and other Derivatives” (Hull, 2006) is shortly presented and utilized here. The rationale aims at finding and applying a risk-adjusted drift rate in the underlying asset, and by doing so the regular risk free discounting of the B&S formula is allowed for. In this case the risk adjusted drift rate is the risk adjusted growth in the TC freight rates.

Denote this parameter α :

$$\alpha = \mu - \lambda * \sigma \quad (5.3)$$

In equation (5.3) μ represents the expected annual growth rate in the underlying asset for a given period of time. As stated, the α is not only employed as a parameter in the calculation of the current value of the underlying asset in equation (5.2). It is also relevant for the development of the TC freight rates until the time of exercise. As these two calculations refer to a five year period and an eighteen year period respectively, different μ 's have to be used because the expected yearly growth rate varies for different time perspectives.

The parameter σ in equation (5.3) is the volatility of the TC freight rates, while λ is a measure of the market price per unit of asset risk. λ is given by:

$$\lambda = \lambda_m \times \rho_{x,m} = \frac{\mu_m - r}{\sigma_m} \times \rho_{x,m} \quad (5.4)$$

where λ_m is the market price per unit of market risk and $\rho_{x,m}$ the correlation coefficient between the TC freight rates and the market given by an adequate market index. μ_m is the expected rate of return and σ_m the volatility of this market index, whilst r is the risk free interest rate.

By utilizing α as the expected rate of return in the B&S formula in stead of $r-\delta$, the risk embodied in the development of the TC freight rates is equivalent to that of the risk free approach in equation (3.1). Intuitively this could be interpreted as indifference between receiving an amount today with certainty, or an uncertain future cash flow with a present value equal to this amount. Applying the risk adjusted growth rate of the TC freight rate α deals with the risk embodied in the development of the TC freight rate, which again implies that discounting in the B&S model based on the risk free interest rate is adequate. Finally, the risk adjustment calls for certain substitutions in the B&S formula. By combining equation (3.1) and that $\alpha = r-\delta$, the value of the extension option is given by an altered version of the B&S formula:

$$C_0 = X_0 \times e^{-(r-\alpha) \times T} \times N(d_1) - K \times e^{-r \times T} \times N(d_2) \quad (5.5)$$

where

$$d_1 = \frac{\ln\left(\frac{X_0}{K}\right) + \left(\alpha + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} \quad (5.6)$$

and

$$d_2 = d_1 - \sigma\sqrt{T} \quad (5.7)$$

5.5 Calculus

A good point of departure is to find an estimate of the two α 's for the five and eighteen years perspectives. The first step is to annualize the standard deviation of the quarterly quoted new building prices of 2,7%:

$$\sigma_{ANNUAL} = \sigma_{QUARTERLY} \times \sqrt{T} = 2,7\% \times \sqrt{4} = 5,4\% \quad (5.8)$$

The second step is to find the market price per unit of asset risk. When assuming that S&P500 represents the market, the market risk premium was found to be approximately 4 percent and the volatility 20 percent (Bloomberg software, CASS Business School). Additionally, the correlation coefficient between S&P500 and the TC freight rates is estimated to be 0,206 (see Appendix C). λ is then found equal to:

$$\lambda = \lambda_m \times \rho_{x,m} = \frac{\mu_m - r}{\sigma_m} \times \rho_{x,m} = \frac{0,04}{0,20} \times 0,206 = 0,0412 \quad (5.9)$$

To finalize the calculation of the two α 's, the expected growth μ in the TC freight rates for the two time perspectives of five and eighteen years must be estimated. On a five years horizon market practitioners point at several new projects coming on stream which will increase the demand for tonnage. Yet, most of these projects have dedicated vessels under constructions, and significant delays are not anticipated. In addition to this, nine percent of tonnage currently on orderbook is ordered on speculative basis (Drewry 2006), which means vessels that are not yet dedicated to projects. The overcapacity will expectedly restrain the growth in the TC freight rates, but as demand is expected to catch up with supply around 2010 and 2011 a growth is expected at the end of this period. An annual growth of one percent in this period is adequate based on the market expectations. When looking to historical data, the quarterly quoted TC freight rates indicate a three percent annual real growth in the TC freight rates over the last five years. The expected cool-down in the market from this level corresponds to this one percent expected growth.

The eighteen year growth estimate is more intricate. Although a fundamental growth in the consumption and trade of LNG is expected on a medium to long term perspective, it is important to keep in mind that it is the balance of tonnage that largely determines the freight rates in the market, not the overall demand for the commodity. As this balance is impossible

to predict with certainty, it is difficult to state assumptions for the growth parameter based on market expectations. However, the seventeen year sample of the historical TC freight rates indicates a slight decrease of 0,2 percent annually. Assuming the annual growth rate in the TC freight rates over eighteen years to be zero is thus no severe violation.

The two α 's are then found to be:

$$\alpha_5 = \mu - \lambda \times \sigma = 1\% - 0,0412 \times 5,4\% = \underline{0,78\%} \quad (5.10)$$

$$\alpha_{18} = \mu - \lambda \times \sigma = 0 - 0,0412 \times 5,4\% = \underline{-0,22\%} \quad (5.11)$$

Now, the present values of the two five year cash flows presented in equation (5.1) and (5.2) in section 5.3 will be calculated. By assuming a risk free interest rate of 4,6% p.a. equal to the yield of twenty year US treasury bonds (Bloomberg software, CASS Business School), 357 operational days per year, and a daily TC freight rate of 86'000 USD, the present value at the time of exercise eighteen years ahead in time for the secure cash flow generated in the option, is found as:

$$K = \frac{1}{(1 + 0,046)^2} \times \left[86'000 \times \frac{357}{12} \right] \times \frac{1}{0,046/12} \times \left[1 - \frac{1}{\left(1 + 0,046/12\right)^{5 \times 12}} \right] = \underline{125'125'847} \quad (5.12)$$

This measure will serve as the exercise price in the B&S formula. Correspondingly, the discounted five year TC freight rate observed in the market today will be used as today's stock price in the B&S formula. The calculations undertaken for finding the historical TC freight rates rendered today's spot TC freight rate x_0 to be 85'000 USD per day. The α of 0,78percent is also employed here to estimate the risk adjusted value:

$$X_0 = \frac{1}{(1 + 0,46)^2} \times \left[85'000 \times \frac{357}{12} \right] \times \frac{1}{(0,046 - 0,0078)/12} \times \left[1 - \frac{\left(1 + 0,0078/12\right)^{5 \times 12}}{\left(1 + 0,046/12\right)^{5 \times 12}} \right]$$

$$= \underline{125'970'288} \quad (5.13)$$

Moving to the B&S formula, d_1 and d_2 are found to be:

$$d_1 = \frac{\ln\left(\frac{125'970'288}{125'125'847}\right) + \left[(-0,0022) + \frac{1}{2}0,054^2\right] \times 18}{0,054 \times \sqrt{18}} = \underline{-0,0311} \quad (5.14)$$

$$d_2 = -0,0311 - 0,054 \times \sqrt{18} = \underline{-0,2602} \quad (5.15)$$

Employing the cumulative normal distribution function, $N(d_1) = 0,4876$ and $N(d_2) = 0,3974$. The rather intermediary values of these terms indicate that there is not a very high but still a fair probability that the option will be exercised.

Finally by using the altered version of the B&S formula presented in equation (5.5), the value of the call option is found to be:

$$C = \left[125'970'288 \times e^{-((0,046 - (-0,0022)) \times 18)} \times 0,4876 \right] - \left[125'125'847 \times e^{-(0,046 \times 18)} \times 0,3974 \right]$$

$$= \underline{4,1 \text{ million USD}} \quad (5.16)$$

The five year extension option thus has a substantial value of more than 4 million USD, a value the ship owner today to a large extent gives away for free.

5.6 Sensitivity analysis

In the previous calculation some of the parameters were either assumed or estimated. In this sensitivity analysis the behaviour of the option price is measured as the different input parameters are being changed. The range of variation is generally set to be \pm twenty percent of the initial input value, with ten percent intervals. This style is chosen based on personal preferences, but shows also the two main objectives of this section in a clear and intuitive way: Firstly, to analyse and consider the relevance of possible errors in the assumed levels of the various input parameters. These error deviations are believed to be within the range of \pm twenty percent. The second objective is to give the reader a deeper understanding of the impact various fundamental parameters and real economic factors have on the option value. And the relative significance of these fundamental elements is better illustrated when the percentage changes along the X-axis are fixed and equal for all elements. In addition to these two objectives, a sensitivity analysis is a good approach to test the models explanatory validity and consistency with conventional options theory.

5.6.1 Volatility

Volatility is one of the most decisive variables in options pricing and can not be observed directly. Based on the quarterly quoted TC freight rate generated from the historical new building prices, a historical volatility was derived. Figure 5.4 shows a positive elasticity between volatility and option value, a relation well known from options theory.

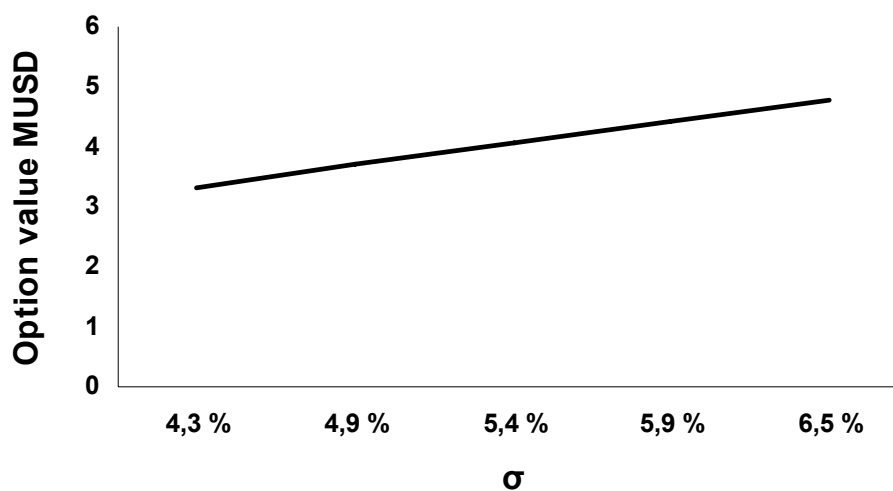


Figure 5.4: *Volatility and option value*

The effect of increasing the volatility works in two ways. Firstly, the higher volatility increases the probability that the option will expire in-the-money, and thus raises the option value. Secondly, an increased volatility reduces the level of the risk adjusted drift rate in the TC freight rates in equations (5.3) and (5.4). This again decreases the present value of the five year TC spot rate observed in the market today, which impacts the option value negatively. However, it is evident that the first effect is the stronger. Intuitively, this could be perceived as a lower stock price but a higher volatility. That options increase in value the more volatile the market, is an important insight for business managers.

5.6.2 Time until exercise

Also the time until exercise affects the option price in different fashions. A longer time span lowers the present value of the exercise price, which affects the option value positively. In addition to this would a longer time until exercise theoretically increase the possibility for expire far in-the-money because of the volatility of the underlying TC freight rates. On the other hand, the expected non-growth in the TC freight rates and the moderate volatility lead to a negative risk neutral drift rate for the TC freight rates. This implies that there is an expected risk neutral decline in the TC freight rates, and the longer the time until exercise, the lower should the probability of expiry far in-the-money be. An older vessel would also call for higher operational costs, and the profit margin would consequently be reduced correspondingly. It appears in figure 5.5 that the two latter effects are the stronger. It is important to point out that these two effects are unique for this example, and that longer time until exercise normally has a positive influence on option values.

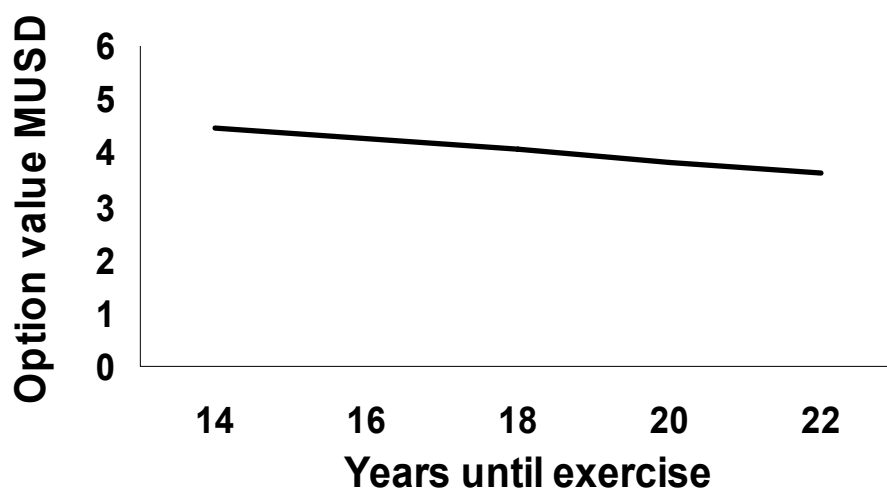


Figure 5.5: Time until exercise and option value

5.6.3. Risk free interest rate

A strong positive correlation is normally observed between the option value and the risk free interest rate. The argumentation for this is rather straight forward: A higher interest rate will reduce the present value of the options exercise price, as the discounting of the second term in equation (3.1) shows. However, figure 5.6 below indicates that this positive correlation does not exist in the case of the extension option, rather to the contrary. This is evident from equations (5.1), (5.2) and (5.5), were not only the exercise price but also the current value of the underlying asset is being discounted by the risk free rate. This is because both X_0 and K are calculated as present values of cash flows. Analyses of this discounting process have shown that the current value of the underlying asset X_0 is more sensible to interest changes than is the exercise price K , which leads to the depicted negative relationship in figure 5.6. This negative effect is in diametrical contrast to the usual relation between interest rate and option value.

Also important to notice is that as X_0 decreases more than K , the probability of exercise is affected negatively, as shown by equation (5.6). This strengthens the negative relation between the option value and the interest rate even further.

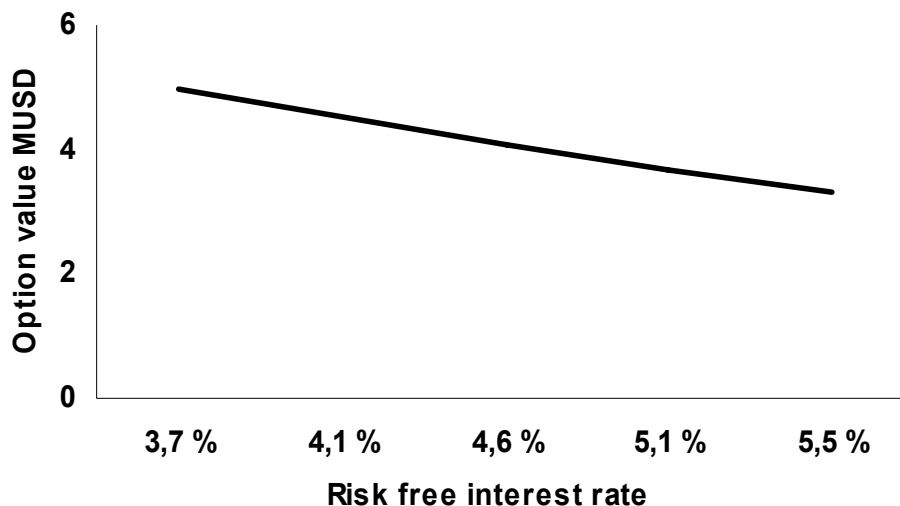


Figure 5.6: Risk free interest rate and option value

5.6.4 Growth in TC freight rates

The assumed growth in the TC freight rates over five and eighteen years have proven to be decisive factors for the option valuation, as shown in figure 5.7 and 5.8. In addition, these values are based on market expectations and historical data, and their levels are consequently

to some extent uncertain. The assumed levels of growth μ affect the risk adjusted growth rates α through equation (5.3), which again impact the option value in two ways: Firstly, a higher expected TC growth rate over eighteen years leads to a higher risk adjusted growth rate α_{18} for the same period, which again affects the probability for expiration far in-the-money positively. In figure 5.7 it appears that only small changes in the assumed levels of annual growth have major impact on the option value: Increasing the growth estimate from zero to one percent more than doubles the option value from four to ten million USD. However, it is important to emphasize that a clearly positive (negative) growth in the TC freight rates over eighteen consecutive years leading to several consecutive years of high (low) profits is highly unlikely because competition will bring the market back to a more stable equilibrium. That the annual real growth over this period will prove to be close the assumed zero-growth is thus highly probable.

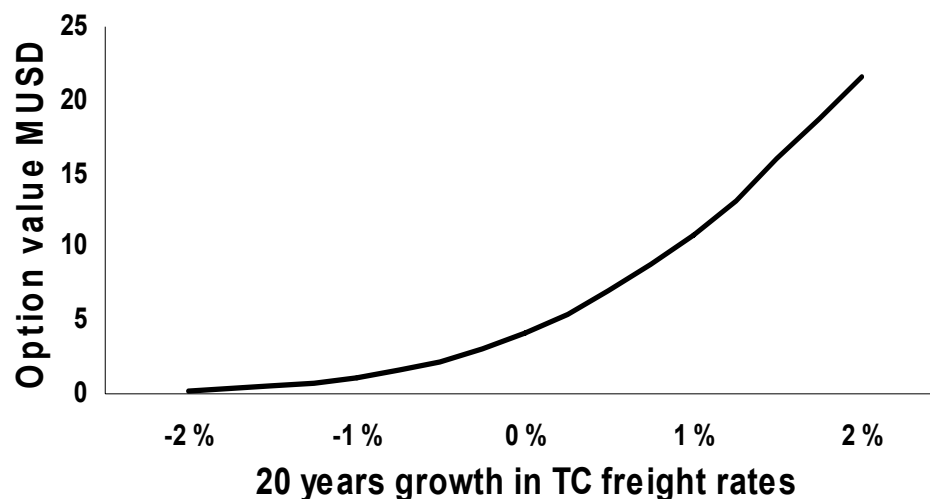


Figure 5.7: 20 years annual TC growth and option value

Secondly, a higher expected annual five year TC growth rate also leads to a higher risk adjusted five years growth α_5 . The higher α_5 impacts the discounted value of the five year TC freight rate observed in the market today positively (equation (5.2), and as this element is the underlying asset of the option, the option value rises. Intuitively this is equivalent to increasing the current stock value in a financial option while keeping the exercise price unchanged. This would naturally increase the option value. Yet, figure 5.8 shows that the impact of this parameter is much weaker than the impact of the eighteen year assumption above. However, the assumed level for this short to medium term growth is likely to be somewhat more uncertain than the assumed level for the long term growth, although market

predictions are easier to state. This is so because the balance of the short to medium term market is much more affected by inertia of supply and demand, and deviations caused by unforeseen market developments can occur and persist for some time.

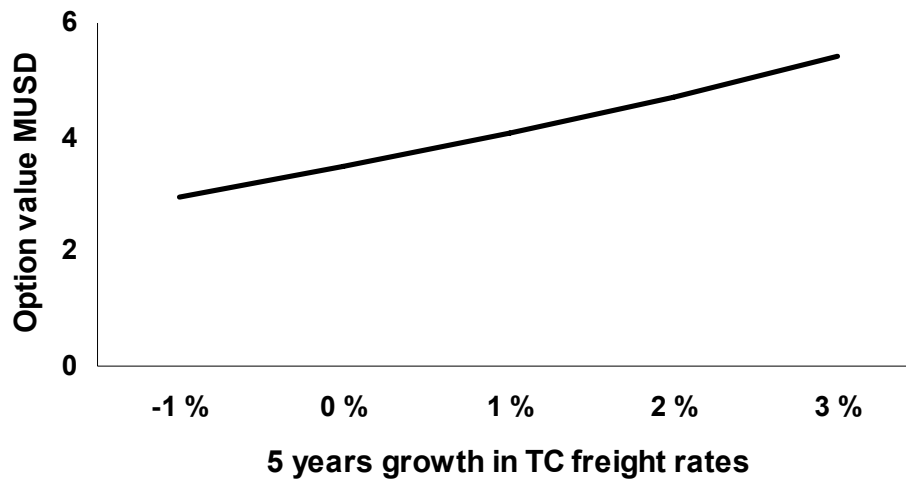


Figure 5.8: 5 years annual TC growth and option value

The risk adjustment performed on the uncertain TC freight rate development was called for because the B&S framework assumes risk free discounting and because investors are risk averse. This aspect could be neglected, but that would involve the improbable assumption that investors do not demand compensation for carrying risk. The growth assumptions discussed above have significant impacts on the option value, which shows how difficult it is to create good estimates on option values with long time horizons. Yet, the assumptions are credible, and made on the best information available.

McDonald (2006) points out that business managers tend to adjust parameters in DCF methods to take account for real option values. This indicates that there might be willingness to adjust the discount rates for the relevant risky elements in the valuation framework and calculate the option value without paying respect to a proper risk assessment. This could still render credible option values, but it is important to emphasize that this is an informal procedure without academic support.

5.6.5 Exercise price

The exercise price for this option is the present value of the TC freight rates payable throughout the option period found by equation (5.1). The higher the exercise price the lower is the economic gain for the charterer, in addition to a lower probability of exercise. Thus, a change in this variable leads to a significant negative elastic change in the option value, as depicted in figure 5.7.

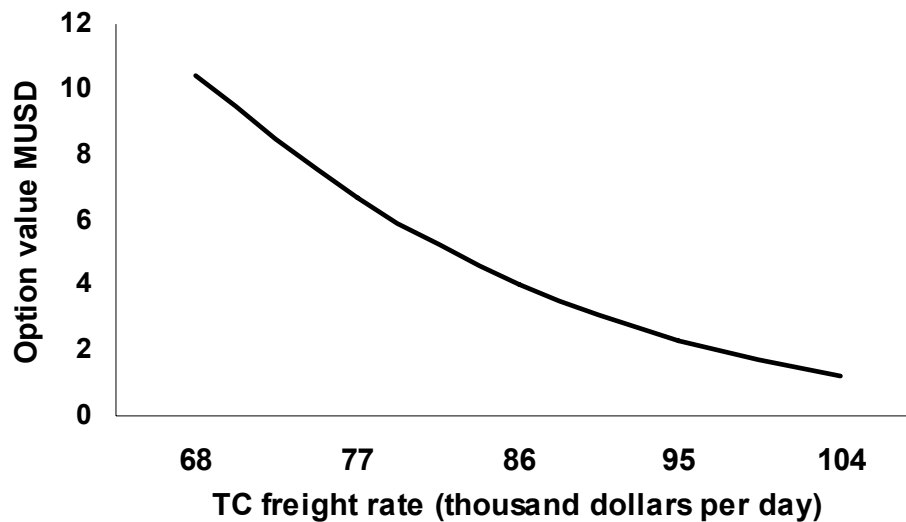


Figure 5.9: *Exercise price and option value*

An increase in the exercise price of 10% reduces the option value by nearly 50%, while a similar reduction increases the value by 70%. This convex shape is evident in figure 5.9, and indicates that not only does a lower exercise price increase the charterer's economic gain and thereby raise the option value, but also that the increasing probability for exercise amplifies this effect. From a ship owner's point of view it is evident that only a slight reduction of the TC freight rate in the option period should be balanced out with a reciprocal compensation in the pre-option cash flow.

5.6.6 Time gap

The time gap encompasses the two years between the exercise decision after eighteen years and the start of the options period when the initial TC contract matures after twenty years, as illustrated by figure 5.3. Altering the duration of this time gap affects the valuation of the exercise price K and the current value of the underlying asset X_0 from equation (5.1) and (5.2). Yet the impact is only moderate, and an increase (decrease) of one year only lowers (rises) the option value by approximately 4,5 percent. An intuitive explanation of this is that

the longer the time gap between the exercise decision and the optional period is, the higher is the uncertainty the charterer takes when exercising. And the earlier the ship owner knows the charterer's decision, the better he can optimize his position. The reciprocity between the ship owner's flexibility and charterer's uncertainty is thus reflected in this negative relation between the time gap and the option value.

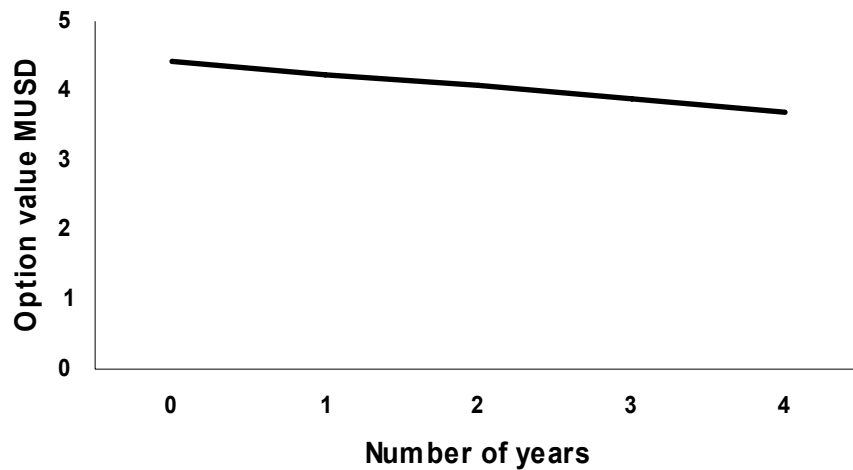


Figure 5.10: *Time gap and option value*

5.6.7 Market correlation

The market correlation is one of the parameters necessary for the risk adjustment presented in equation (5.3) and (5.4). As it is measured based on seventeen years of historical data the estimated value of 0,20623 is believed to be rather accurate. A higher market correlation reduces the expected risk neutral growth in the TC freight rates α slightly, which again reduces the option value as described in section 5.6.4. This marginal impact is evident in figure 5.11.

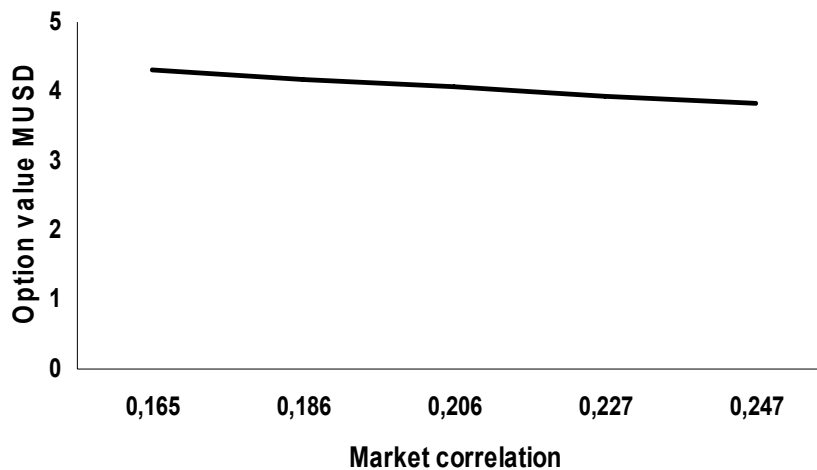


Figure 5.11: Market correlation and option value

5.6.8 Price per unit of market risk

An increase in the price per unit of market risk leads a risk-averse investor to demand a higher compensation for carrying systematic risk. Equations (5.3) and (5.4) express the negative impact a higher price per unit market risk has on the risk neutral expected growth rate α . This again leads to a lower value of the option. Figure 5.12 shows a rather marginal but still clearly negative relation between the price per unit market risk and the option value.

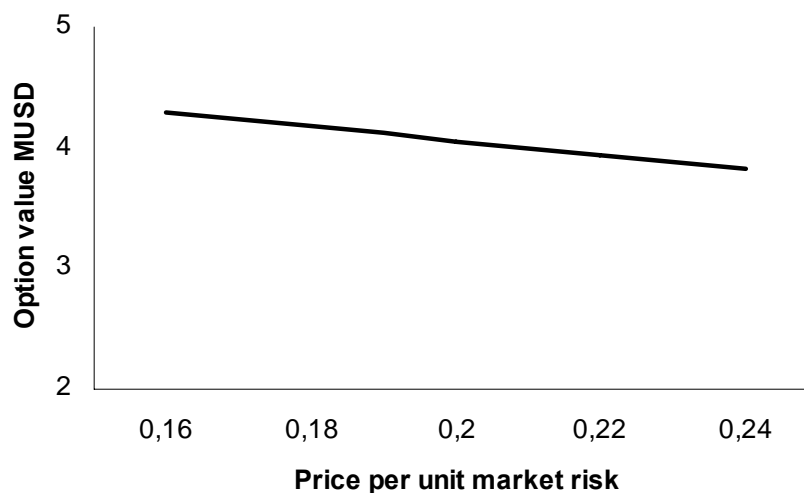


Figure 5.12: Price of market risk and option value

5.7 Conclusion and suggested improvements

The option to extend a TC contract is one of the most commonly used real options within the shipping industry. Although the calculations above are not directly associated with a real world case, it is consistent with real scenarios and contains real figures. The insights obtained and the valuation framework presented are most applicable to real cases, and the findings supported the aim to a high extent: To show that an extension option comprises a significant value and that ship owners can demand compensation for providing such flexibility.

The sensitivity analysis explained the behaviour of option fundamentals in an intuitive way, and proved the significance and impact of various economic factors. The expected growth of the TC freight rate over eighteen years was by far the most decisive variable, and unfortunately somewhat uncertain. However, too high or low returns in an international market are not sustainable over a long period of time, and as debated in section 5.6.4, the zero-growth is therefore assumed to be a rather credible estimate. The exercise price and the volatility of the TC freight rates proved to be other determining variables, and their consistency with conventional options theory supports the validity of the model. That the risk adjustment causes the time until exercise and the risk free interest rate to have negative impact on the option value is surprising, but still interesting from an academic point of view.

The development of the quarterly quoted TC freight rates was a newly cleared ground within the LNG industry, and essential for the valuation undertaken in this chapter. However, the tools and parameters employed to calculate this time series could be further adapted to better fit the market conditions at each specific point in time. Specifically, historical data on payment schemes and return on equity and debt could improve this analysis. However, this would presumably not render significantly different solutions.

6.0 Case 2: New building option

A new building option comprises the right but not the obligation to at a future date order the construction of a new vessel. Such options are among the most commonly used options within several maritime industries, and the asset play within the tanker, rig, and bulk industries have created a rather liquid market for such real options. Today LNG new buildings amount to market values of incredible 225 million USD, and the possible high value of related options should expectedly be of considerable interest to ship owners. But despite ship owner's long position, such options are often perceived as contracting of new vessels only. A deep-rooted business conduct in a practically oriented industry could be one of the reasons for this, yet a lack of adequate valuation tools and an absence of general understandings about options could be just as important.

In this chapter a realistic example of such a new building option will be presented, together with a valuation framework, a substantial option value and a sensitivity analysis. The intuitive and holistic content puts forward important insights regarding option structures, fundamental value drivers and valuation tools important for business managers. This will hopefully urge LNG industry participants to employ some new rationales in their business practice and procedures when dealing with such assets.

6.1 Presentation of the case and the problem to be addressed

When one or more new buildings are contracted, an option comprising construction of an additional vessel is often included in the deal. The vessel in this new building option is highly similar to the vessel (-s) being constructed under the initial contract. The option normally has to be exercised during the first six months after the contract has been signed, and the yard is committed to keeping a slot open and await the ship owner's possible exercise decision. Although this lap of time is rather short, it may involve yards having to refuse possible commercial opportunities. In addition to this, the time until exercise makes the yard being exposed to currency and interest risks. These issues are to some extent dealt with through contractual clauses, but the loss of flexibility and the short position in the option are inconveniences the yard has to carry.

One could argue that the ship owner's exercise decision is subject to already having committed the specific vessel to trade and that LNG shipping companies do not order vessels on speculative basis. However, it is here assumed that if the new building price in the market

exceeds the exercise price at the time the option matures, the option will be exercised.

Arbitrage arguments support this assumption, meaning that the ship owner will exercise the option as long as it is in-the-money. This is so because exercising the option and at the same time selling the vessel would render a profit¹¹. The ship owner's ability to close contracts is also not a relevant issue of this dissertation.

The ship owner's position is hence characterized by being long in a call option:

$$\text{Payoff to shipholder} : \max(\text{Newbuilding price in the market} - \text{contracted building price}, 0)$$

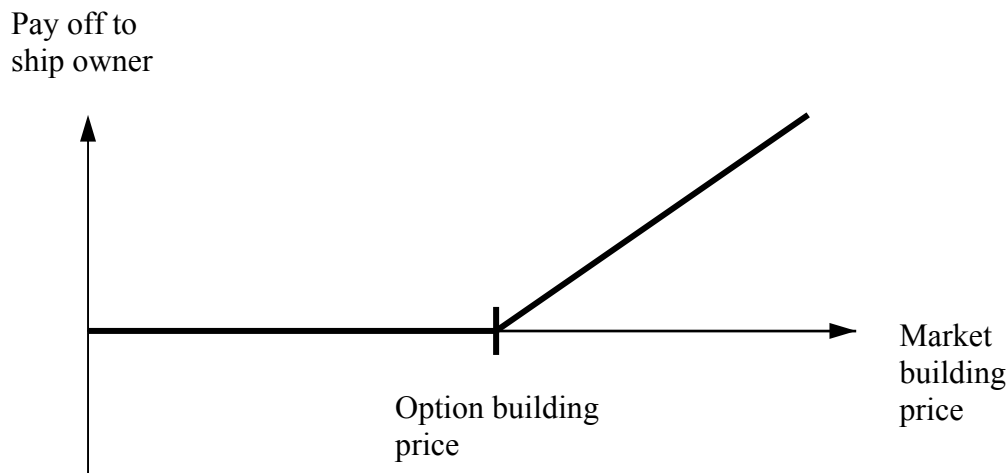


Figure 6.1: Ship owner's payoff at expiry

6.2 Gathering and processing of data

In this option new building prices are employed as the underlying asset. As the best estimates for predicting the future development of these new building prices are found in historical data, an assessment of the historical data material was necessary. The same quarterly quoted new building prices between 1990 and 2006 used for the basis of the TC calculations in chapter 5 were also employed here. However, in contrast to the extension option, a further comprehensive data processing was not necessary. Based on the historical new building prices, statistic analysis tools in Excel were used to render relevant parameters for the option valuation process, like the volatility and historical growth rates. The quarterly quoted new building prices are assumed adequate for the valuation purpose, and are cited in appendix A.

¹¹ The ship owner could also sell the option at the time of exercise and cash in the same profit

6.3 Framework for valuation

To make the comprehension of this second option more intuitive, figure 6.1 illustrates its chronological structure. It appears that the ship owner faces not only the choice of whether or not to exercise, but also *when* to exercise.

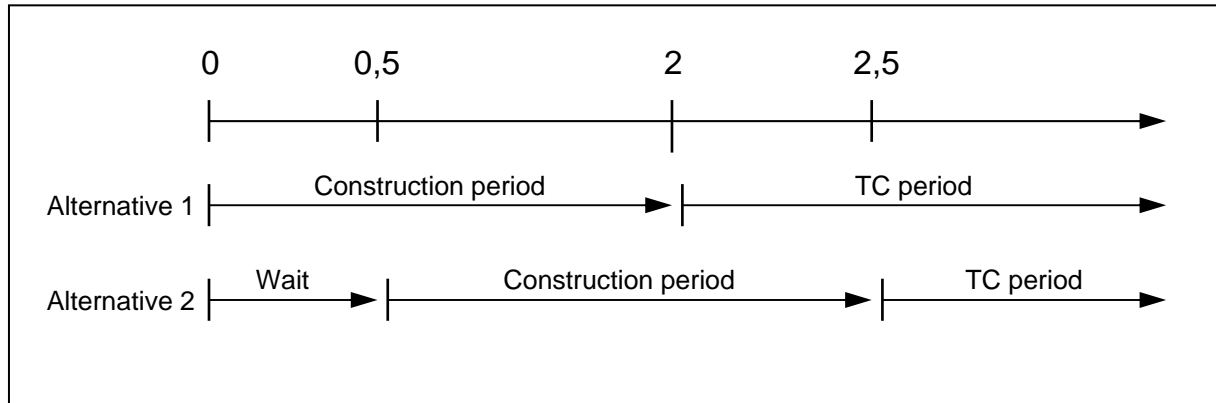


Figure 6.2: *Chronological structure of the new building option*

That the exercise can take place at any time before or at expiry makes this option involve properties of an American option. If the underlying asset pays dividends, an American option may have a higher value than a corresponding European option. The presentation of the risk adjusted parameter α in section 5.4 showed that $\alpha = r - \delta$, thus $\delta = r - \alpha$. δ is defined as the dividend rate of the ordinary B&S formula, and δ is positive when $r > \alpha$. It can be shown that $r > \alpha$ as long as the expected growth in the new building prices μ is lower than six percent. The interesting aspect here is that the B&S model adjusted for the risk neutral drift rate α indirectly assumes a dividend paying underlying asset as long as the expected annual growth of the new building prices is less than six percent. Ship brokers anticipate growth rates relatively far below this measure, and it is thus to conclude that the dividend aspect is relevant for this option valuation. The valuation framework should as a consequence be based on American options in stead of European options. However, the six months time until exercise for this option is a relatively short period of time, which indicates that the option values calculated by the two alternative methods would expectedly be fairly similar. It is thus assumed that the valuation framework of a European option familiar from chapter 5 is adequate also for the valuation of the new building option in this chapter. This assumption is also supported by the industry practice, as early exercise is a rather rare event. This is so because the time until exercise is perceived valuable for thorough assessments of alternative commercial opportunities.

Alternative 2 in figure 6.2 shows that a postponement of the exercise decision until option expiry will lead to a corresponding delay in the delivery of the vessel, and thereby also a delay in the beginning of the revenue generating operational period. Since this delayed cash flow has a lower present value at time zero than the one of imminent exercise, one could argue that the option valuation should take this into consideration¹². However, as no costs due to aging of the vessel accrue in this period and no payments are made before the construction period starts, the following framework and calculus for valuing European options will ignore this factor. This is also the approach of the industry.

As mentioned in section 6.1, the time until exercise makes possible interest and currency fluctuations pose a risk to the ship yards. Interest risk is a result of possible changes in the capital costs during the time until exercise, whilst the currency risk arises because the agreed upon new building price usually is in USD and a considerable part of the costs are in local or other international currency. Some yards handle these risks by leaving some flexibility in the price of the new building that has to be built if the ship owner exercises the option. And this is the option's exercise price. Consequently, the new building option operates with two different exercise prices: Exercise price A is created when the option is written at time zero, and is set equal to the current market price of new building contracts at time zero. A is thus the standard exercise price of options. The second exercise price B is set at the time of exercise, and is what the ship owner really has to pay to exercise the option and initiate the construction of the new building. Exercise price B is based on the market price used for exercise price A, but is adjusted for the new levels of the above mentioned interest and exchange rates.

It is evident that the recalculation of the exercise price distinguishes itself from the common practice of options. However, this is a measure to circumvent the two mentioned financial developments, and the option is still subject to market developments that affect the new building prices¹³. Another solution to deal with these two financial risk elements is to add them to the aggregated risk held by the yard. This would consequently be reflected in a higher standard deviation of the option, a relation being highlighted in section 6.5.1, where the option value's sensitivity to volatility is described. For the following sections these two risk elements will be disregarded, as it is to believe that the short time until exercise will reduce the real impact of the two.

¹² The framework used to value options on prepaid forwards could then be used

¹³ Direct costs of ship building, freight rates, second hand prices and the balance of the orderbook (Tamvakis, 2007)

The structure of different real options and the extent to which the option seller can demand compensation are often subject to negotiation power and business conduct, as pointed out earlier. The yard may thus receive full compensation, partial compensation or no compensation at all for the offered new building option. And in some cases the option price is only paid if exercise is desirable. That the practical applications of this option in the LNG market might be inconsistent and distinctly different from generally accepted option structures is evident. The following valuation framework is better suited if based on a more theoretically correct approach, than on a model specifically adapted to one single real world example. Richard Goss emphasizes the importance of adhering to the academic perspectives in his article “The future of maritime economics” (2002, referred to in Grammenos 2002: 7), where he states that “a good deal of future effort [of maritime economics] may well turn out to consist of gaining acceptance amongst those who operate maritime services, in ships and ports, for ideas which are already common ground within the profession”. The model thus assumes that the exercise price A is also the ultimate exercise price, and that a fair option value is paid to the yard when the option is accepted by the ship owner at time zero.

Some concluding words are suitable for this all-embracing and intricate section. It was firstly concluded that both the possibility for early exercise and the implications caused by late exercise were to be neglected. And due to the relatively short time until exercise, this was also the case for the currency and interest rate risks. By asserting these assumptions and accepting that a more general and a more theoretically consistent model is better suited for valuing this standardized real world case, the B&S model for a European option is adequate. The following section and valuation is thus based on the framework firstly presented in chapter 3 and further developed in chapter 5.

6.4 Calculus

The B&S model presented in chapter 5 introduced α , a measure of the risk adjusted drift rate in the underlying asset defined by equation (5.3) and (5.4). In this chapter α represents the annual risk adjusted growth rate in the new building prices, and estimating this parameter is a suitable point of departure. The historical data indicates a slight decrease in the real new building prices the last 17 years, but due to the booming new building market of today this estimate must be adjusted upwards. An expected short term increase in steel prices supports this (Lloyd’s List, 2007). On the other hand will several vessels end their present charter

parties in the near future (Drewry, 2006), which will reduce the demand for newly built tonnage. Brokers are in doubt which of the two effects will be the stronger, and the expected short term growth is expected to be zero. The market price per unit market risk has previously been estimated to be 0,2, and the correlation between the new building prices and the S&P500 is 0,1974. Applying equation (5.3) and (5.4) and an annualized standard deviation of 7,32% gives:

$$\alpha = 0 - (0,2 \times 0,1974) \times 0,0732 = -0,00289 \quad (6.1)$$

Section 6.3 contained an elaboration on the two different exercise prices A and B. Exercise price A is the one to be employed here and is the regular exercise price familiar from options theory. It was also pointed out that the option is written at-the-money, which implies that the exercise price is set equal to the current market value at the time the option is written. A standard sized LNG new building has today a market value of 225 million USD, and the exercise price of a new building option written today is thus set equal to this amount. Assuming a time until exercise of six months then gives:

$$d_1 = \frac{\ln\left(\frac{225'000'000}{225'000'000}\right) + ((-0,00289) + \frac{1}{2} \times 0,0732^2) \times 0,5}{0,0732 \times \sqrt{0,5}} = -0,00204 \quad (6.2)$$

$$d_2 = (-0,00204) - 0,0732 \times \sqrt{0,5} = -0,05380 \quad (6.3)$$

Employing the cumulative normal distribution function, $N(d_1) = 0,49919$ and $N(d_2) = 0,47855$. When using the one year treasury yield of 4,84 percent (Bloomberg software, CASS Business School), the value of the new building option equals:

$$C = \left[225'000'000 \times e^{-(0,0484 - 0,00289) \times 0,5} \times 0,49919 \right] - \left[225'000'000 \times e^{-(0,0484 \times 0,5)} \times 0,47855 \right] \\ = \underline{4,4 \text{ million USD}} \quad (6.4)$$

It is evident that the new building option has a theoretically high value, despite the short time until exercise.

6.5 Sensitivity analysis

The sensitivity analysis in this section is of particular importance and interest. This is not so much because the different input parameters are uncertain, but more because the learning outcome obtainable through understanding the model's fundamentals is very important for the implementation of a more theoretically correct and consistent framework in the industry. Changes in the risk free interest rate, the correlation with the S&P500 index and the market price per unit market risk only showed marginal impacts on the option value. As they were emphasized in the sensitivity analysis of chapter 5 they are not analyzed further here.

6.5.1 Volatility

Conventional options theory argues for a strong positive correlation between volatility and option price. Figure 6.3 demonstrates that this also is the case here, and calculations show that a marginal increase in the volatility of one percent leads to a one percent increase in the option value. McDonald (2003) points out that vega, the sensitivity of the option price to volatility, tends to be greater for at-the-money options with moderate to long time until expiration. This new building option is at-the-money, and the impact of the volatility is evident. However, the time until exercise is relatively short, and the sensitivity to volatility is as a result somewhat limited by this. Although the new building market is volatile more on medium to long term basis, the positive correlation between volatility and option value is an important option feature business managers should be aware of.

In section 6.3 it was pointed out that interest and currency risk were to be neglected in the calculations. However, if we accept that these two elements would add to the overall risk held by the ship yard, and that the yard can not recalculate the exercise price to allow for changes in the two, the yard is likely to demand a somewhat higher option price. This relation is evident in the figure below.

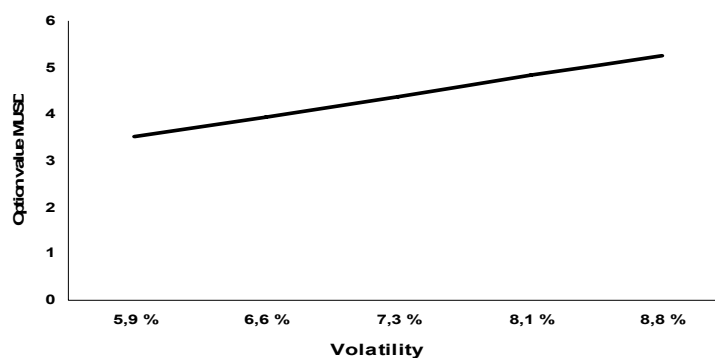


Figure 6.3: *Volatility and option value*

6.5.2 Time until exercise

Longer time until exercise normally affects the option value positively, and figure 6.4 shows that this positive relation also is evident in this real world example. McDonald (2003) reports that theta, the change in the value of the option due to the passage of time, is the most negative for an at-the-money option with short time until exercise. The practical implication of this is that the value of the at-the-money newbuilding option decays rapidly as exercise approaches, which also is evident in the figure below. The latter is of special interest when a new building option close to being at-the-money is sold to a third party before exercise.

The increase in the time until exercise impacts the option value positively in two ways: Firstly, the exercise price is discounted over a longer period which reduces its present value. Secondly, the period in which the option can turn in-the-money is longer. Business managers in shipping ought to be aware of this positive relation, and could possibly exploit the inadequate pricing methods by pursuing longer time until exercise in the options offered to them.

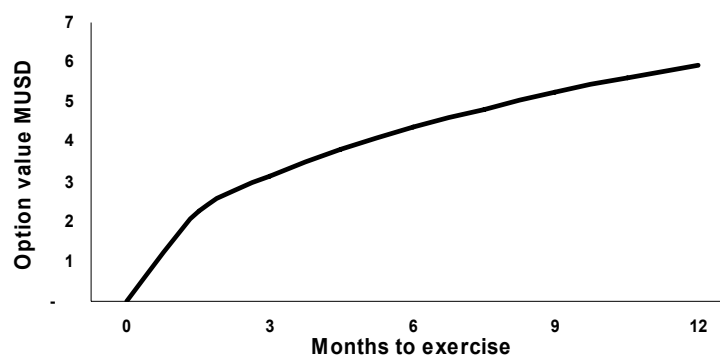


Figure 6.4: *Time until exercise and option value*

6.5.3 Expected annual growth in new building prices

Figure 6.5 depicts a clearly positive correlation between the expected growth in the new building prices and the option value. A higher expected growth first of all increases the probability for expiry in-the-money, in addition to affecting the discounting of the current market value in the B&S model positively¹⁴.

Seeing that this α is a growth estimate for one year only, and to that being based on sound information from brokers and media, the assumed level is regarded credible.

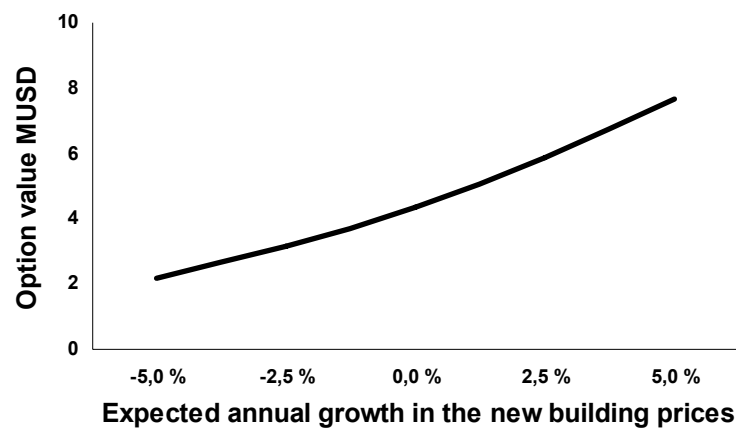


Figure 6.5: *Annual growth in new building prices and option value*

6.5.4 Exercise price

Figure 6.6 below shows the behaviour of the option value at time zero for varying levels of the exercise price. The strong negative relationship can be attributed to two factors: Firstly, that a higher exercise price lowers the payoff if exercise is desirable, and secondly, that the higher the exercise price the lower is the probability of the option being exercised. A 2,2 percent reduction in the exercise price from 225 million USD to 220 million USD leads to a 60 percent increase in the option value, whilst a corresponding increase reduces the option value by 44 percent. This convexity is distinctive in figure 6.6. Taken this highly elastic relationship and a half year standard deviation of only 3,7 percent into account, it is to expect that deviations from the market price will be rather marginal when the exercise price is being set. Yet it is evident that if the two differ significantly, a substantial alteration of the option value is necessary. In this market yards thus deserve to demand a high compensation on the option if ship owner bids the exercise price of the optional vessel down.

¹⁴ See equations (5.5) or (6.4)

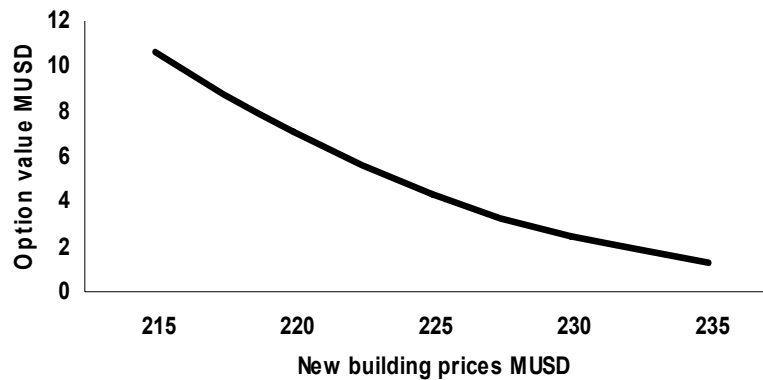


Figure 6.6: *Exercise price and option value*

6.5.5 Market prices on new buildings

Another interesting aspect is to see how the option value changes if the market prices for new buildings changes before the time of exercise. Figure 6.6 shows the option value three months before exercise, for varying levels of the prevailing market price for new buildings. It is evident that fluctuations in the market value drastically affect the option value when the time until exercise is short. This is a very interesting aspect if sale of the option to a third party before or at exercise is an alternative.

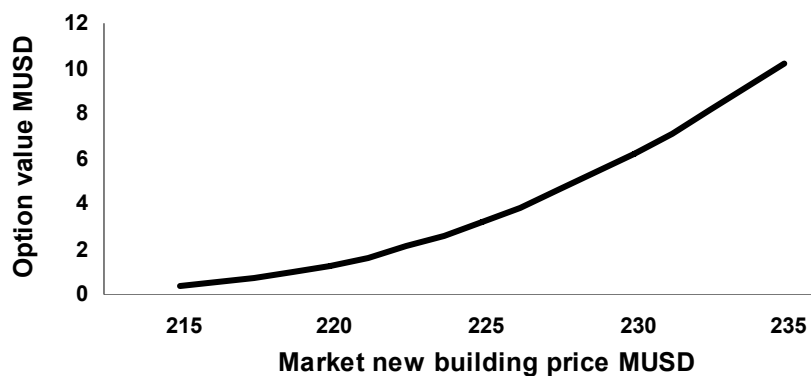


Figure 6.7: *New building price and option value 3 months before exercise*

6.6 Conclusion and suggested improvements

The aim set in this chapter focused mainly on the development and presentation of an adequate valuation framework for one of the most commonly used options within the maritime industries. In addition to this came the calculation of a credible option value and how different underlying parameters affect it.

The valuation framework and option value have proven highly acceptable to industry practitioners and conform to their expectations. There also exists understanding that the current treatment of LNG new building options is somewhat lenient, and that there could be a need for a more consistent structure when options are used. This especially refers to the structures of payment for the option mentioned in section 6.3. An option ought to be paid for in any case, and usually when it is bought. The issues emphasized and discussed in this chapter can thus propose guide lines for possible future improvements of the practice.

Section 6.3 also contained a discussion on various valuation approaches and the treatment of different properties. A valuation based on American options or a valuation where the interest rate and currency risks are included in the framework, constitute elements for further analysis. The discussion in section 6.3 also shed light on some of the difficulties arising when trying to fit a model to a complex reality. Yet, it is important to emphasize that the low uncertainty level in the various parameters and the limited amount of assumptions make the valuation performed in this chapter precise and well founded. And the model's fit to the real world is after all very good.

The sensitivity analysis provided an insight into the fundamentals of the value-drivers of this new building option. In addition to presenting important understandings and relationships, the sensitivity analysis proved that the model was highly consistent with options theory. This strengthens the presented framework, and the joint goal of the chapter is perceived to be reached.

7.0 Case 3: Option on purchase of vessel

Options regarding a sale, purchase or lease-back of vessels are among the most commonly used options in today's maritime business, and a variety of such options exist both for financial, tax, partnership and commercial purposes. This chapter will however treat a rather straight forward example where the charterer has the option to buy the LNG carrier at the end of a twenty year long TC contract. Receiving proper compensation for offering such options is rare, although many ship owners are aware that values slip through their hands. This problem is partly due to old-established business standards and negotiating power, and partly due to the absence of proper and generally accepted calculation methods. Another crucial issue is the lack of reliable historical data necessary for such valuations. By providing a valuation framework applied to a specific case, this will hopefully render insights that will contribute positively to solve this shortcoming.

7.1 Presentation of the case and the problem to be addressed

As TC contracts are signed, charterer is often given the option to buy the vessel utilized in the TC contract at a predetermined price at a given point in time. All terms of sale are settled in the initial contract, and the option has to be exercised two years before the exercise price is paid and the vessel is handed over to the new owners. As markets and vessel values might fluctuate heavily during the lifetime of a twenty year contract, such an optional purchase represents a handsome value to the charterer. In this chapter an option to buy a twenty year old vessel at the end of a twenty year long TC contract is valued.

The charterer's investment policy is to exercise the option and acquire the vessel as long as the cost of this is lower than the market price. Martin Stopford (oral communication, CASS Business School, 09.10.2007) stated that "the LNG industry will turn more and more liquid and approach other shipping segments. It might be a timely and stepwise process, but we have already seen the beginning of it". In addition does Drewry (2006: 85-99) list a series of factors that combined allow for the development of an expanding LNG short-term market. That these factors also contribute to a more liquid asset market is a fair assumption. Assuming that the LNG market develops into being more liquid makes arbitrage arguments support the above mentioned economic rationale: The charterer will exercise the option because he acquires a vessel to a lower price than the one demanded in the market. This renders a profit which the charterer may capitalize on by immediately selling the vessel to the market price.

The ship owner is hence short in a call option, because he has to comply with the charterer's decision:

$$\text{Payoff to ship owner: } - \max (\text{Market price} - \text{Contracted purchase price}, 0)$$

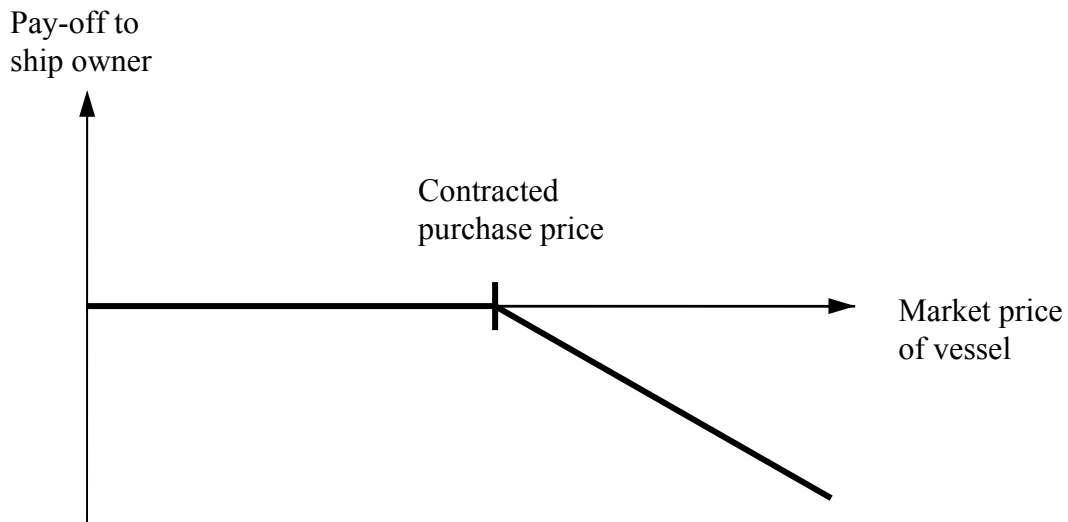


Figure 7.1: *Ship owner's short position in the option*

7.2 Gathering and processing of data

The relevant underlying asset for this option is the second hand prices of twenty year old LNG carriers. Forward prices for such vessels could also have been employed, but due to scarcity of market data none of the two are accessible. Estimations for this parameter are thus called for. It is a common assumption that the value of a vessel in the second hand market equals the present value of its future revenue potential including the present value of its scrap price. However, Stopford (1997) points out the difficulty of assessing values of specialized vessels like LNG carriers based on this approach, because the second hand market for such tonnage is very thin and revenue potentials would not be fully reflected in the second hand prices. Collecting estimates from various independent brokers was his recommended approach, and this solution has been used when finding the current second hand value from the market applied in the B&S model, later denoted M_0 . However, for estimation of the volatility and the growth in the second hand prices no applicable historical data from which they could be extracted existed. The optimal solution to find these two parameters was to

create a synthetic price path based on the sum of the residual vessel value after twenty discounting years¹⁵ and the present value of the expected scrap price.

When creating this price path some assumptions must be taken to fit the data to the real world. For instance is it assumed that the construction of an LNG carrier lasts 47 months and that the building price is paid in five partial payments of twenty percent during this construction period. This yields predelivery capital costs which add to the building price. The actual new building price is thus the sum of the two; the so-called “delivered vessel cost”. By applying standard discounting rules to this unit of measure, the residual value of the delivered vessel cost after twenty years is found¹⁶. To obtain a good estimate on the second hand price, the present value of the expected scrap price is added to this residual value. By applying this rationale to the historical new building prices, a data set of historical second hand values of twenty year old LNG carriers was obtained. Visual Basic and Excel were helpful tools in this demanding processing of data. The historical residual values and the second hand vessel values are reproduced in appendix D.

The present value of the scrap price deserves some elaboration. LNG carriers have an expected operating life time of approximately thirty to thirty-five years, after which they are scrapped. Merchant ships contain substantial values of steel and other components, implying that when acquiring an old vessel the scrap revenue constitutes a substantial share of the vessel’s value. Because the scrap price for standard LNG carriers only has shown minor fluctuations around 15 million USD (Drewry, 2006), this parameter is assumed to be fixed at this level. Yet, in more volatile markets the volatility of the scrap value could be incorporated into the option valuation. However, the sensitivity analysis of the volatility in section 7.5.3 shows that a slightly higher volatility would only impact the option value marginally, and the fixed scrap prices are thus assumed adequate.

One could also expect second hand prices to be more volatile than new building prices, because prompt delivery makes it possible to capture and capitalize on temporary commercial opportunities. The synthetic second hand price path presented above might thus neglect some historical market fluctuations because it is based on historical new building prices. More

¹⁵ The residual value is the remaining accounting value of an asset after being discounted over a given number of years

¹⁶ A much used methodology to assess residual values also utilizes inflation and expected market cycles. However, the long lasting duration of the TC’s in the LNG business makes credible estimates for these parameters difficult to obtain

specifically, this could imply that the standard deviation retrieved from this synthetic price path could be too low, which would eventually render too low an option value. However, Stopford (2004: 110) states that “ship building prices are just as volatile as second-hand prices and are closely correlated with them”. Based on this statement the synthetic second hand price path and the information retrieved from it are deemed adequate for the valuation performed in this chapter.

7.3 Framework for valuation

As described above, the standard deviation σ and the risk adjusted growth rate in the second hand prices α were found from the synthetic second hand prices. And the current value of the underlying asset denoted M_0 , which is today’s value of the twenty year old LNG carrier, was obtained through ship brokers. In the following let K be the exercise price of the option, r the risk free interest rate and T the time until exercise. As shown in figure 7.2, the exercise decision is made two years before the ownership of the vessel changes and the exercise price is transferred. Denote this time gap h .

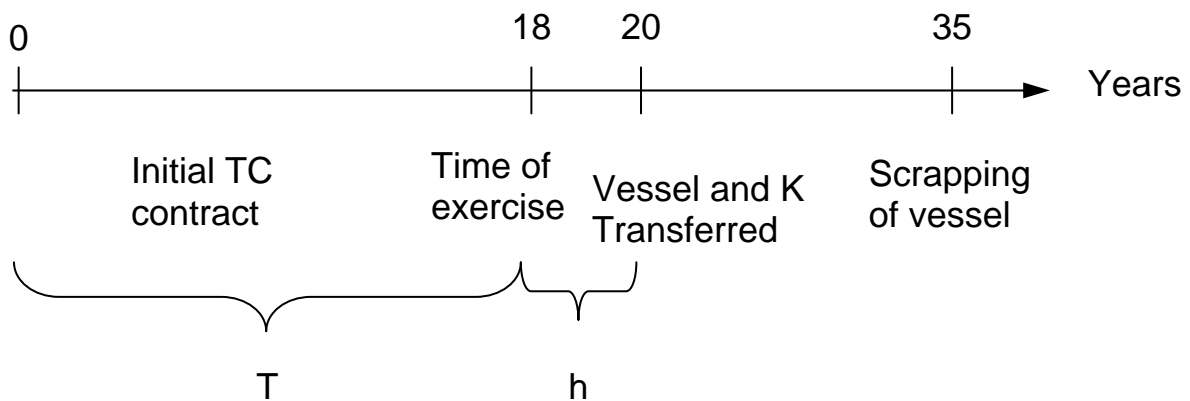


Figure 7.2: Chronological structure of the purchase of vessel option

Since the exercise price is paid two years after the exercise decision is made, a discounting of the exercise price over this time period is necessary. This again calls for an equivalent discounting of the present value of the underlying asset M_0 . This discounting is evident in the first term of the numerator in equation (7.1). K is discounted by the risk free hurdle rate r because its future value is known with certainty. This is not the case for the development of M_0 . Consequently it must be discounted by the previously presented risk equivalent factor $r-\alpha$, where r is the risk free rate of interest and α is familiar from equation (5.3) and (5.4).

$$d_1 = \frac{\ln\left(\frac{M_0 \times e^{-(r-\alpha) \times h}}{K \times e^{-(r \times h)}}\right) + \left(\alpha + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} \quad (7.1)$$

$$d_2 = d_1 - \sigma\sqrt{T} \quad (7.2)$$

The value of the call option is described by equation (7.3):

$$\begin{aligned} C &= \left[M_0 \times e^{-(r-\alpha) \times h} \right] \times e^{-(r-\alpha) \times T} \times N(d_1) - \left[K \times e^{-r \times h} \right] \times e^{-r \times T} \times N(d_2) \\ &= M_0 \times e^{-(r-\alpha) \times (h+T)} \times N(d_1) - K \times e^{-r \times (h+T)} \times N(d_2) \end{aligned} \quad (7.3)$$

7.4 Calculus

An appropriate place to start is to estimate the value of the risk equivalent factor α . By employing the market price per unit of market risk equal to 0,2 found in equation (5.9), and having estimated the correlation between S&P500 and the delivered vessel value to be 0,19837, equation (7.4) yields a market price per unit of systematic risk coherent to the delivered vessel values equal to:

$$\lambda = 0,2 \times 0,19837 = -0,039674 \quad (7.4)$$

For the further calculation of α , the expected annual growth of twenty year old vessel values for the next twenty years need to be found. However, the long time horizon makes this a difficult parameter to assess, and the only obtainable alternative is to lean towards historical data, which renders a value of -0,603 percent. The sensitivity analysis of the expected annual growth in the second hand prices in section 7.5.2 elaborates more on this parameter. Given an annual standard deviation of 7,02 percent, the α is then found to be:

$$\alpha = -0,00603 - (0,039674 \times 0,0702) = -0,008815 \approx -0,0088 \quad (7.5)$$

A conservative estimate of the market value of a twenty year old standard LNG carrier is today approximately 63 million USD¹⁷. Assuming an exercise price of 50 million USD, eighteen year time until exercise and a risk free interest rate of 4,6 percent gives:

$$d_1 = \frac{\ln\left(\frac{63'000'000 \times e^{-(0,046 - (-0,0088)) \times 2}}{50'000'000 \times e^{-(0,046 \times 2)}}\right) + \left((-0,0088) + \frac{1}{2} \times 0,0702^2\right) \times 18}{0,0702 \times \sqrt{18}}$$

$$= 0,3329 \quad (7.6)$$

$$d_2 = 0,3329 - 0,0702 \times \sqrt{18} = 0,0351 \quad (7.7)$$

The cumulative normal distribution function yields $N(d_1) = 0,6304$ and $N(d_2) = 0,5140$. The option value is then found as:

$$C_0 = \left[63'000'000 \times e^{-(0,046 - (-0,0088)) \times (18+2)} \times 0,6304 \right] - \left[50'000'000 \times e^{-0,046 \times (18+2)} \times 0,5140 \right]$$

$$= \underline{3,03 \text{ million USD}} \quad (7.8)$$

¹⁷ This value is very similar to the estimate based on the residual value of the delivered vessel cost in today's market plus the present value of the scrap price. This strengthens the credibility of the synthetic price path for second hand LNG carriers debated in section 7.2

7.5 Sensitivity analysis

The sensitivity analyses performed in the two previous chapters were presented in detail and showed a clear accordance with conventional options theory. Seeing that the coherence with the theory also is evident for this third option, an extensive analysis including the standardized parameters presented in the sensitivity analyses in section 5.6 and 6.5 is not necessary. Hence, only the insights resulting from new and above discussed parameters will be put forward in this section.

7.5.1 Second hand value of vessel

Good estimates of second hand prices of LNG carriers are hard to obtain because the LNG asset market is so illiquid. The option valuation was thus based on an assumed second hand value of 63 million USD, which according to brokers is a fair but still conservative estimate. In figure 7.3 it is evident that a higher second hand value today increases the option value, which conveys an important message to ship owners: in a good market the compensation for offering an option ought to be higher, although the transfer of the vessel and the strike price takes place several years into the future.

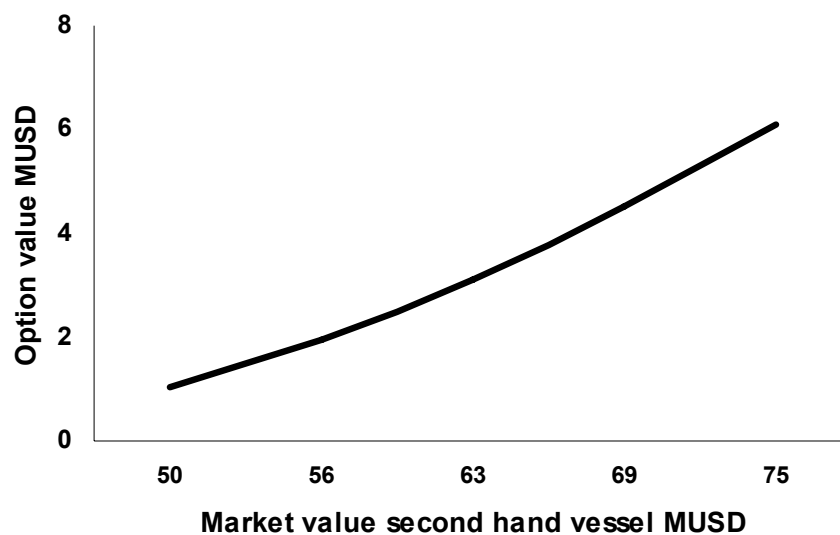


Figure 7.3: *Second hand value and option value*

7.5.2 Expected annual growth in the second hand prices

Predicting the annual growth in the second hand prices over eighteen to twenty years is a very challenging task, and a parameter of -0,603 percent gathered from historical data was assumed to be adequate. Stopford (2004) points out that eleven separate market cycles were registered over the last century, with different market impact and duration. As the market conditions have a powerful effect on the second hand prices, an imagined long term real growth in these prices would presumably fluctuate around a mean of zero. And a future even harder competition in the new building market and more efficient production techniques would probably lead to a real decline in the new building prices, which naturally affects the second hand market through alternative cheaper newly built tonnage. The moderate real decline in the second hand prices is maybe a rather good estimate after all.

Figure 7.4 shows the same positive relation between the expected real growth rate and the option value as were the cases in the two previous chapters. This parameter might appear somewhat diffuse and intricate, but for interpretation and prediction purposes it is worth mentioning that market shifts that affect the long term level and growth in the second hand prices must be adopted into the option valuation. Such changes could involve a growing and significant market share for price cutting Chinese yards or severe restrictions put on LNG carriers by the IMO equivalent to the single-hull phase-out in the tank market.

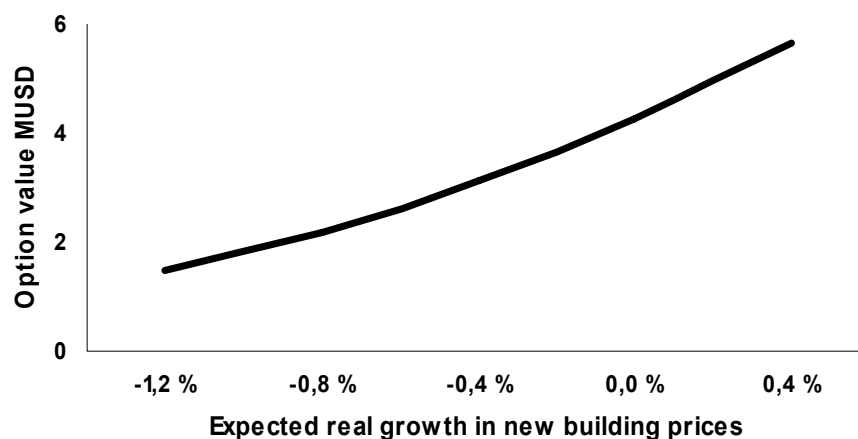


Figure 7.4: *Growth in new building prices and option value*

7.5.3 Volatility

The volatility was estimated to be 7,02 percent based on historical data, and its impact on the option value is given in the figure below. In section 7.2 it was discussed whether the volatility derived from the synthetic second hand prices was too low, but it was concluded that this estimate was sufficient for the valuation purposes. Yet, it is evident from figure 7.5 that an increasing volatility would affect the option value positively, but the impact is not extremely decisive: Increasing the volatility rather drastically from seven to eleven percent increases the option value with less than one million USD. The estimated value of 7,02 percent is thus regarded as adequate, which increases the credibility of the calculated option value. In section 7.2 also the impact of incorporating the volatility of the scrap price into the volatility of the option was discussed. This would presumably affect the joint volatility only marginally, and the ultimate impact on the option value would be negligible.

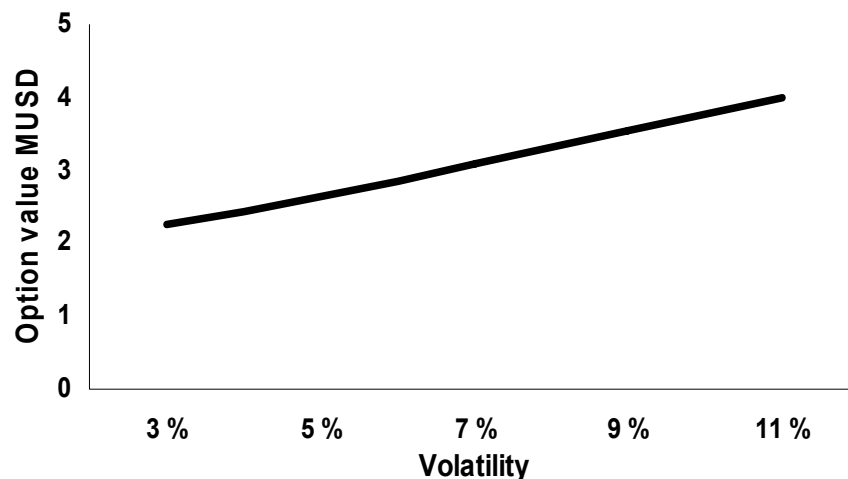


Figure 7.5: *Volatility and option value*

7.5.4 Comments on time until exercise and vessel lifetime

The valuation framework applied in this chapter does not take the increasing operational costs caused by an ageing vessel into consideration because operational costs are viewed as an external factor. As a consequence, the model predicts a slightly positive relation between the time until exercise and the option value, because it only reduces the present value of the exercise price. Yet, a longer time until exercise naturally increases the age of the vessel at the time the ownership is transferred, which results in higher operational costs and shorter remaining operational lifetime. This leads to a higher cost level and a shorter revenue generating potential. Consequently, the net relation between the time until exercise and the

option value is anticipated to be negative because the vessel has a decreasing value as time passes.

Neither is the relationship between vessel lifetime and vessel value comprised by the model. This is because the vessel values were either calculated as the sum of the residual value¹⁸ plus the scrap value or based on broker's estimates, and not on the prospected revenue potential over the remaining lifetime. As explained above is there a positive relation between vessel lifetime and vessel value, and an increased vessel value will increase the option value if all other is kept constant. LNG carriers are known for being sophisticated vessels of high quality, and thereby having a low loss frequency and a long expected operational lifetime. As a proof of this there are today 40 year old vessels trading with impeccable records. Demanding a higher compensation for a vessel of good quality is thus justified, because a higher quality of the vessel extends the revenue generating period.

¹⁸ Residual values are based on either a given depreciation rate per year or a given depreciation time. Because the depreciation time is an accounting figure it very often differs from the real lifetime of the vessel. The latter is normally longer than the depreciation time and in addition varies with the market cycle

7.6 Conclusion and suggested improvements

A target was set in the introduction to this chapter; to present a valuation framework applied to a specific case, in addition to providing insights that could increase ship owner's and charterer's understandings for the value and valuation of such an option. The presented framework was based on insights gained in previous chapters, and a sensitivity analysis tested and presented the impact of various parameters on it. Based on a credible and substantial option value in addition to a solid valuation framework, professionals in the industry will now hopefully apply some of their new insights in their business operations. The aim of this chapter is hence assumed to having been fulfilled.

The present market value of the vessel was based on anticipated values from ship brokers, and was deemed to be somewhat conservative. Tradewinds (2007) reported the sale of two 38 years old 71'651 cubic metres sister vessels from BG Group to Sovcomflot in 2006 for 46,5 million USD each. These vessels are significantly smaller and also much older than the standard LNG carrier of this dissertation, but were priced not very much lower than the 63 million USD assumed in this chapter. Because second hand sales are so rare in this industry this sale must be used as a benchmark, and it confirms the sound but conservative estimate employed in the valuation.

Although this broker's market value stands out as credible, further studies regarding the valuation of second hand LNG carriers could prove to be highly interesting. If the LNG asset market develops into being more liquid, such valuations can prove to be very handsome decision making tools for the industry.

8.0 Summary and conclusion of the dissertation

In the first chapter of this dissertation the aim was set to “present credible option values and reliable valuation tools to convince participants in the LNG industry that options do comprise substantial values and that the insights and rationales ought to be adopted into business management”.

The obtained achievements and results received praise when presented to Höegh LNG. Not only were the solutions sound, but the framework and rationales employed to obtain the results were also well-founded and intuitive. It was now possible for Höegh LNG to apply the valuations to actual cases, and advance demands facilitated by a solid model. With respect to this, the aim of the dissertation is regarded to be achieved.

In other dissertations where focus has been put on different valuation methods or other maritime segments, abundant access to market data has simplified the process of developing adequate frameworks and obtaining credible results. This dissertation has on the other hand had a scope more in the direction of research: The scarcity of LNG specific data material and the fact that equivalent valuations never or rarely have been undertaken before, made an extensive collection and processing of both data and ordinary options parameters necessary. Particularly the development of several time series for the LNG industry has been an important and valuable attainment. Without such data material the option valuations would not have been possible, and it opens up for further studies and analyses within this topic.

The adverse relationship between certain parameters and the option value caused by the negative risk adjusted drift rates is an interesting issue. The background for this is that the real decline in the historical newbuilding prices also affected the historical development of the TC freight rate and the second hand vessel values. The various risk adjusted drift rates were again based on these developments, and this led to some adverse relations compared to option theory. Yet, this does not imply that the models are faulty, this is merely a property caused by the risk adjustment.

Throughout the work with this dissertation I have experienced enthusiasm, interest, and initiative from several participants within the maritime cluster, in particular among participants in the LNG industry and ship brokers. This substantiates the need for such tools and the willingness to gain more insights into this topic. It is worthwhile to elaborate a little on this. Not only has the maritime industry experienced increasing vertical integration together with specialization, but also a generational and knowledge change. In addition have derivative instruments been developed and adopted for risk management, and the use of options elements both in contracts and for speculation purposes have increased. The media's focus has also contributed to boosting the interest for such tools and opportunities.

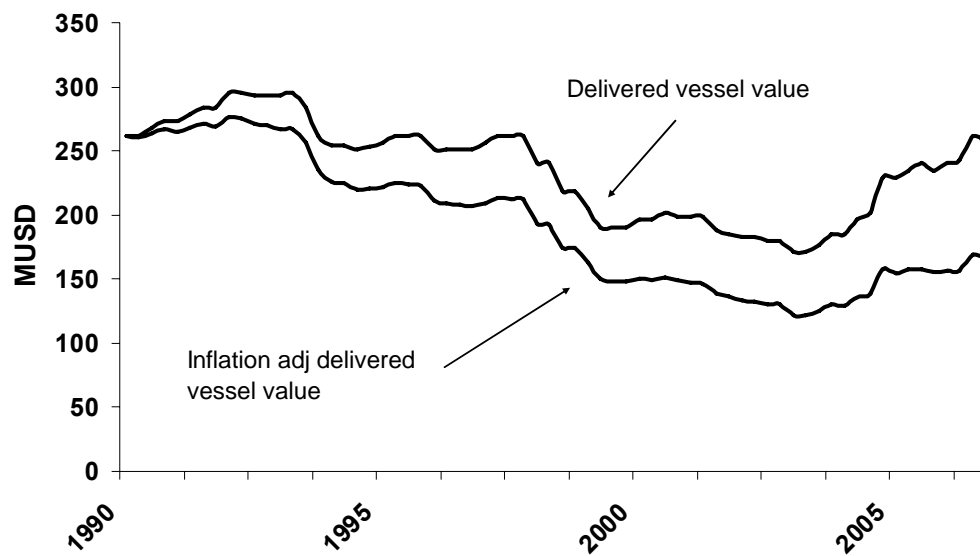
Throughout the last decades new powerful regions have developed, and distortion of power have followed the highly volatile cycles. And all ship owners agree that the right time for strategic positioning is at the peak of a cycle. Which many believe is now.

The combination of all these factors has put forward ways and desires to capture values and increase flexibility, for which options are ideal instruments. However, usage of such tools demands insight into sound valuation methods and options fundamentals. I hope this dissertation can be an instructive and intuitive source of information for such understandings.

9.0 Appendix

In this chapter important graphs and tools used in the valuation framework are presented shortly.

Appendix A: Delivered vessel values and inflation adjusted delivered vessel values



Comment:

The calculation of the delivered vessel value was based on historical new building prices, market data, and capital budgeting parameters. Spreadsheets and macro programming were tools thoroughly used for data processing purposes. By adopting the US CPI for the same period, real values for the delivered vessel values were rendered based on inflation adjustment. The information retrieved from this time series was then employed in the option valuations.

Appendix B: Visual Basic macro code applied in spreadsheet for the calculation of the TC freight rates

Sub SpotTC()

'The macro calculates TC necessary to cover CAPEX and OPEX given in the indata, given the new building prices at each and every quarter from 1Q 1990 to 1Q 2007.

'Declaring variables

Dim Inrow, Incolumn, Outcolumn

'Defining what cells to be read from and written to

Inrow = Range("instartcell").Row

Incolumn = Range("instartcell").Column

Outcolumn = Range("outstartcell").Column

Outcolumn2 = Range("outstartcell2").Column

'Defining iterations to proceed until no value in the column for NB prices

Do While Cells(Inrow, Incolumn).Value <> ""

'Read "standard large lng/c" cell, write to indata cell for buildingprice

Range("buildingprice").Value = Cells(Inrow, Incolumn).Value

'Read result from "TC" cell, write to TC column

Cells(Inrow, Outcolumn).Value = Range("TC").Value

'Read from "vesseldeliveredcost" cell, write to vessel delivered cost column

Cells(Inrow, Outcolumn2).Value = Range("vesseldeliveredcost").Value

'Increases row-counter by one to jump to next row for new iteration

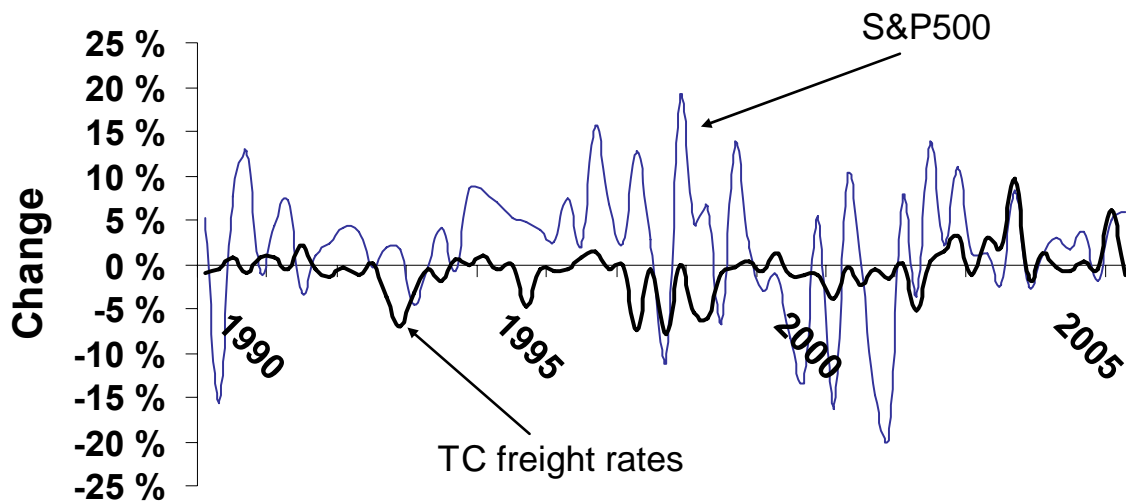
Inrow = Inrow + 1

Loop

End Sub

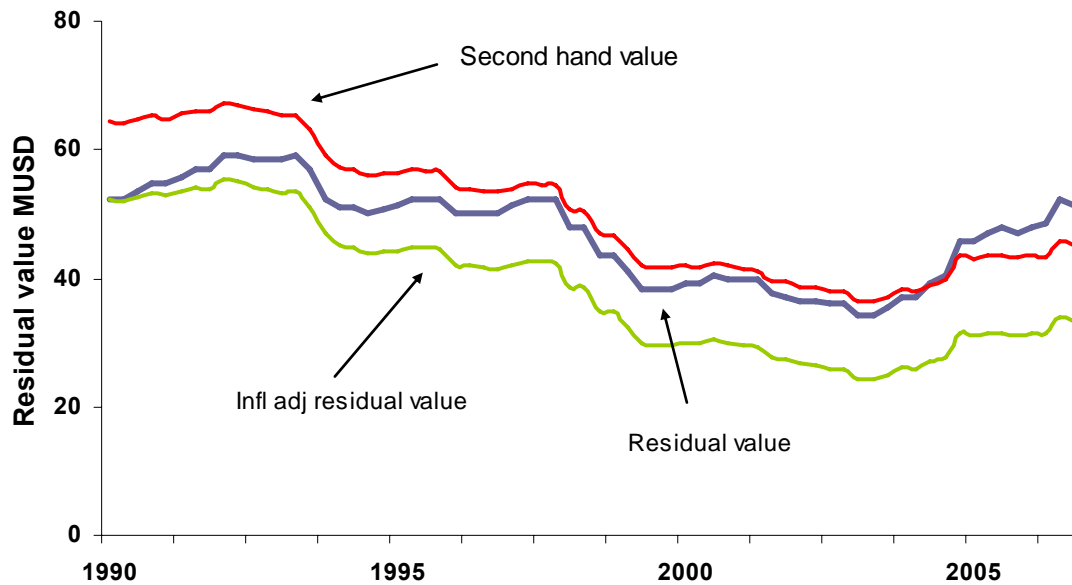
Comment:

This macro enabled the processing of a vast data material in an advanced spreadsheet model: By naming cells, using formulas and setting input parameters in the spreadsheet, a nominal new building price was employed to calculate the corresponding real TC freight rate at that time. The macro repeated this calculation for the whole range of historical new building prices, and generated a time series of TC freight rates.

Appendix C: Correlation between TC freight rates and S&P500**Comment:**

This graph depicts the correlation between the S&P500 and the TC freight rates from 1990 until the present. The correlation coefficient was found to be 0,206, and was an important parameter for the calculation of the risk adjusted expected growth in the TC freight rate.

Equivalent analyses were also done for the new building prices in chapter six, and for the residual vessel values in chapter seven.

Appendix D: Residual vessel values after 20 years depreciation**Comment:**

The residual values were based on delivered vessel costs, capital budgeting parameters, and the expected lifetime of an LNG carrier. These values were inflation adjusted based on the US CPI for the same period. Information gathered from statistical analyses tools employed to this data material were further employed in the valuation of the option on the sale of a twenty year old LNG carrier. Adding to this the present value of scrap prices yielded a time series of synthetic second hand values.

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