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School of Business and Management

Master's Programme in Strategic Finance and Business Analytics

Master’s Thesis

Derivative hedging strategies for bitumen price risk

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13.3.2016

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ABSTRACT

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Title: Derivative hedging strategies for bitumen price risk

Faculty: School of Business and Management

Year: 2016

Master's Thesis: Lappeenranta University of Technology, 67 pages, 11 figures, 6 tables and 2 appendices

Examiners: Professor Eero Pätäri and Doctoral Student Ville Karell

Keywords: Bitumen hedging, hedging strategies, term structure strategy

The objective of the study is to extend the existing hedging literature of the commodity price risks by investigating what kind of hedging strategies can be used in companies using bitumen as raw material in their production. Five different alternative swap hedging strategies in bitumen markets are empirically tested. Strategies tested are full hedge strategy, simple, conservative, and aggressive term structure strategies, and implied volatility strategy.

The effectiveness of the alternative strategies is measured by excess returns compared to no hedge strategy. In addition, the downside risk of each strategy is measured with target absolute semi-deviation.

Results indicate that any of the tested strategies does not outperform the no hedge strategy in terms of excess returns in all maturities. The best-performing aggressive term structure strategy succeeds to create positive excess returns only in short maturities. However, risk seems to increase hand-in-hand with the excess returns so that the best-performing strategies get the highest risk metrics as well. This implicates that the company willing to gain from favorable price movements must be ready to bear a greater risk. Thus, no superior hedging strategy over the others is found.

ACKNOWLEDGEMENTS

The process of writing this thesis has not been easy. The research subject was really interesting for me, maybe too interesting as I spent hundreds of hours reading research papers closely related to topic but not exactly matching my research question. It was hard to make the limitations to the study, to leave out so much important information. However, the project gave me a lot even though it was frustrating at times. To write these final words certainly is rewarding.

I would not be here today without help. I want to express my sincere gratitude towards Ilkka Salonen for giving me the opportunity to finalize my studies after so many years in working life. Thank you Eero Pätäri for all your support and guidance during my thesis project. Thank you mom for believing in me throughout all these years. And Matti, I am forever grateful for your patient, support and love during these “turbulent” months. I also want to thank all my friends and colleagues for encouraging and supporting me through my studies. Thank you all!

Espoo 13.3.2016

Melina Lönnrot

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1 INTRODUCTION

Risk management and financial hedging are widely investigated topics in the academic world, because the risk has an effect on every investor’s and company’s decision making. Companies face several risks in their operations of which most are related to the business operations themselves, but many risks are also economic on their nature. One of the economic risks is commodity price risk. While foreign exchange rate risks and interest rate risks have got a much attention in the literature, commodity risks are less studied. But despite the rather young literature, many attempts have been made to obtain optimal hedging strategies also for commodity risks although the most studies tend to take producer’s perspective. Luckily, commodity markets are fairly well investigated from the investor’s point of view. That offers a great opportunity to discover price behavior of commodities.

To extend the existing hedging literature of commodity price risks this study focuses on investigating what kind of bitumen price hedging strategies can be used in companies using bitumen as a raw material in their production. Moreover, five different alternative swap hedging strategies in bitumen markets are empirically tested to figure out whether a superior strategy over others is to be found.

Bitumen is an oil distillate and its price is highly correlated with that if crude oil. The oil market is the biggest commodity market in the world and crude oil price fluctuation has increased dramatically during the last years. Its price development from 1988 to 2016 is shown in Figure 1.

Figure 1: Brent price development 1988-2015 (source: Thomson Reuters Eikon)

Due to high price volatility in the oil market, the price risk management has gain even more important role in the overall risk management framework in the companies operating in oil business or consuming oil products. One of the main objectives of this study is to increase the knowledge about possible hedging strategies in the companies facing the bitumen price risk in their operations.

1.1 Research question

The aim of the study is to investigate how a global construction company can manage bitumen price risk in its customer projects. The bitumen price risk in construction companies arise when they enter into project where bitumen is used as a raw material. Typically, the project is sold to the customer for a fixed price that includes a bitumen price component. The bitumen is then purchased later when needed at the price prevailing at the markets on that time. Thus, the purchase price of bitumen is unknown at the point of time when the project is priced. In other words, the company has a short position in bitumen and is exposed to bitumen price movements in the oil markets.

Different hedging strategies are investigated in this study, and some of them are empirically analyzed. The main objective is to find out whether a superior hedging strategy over others exists and especially, whether the so-called term structure strategy can outperform common full hedge strategy in terms of greater revenues. To cover these objectives some background research is done as well.

First of all, the price behavior of oil and refined products, as well as characteristics affecting the prices should be explored before making any hedging suggestions. This theme is covered in the theoretical part of this study by presenting earlier research about the price determination of commodities and especially oil and refined products.

Second, the rationales for financial hedging are investigated to find out, whether there are factors affecting the decisions to hedge or not. This part of the study focuses on financial theories explaining hedging behavior.

To be able to form hedging strategies, various hedging instruments are explored to find out which are the alternatives in hedging. Thus, derivative instruments available in the oil markets are presented and their main characteristics and suitability for the non-financial company's hedging are evaluated.

Moreover, hedging effectiveness should be somehow evaluated. For that purpose, several related theories are introduced, before moving to the hedging strategies themselves.

Once the above mentioned questions are solved, the different hedging strategies developed for the commodity hedging in the earlier literature are explored and presented. Thus, this part answers to the one of the main research questions: What kind of hedging strategies exist for bitumen consumer company?

Moreover, while the research on commodity hedging is rather limited, some literature concerning commodity investing strategies have been published during the recent years. These investing strategies are used to form the hedging strategies which are tested in the empirical part of this study. It follows that the main objective of the study (i.e., to find out whether there is a superior hedging strategy for company consuming bitumen as a raw material in its production), is tested with five alternative swap hedging strategies derived from those investing strategies. More precisely, three different term structure based strategies are tested together with common full hedge strategy and less investigated implied volatility strategy.

The effectiveness of the strategies is evaluated in forms of excess returns that are calculated by comparing each five strategies to no-hedge strategy used as the benchmark of this study. In addition, risk measures standard deviation and target absolute semi-deviation are calculated for each strategy to find out what kind of trade off should be accepted for possibly greater revenues.

1.2 Outline of the study

Despite the writer’s high interest concerning the topic of this study, some limitations are necessary to keep content somehow manageable. The scope of the study is purely bitumen price risk management in a non-financial company which uses bitumen as a raw material in its production. Any other risks related to procurement, like possible foreign exchange rate risk, counterparty risk, quality risk etc. are not discussed.

Moreover, the price risk investigated in this study is based on Northern European markets, measured with quotations of High Sulphur Fuel Oil 3.5% based on delivery terms FOB Amsterdam-Rotterdam-Antwerp.

The most restrictive limitation in this study is related to options. Options and option strategies were widely investigated during the writing of this thesis and are seen highly interesting and possibly effective hedging instruments to hedge bitumen price risks. Thus, to answer the research question about available hedging instruments and strategies, different kind of option instruments and option strategies are covered, but in the empirical part of this study, they are scoped out. This is due to the unavailability of the suitable option quotations or simple equation to price those. Moreover, the valuation of Asian commodity options, which are used in the industry, is neither straightforward nor transparent. There is a lot of research trying to solve a problem concerning pricing of Asian commodity options, but none of them have got much support. To try to price Asian bitumen options for empirical part of this study would have resulted a whole new independent study itself. For these reasons, empirical examination of Asian options as an alternative derivative instrument in different commodity hedging strategies are left for further research.

1.3 Structure of the study

This study includes seven sections which are divided into two parts. First, the theoretical part introduces the background and existing literature of the theme. In the latter part, the data and methodology followed by the empirical findings are presented.

Following the introduction, the oil markets and its characteristics are shortly presented in the second section. Moreover, the price determination of oil and oil distillates are explained. In the third section the focus is on the risk management literature, and rationales for risk management are also explored. Hedging theories and instruments are introduced in the section 4 followed by a description of different kind of commodity hedging strategies.

Empirical part begins with section 5 describing the data and methodology used in this thesis. Section 6 presents the empirical test results. Validity, reliability and robustness issues are also discussed at the end of section 6. Finally, section 7 concludes the study and the results of empirical tests.

2 OIL MARKETS

Energy became a tradable commodity during the 1980s. After that the oil market has become the greatest commodity market in the world, with both a very large physical market and a financial market (Geman, 2005). Moreover, energy prices have been much more volatile than those of other asset classes, such as fixed-income, currencies, and equitie (Eydeland and Wolyniec, 2003).

There are several types of oil and prices, but the industry has focused on a few references, so called benchmarks. Other types of oil are priced as differentials of these benchmark prices (Geman, 2005). Two major benchmarks are Brent (North West Europe origin) and WTI (West Texas Intermediate, US origin), and as the focus of this paper is in the European oil market, the Brent as a benchmark is discussed next.

2.1 Brent markets

The price of Brent is determined in five different markets (Geman, 2005). The first one is the spot market, known as dated Brent. Unlike other financial spot markets, the oil is rarely traded immediately or even within few days. In practice, the dated Brent means a cargo loading within the next 10-21 days (Schofield, 2007). The second market is the forward market, which practically starts beyond 21 days. When entering the forward contract, the exact delivery date is unknown, but the month of the loading is stated. Thus, the price reflects the value of the physical delivery within the delivery month. The third market is CFDs (Contracts For Differences). CFDs are financial contracts, swaps, used for hedging basis risk (Geman, 2005). The price of CFD contract represents the difference between the current second month forward quotation and dated Brent quotation over a given loading week (Schofield, 2007). The fourth market is the futures market. The Brent futures contracts are highly attractive because of their good liquidity and far reaching forward curve (Schofield, 2007). Futures are either physically delivered or cash settled at expiry. Like the Brent forwards, Brent futures only specify the month of loading and not the exact date of delivery. Even though the futures are available for maturities up to 6 years, liquidity tends to decrease as maturity increases. As the fifth market there is a liquid OTC market for Brent swaps. These swap contracts are available also for longer term maturities, even up to 10 years. (Geman, 2005)

2.2 Oil distillates

Refineries convert crude oil into various products. Simplified refining process is presented in the Figure 2 below.

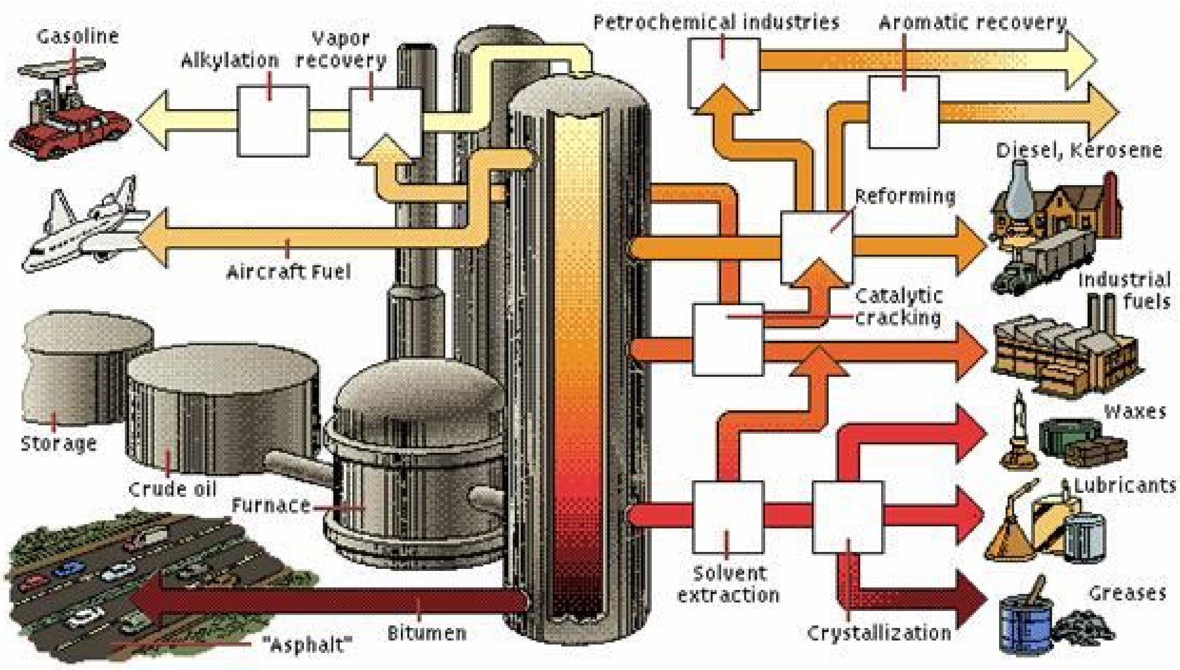

Figure 2: Oil refining process (source: www.angelfire.com)

Refined products are usually divided into three different groups according to their characteristics: light distillates (LPG and gasoline), middle distillates (heating oil, kerosene and diesel fuel) and heavy distillates (fuel oil, lubricating oils, wax and tar). Bitumen belongs to the heavy distillates. (Öljy- ja biopolttoaineala ry, 2015) Bitumen is mainly used in paving business as it is the binding agent of asphalt but it is also used largely in roof industry.

In Europe, the refining industry is divided geographically into two areas: ARA (Amsterdam-Rotterdam-Antwerp) and Mediterranean (Genoa). In this study, the focus is in the ARA market.

2.3 Market participants

Natural participants in the oil markets are those who produce, refine or consume oil and oil products. In addition to sell or buy oil and different distillates in the physical markets, there is a second motive for trading oil as well, and that is risk management. The market price risk arises from selling and buying oil and that risk can be managed by using oil derivatives. A third motive for participating oil markets is speculation, performed by market participants that wish to make money from anticipated movements in oil markets. These participants can be financial institutions or individual investors.

2.4 Price of oil and refined products

The price of oil is determined by equilibrium of supply and demand, like any prices concerning common tradable assets. However, oil markets have some special characteristics. Supply side has a key role because the production is centralized for relatively small amount of oil producers and the world economy is dependent on oil. In the long run, also adequacy of oil resources has effect on supply side. (Öljy- ja biopolttoaineala ry, 2015)

Thus, oil prices fluctuate in response to several factors. For that reason price prediction is difficult and nobody knows exactly what will happen to oil markets and prices in the future. Analysts try to make forecasts based on current economic, political and market conditions but after all, it is just a guess. Many economic factors including production and consumption, international politics, governmental export controls, global wars, stockpiling policy, changing economic patterns, devaluations of currencies, excess speculation relative to hedging, and structural changes within the oil market have created considerable uncertainty on the future direction of the market and thus, to price irregularity. (EIA, 2015 and Mercatus Energy Advisors, 2012)

There are several approaches to try to explain behavior of commodity prices. The theory of normal backwardation, first introduced by Keynes in 1930 and Hicks in 1939, states that if the demand for short hedging exceeds the demand of long speculation, the hedgers must compensate speculators with an additional risk premium to encourage them to balance the excess demand for short hedging, and therefore futures prices are downward biased estimates of future spot prices. The theory assumes that most of the hedgers are producers of the commodity in question, and thus hold a short position in futures.

Later, in 1960 Cootner extended the theory to the hedging pressure hypothesis, which recognizes that hedgers may in fact be either net short or long in futures depending on their position on the physical commodity. For example, manufacturers utilize commodities in their production and might be willing to pay extra for securing price level. As a consequence a risk premia exists in the futures price regardless of the term structure having a shape of contango or backwardation. Thus, the sign of risk premium can be either positive or negative varying between commodities and possibly over time. (Brooks et al., 2013)

Recently, when the commodity futures and options markets started to grow rapidly in terms of held positions and traded volume, referred as financialization, around 2004 the concern that speculators' trading behavior can dominate the prices in commodity markets raised (Irwin and Sanders 2012). This so-called speculative pressure opposite to hedging pressure occur when demand for long speculation exceeds short hedging needs and may result in changed price levels. Both of the concepts, hedging and speculative pressure assume that movements in futures prices are directly affected by changes in hedgers' or speculators' positions. Some evidence for hedging pressure as well as for speculative pressure have been found, but some studies in contrast have had difficulties to find any evidence that either hedgers' or speculator's positions drive prices. Interestingly, Lehecka's (2015) empirical study support earlier findings that the contemporaneous relationship between prices and positions exists but that the causality may actually be reverse. He found strong evidence that prices tend to lead variables on positions and on hedging and speculative activity. These results hold even over the periods before and after the financialization of commodity markets. Anyway, the public opinion still widely is that futures prices are characterized by speculative pressure. (Lehecka, 2015)

Inventories are in the important role to predict how the future supply and demand will evolve. If demand is expected to go up, producers tend to increase inventories to meet this extra demand, or the inventories could be kept fixed, and as production must then increase, the prices will rise until demand is back to normal. In other words, the production (supply) does not need to be equal to demand all the time and the spot prices of storable commodities are thus dependent on inventories. (Pindyck, 2001)

The theory of storage (Kaldor, 1939) explains the behavior of commodity prices based on economic fundamentals. It suggests that the relationship between cash and forward prices is determined by the net cost of carrying stock. Physical product can be purchased immediately, or alternatively, later in the future. In the first case, the consumer will finance his/her purchase by borrowing or withdrawing the money from a bank account because the product must be paid immediately. If the consumer borrows the money, there will be an interest rate penalty, which means the loan must be paid with its interest. If the consumer withdraws the money, there will be a loss of interest income on his/her bank account. In addition, there will be insurance and storage costs to be paid. In the second case, buying the product in the future, the consumer will only pay for the product in future. Hence, he/she is able to save on insurance and storage costs. Therefore, the futures price incorporates the costs of finance, insurance and storage, which are known as the carrying charges. The price (fair value) of a forward contract today is therefore, the spot price plus the carrying charges.

In addition to cost of tying up funds and the cost of carrying inventory the theory of storage also incorporates the convenience yield. Convenience yield refers to benefits to the holder of the commodity which arise from the ability to profit from temporary shortage of the commodity, as well as benefit gained from the immediate access to use commodity in production, i.e. the security of the supply. The convenience yield reflects the market's expectations of future supply and demand of the commodity, and is generally stated to be closely related to the inventory levels of the commodity. Moreover, it has been shown that there is inverse relationship between convenience yield and inventory levels. For example Symeonidis et al. (2012) found a strong positive relationship between inventory and forward curve. More precisely, lower inventory is associated with lower basis and forward curves in backwardation and vice versa. Backwardation and contango refers to term structure of commodity prices. The market is said to be in contango when forward prices are higher than spot prices and in backwardation when they are lower than spot prices (Schofield, 2007 and Pindyck, 2001). As the study of Symeonidis et al. use interest-adjusted basis representing storage costs and convenience yield, their results provide support for the relationship between convenience yield and inventory as stated earlier.

The intuition behind the inverse relationship is that a permanent increase in the current and future demand has different impact on current and expected spot prices. (Fama and French, 1988) This results from the situation where demand and supply tend to partially offset the effect of shock on expected prices, thus current spot prices should increase more than expected spot prices, especially at low inventory levels. (Omura and West, 2014) However, the unobservable nature of the convenience yield is the weakness of this theory and makes empirical investigation difficult. Brooks et al. (2013) extended the indirect approach of Fama and French (1987) to examine among others the theory of storage. The results supported this theory as over a longer time scale, evidence of seasonality in the basis enhanced and there were no clear relationship between interest rates and the basis for non-metal commodities, which indicates that other factors like storage costs and convenience yield may be affecting to the basis. Omura and West

(2014) further tested relationship between convenience yield and inventory levels with metal commodities. They found out that option based approach improved both, the accuracy and the precision of the convenience yield estimate, compared to the cost-of-carry approach.

In addition, there is a theory called mean reversion, which means that prices tend to revert back their normal level in the long run. In the short run all above-mentioned factors and many others have an impact on oil prices, which makes oil price volatile. Volatility is a statistical measure of variability in the prices. In other words, it predicts the uncertainty of the future prices. The more volatile the price is, the more uncertain is the future value of the commodity in question. Moreover, the bigger volatility means bigger risk about the future outcomes. Statistically the volatility is measured by the standard deviation of the price movements.

Few other commodity or oil related concepts concerning pricing are also good to know. The price of oil and refined products are usually expressed as FOB (Free On Board), which refers to the point of loading. Another common way of pricing is CIF (Cost, Insurance and Freight), which gives an indication of the cost of delivering oil.

Furthermore, the price of crude oil is mainly quoted in U.S. dollars per barrel. By contrast, the prices of refined products are usually quoted in U.S. dollars per metric ton. This difference in the units should be kept in mind when calculating risk positions of refined products and using crude oil instruments to hedge these positions.

Prices of different distillates are often highly related to crude oil, and can be expressed in terms of price spreads against crude oils. The spread between the crude oil price and the distillate is referred to the crack spread. Bitumen price is derived from HSFO 3.5% (High Sulphur Fuel Oil with Sulphur percentage of 3.5). HSFO 3.5% is highly correlated to Brent crude oil as shown in Figure 3. Thus bitumen price follows the price behavior of Brent fairly well and all the pricing theories presented in this section are applicable to Bitumen price as well.

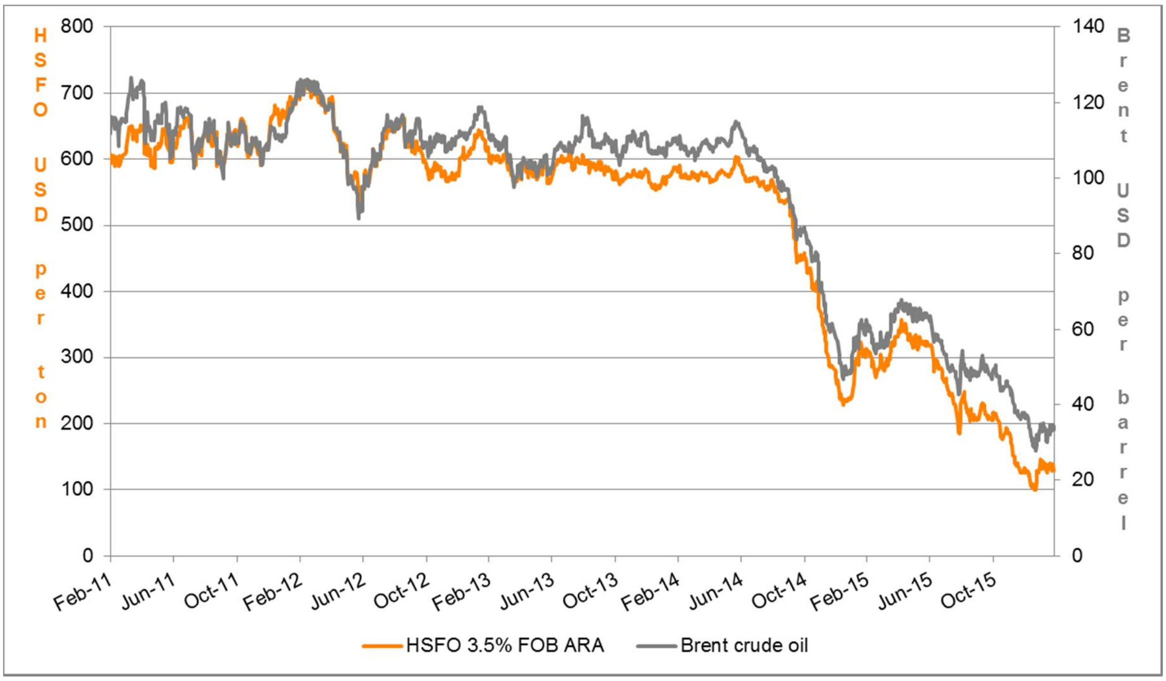

Figure 3: Brent crude oil and High Sulphur Fuel Oil 3.5 % (USD)

Company who uses bitumen regularly in its production typically has a long term purchase agreement with the refining company. In the agreement, price can be determined several ways. One common pricing clause is to set a monthly average price of HSFO 3.5% as a reference price and add some premium on top of it. Thus, purchasing company pays average market price at the time of consumption plus fixed premium. This leads to the need for average price hedging instruments as the future purchasing reference price is unknown.

3 RISK AND RISK MANAGEMENT

Risk is hard to define unambiguously. Risk can mean different things in different situations and contexts, and moreover, the meaning can be different for different people in the same situation and context. However, usually risk is seen as uncertainty of future outcomes. In other words, in business environment risk means fluctuation concerning for example prices and volumes and it can be either negative or positive. (Remenyi and Haefield, 1996)

3.1 Commodity price risk

"In fuel intensive industries, fuel prices can have a significant impact on the bottom line, not to mention adding to the difficult task of budgeting for future fuel expenditures. If fuel costs are not actively managed, they can lead a company to exceed budget forecasts, or worse, lower profit margins or losses." (Mercatus Energy Advisors, 2012)

Commodity price risk arises from the uncertainty of the future prices. Producers face the risk when they don't know the selling price of the production, and consequently future revenue and profit margin are uncertain as well. On the other hand, consumers face the risk when they don't know the purchase price of the needed commodity. Refineries are facing both these risks as they buy crude oil and sell refined products.

De Boer et al. (2001) found out that the procurement cost for industrial companies can be over 50% of their turnover. In addition, commodities like oil and oil distillates are traded in bulk and require large amount of cash for settlement before the corresponding cash flow from sales is received. It can be concluded that financial implications of procurement in commodity intensive businesses represent a major and serious risk (Berling and Rosling, 2005). This is not surprising, as the highly volatile commodity prices can affect profitability and liquidity seriously.

3.2 Risk management

According to classic theory of corporate risk management by Modigliani and Miller (1958) it is irrelevant whether the company hedge or not. In efficient capital markets individual investor can hedge any risk faced by corporate, or offset any hedge taken by corporate. However, the real-world capital markets are not efficient and there is a lot of theoretical support for risk management. Risk management theories can be separated under two different categories, shareholder value maximization and utility maximization for managers. Next the paper shortly presents the risk management incentives. The list is not exhaustive, but covers the most common and known theories.

Financial distress costs are related to probability of the financial distress or bankruptcy. These costs can be either direct or indirect. Direct costs are due to the actual bankruptcy proceedings, e.g. legal and administrative costs and the realization of assets below their market values. Indirect costs used to appear before the actual bankruptcy and refer e.g. to stakeholder protection costs and loss of competitiveness. Leverage is a one measure of a financial distress costs. The tax advantage increases a value of the company when increasing debt, but on the other hand, highly leveraged company has higher risk of financial distress. Financial distress costs are related to risk of default, and if the probability of default can be decreased, the costs of financial distress are reduced. This gives incentive for hedging as it reduces the volatility of the company’s cash flow and profits, and consequently decreases the probability of bankruptcy. (Smith and Stulz, 1985)

Tax incentive arises when the hedging reduces the volatility of pre-tax profits in a convex tax environment (Smith and Stulz, 1985). A stable income will minimize the tax payments and thus increase shareholder value. Another tax advantage concerning volatility is presented by Leland, 1998. He argued that less volatile cash flows enable companies to increase their debt amount and thus increase the tax shield.

Underinvestment problem is one of the agency conflicts and is faced when the company is highly leveraged and has a high default risk. This may lead in the circumstances where even project with the positive net present value is rejected, because it would be financed primarily by equity, but in case of bankruptcy majority of the value creation belongs to the bondholders. (Myers, 1977)

Asset substitution problem (or risk shifting problem) is another agency conflict and appears when the managers choose among investment projects with different riskiness. When managers are acting in the interest of the shareholders, they tend to choose riskier projects, particularly when the leverage of the company is high. Shareholders will benefit from the risky project if the outcome is positive, while bondholders suffer the consequences of negative outcomes first.

Costly external financing, as a one of the hedging incentives, is due to market imperfections. Markets have difficulties in evaluating e.g. the management, riskiness of the investment opportunities of the company, probability of default etc. That is why the investors will require a premium for investing in the firm, which make external funding more costly than internally generated funds. (Froot et al., 1993) Thus, corporates can hedge their cash flows to avoid a shortfall in their funds and need for costly external funding.

Managerial risk aversion refers to theory of utilization maximization for managers. It means that managers might take actions that benefit themselves more than the shareholders. These actions might be e.g. less risky projects than well diversified shareholders may choose or lower debt to equity ratio to decrease the risks of their own income and wealth position. Risk management from the managerial risk reduction perspective can be valuable for shareholders as well. The managers' risk management incentive can be derived from their compensating package. More precisely, managers that are paid with company stocks are more likely to hedge than managers that are rewarded with stock options. (Smith and Stultz, 1985)

4 HEDGING

Meaning of hedging has changed during the decades. Prior to the 1950s, hedging was viewed as an activity to reduce price risk (Blank et al., 1991). This was done by taking a position in futures market that was equal and opposite to the position held in the spot market. The strategy is easy to implement and creates effective risk reduction in cases where spot and futures prices are highly correlated. During the past 50 years, different kind of alternative hedging models have been developed. Researchers have tried to find a hedging model which is superior to that so called naive hedge model.

4.1 Theories of optimal hedging levels

4.1.1 Portfolio Theory

Portfolio theory introduced by Markowitz in 1952 was first an investment strategy. The strategy focused on the problems related to the risk of investment(s). Earlier investment theories were based in the assumption that profit maximization was the only goal of investors. Markowitz believed that investors' decisions are not based only on expected returns, but also on the variance of expected return. The concept is that investors like returns and dislike risks, and it is followed by two other assumptions: investors act rationally, and that investment decisions are based on maximizing the expected return at the level of risk accepted. Rather than focusing the risk of owning an individual asset, portfolio theory suggests that investor's total portfolio risk should be the focus. An investor can identify an efficient frontier by considering all possible combinations of assets, and expected returns and variances of each of these. The efficient frontier then indicates the profit maximizing level for each accepted risk levels, and the investor then selects the most efficient portfolio which represents the desired risk level.

4.1.2 The minimum-variance hedge ratio

One of the main approaches to optimal hedging is the minimum-variance hedge ratio, the ratio of futures contracts to the risk position that minimizes the variance of the income (Lence and Hayes, 1994). The equation for minimum-variance hedge ratio is given as follows:

$$h^* = \rho \frac{\sigma_S}{\sigma_F} \tag{1}$$

Where h^* represents the risk-minimizing hedge ratio, ρ is the correlation coefficient between ΔS and ΔF and σ_S & σ_F are the standard deviations of spot and futures prices.

Collins (1997) has pointed out that minimum-variance approach usually leads to hedge ratios that are very close to the traditional, naive hedge model of taking equal-sized and opposite hedge position to the underlying risk position.

In the case of linear hedging, as for futures, the minimum variance hedge ratio can be used, but this approach is not applicable to option hedging. In linear hedging, the potential gains (losses) from the derivatives offset the losses (gains) on the underlying position, leaving the hedger with no uncertainty. However, in option hedging, hedger may set for example a floor to the losses, but leave the possibility to gain from favorable price movements. The hedged position is therefore asymmetric (non-linear) and the hedging efficiency cannot be evaluated through the conventional variance. (Bajo et al., 2014)

4.1.3 Expected utility-maximization

In the early 1960s, Johnson (1960) and Stein (1961) applied Markowitz's portfolio theory to the hedging decision. They argued that the motives for hedging are equivalent to any investment decision. The aim is to achieve the optimal combination of risk and expected return. Earlier theories presented both the completely hedged and the completely unhedged positions; there were no explanation for observed decision to partially hedge one's risk position before applying portfolio theory to the hedging. This approach is so called expected utility maximization. Johnson (1960) and Stein (1961) stated that an entity chooses to hedge, unhedge, or partially hedge its risk position aiming to maximize expected utility. Thus an entity may limit its losses by setting, for example, a floor to the losses as described above, but keeping the potential upside unaffected. Later the variants of the expected utility-maximization model have been further developed and used by several researchers. Utility maximization models solve some of the problems related to minimum-variance approach. At first, the goal of many hedgers is not risk minimization, but risk reduction. The speculative component of the expected utility-maximization model allows entities to incorporate their price expectations to hedging strategies while still reducing overall price risk exposure. Utility-maximization approach also gives rationale for the no hedge choice of many entities which is not the case in risk-minimization models.

4.1.4 Alternative approaches to optimal hedging level

One of the alternative approaches to define optimal hedging level is a value-at-risk (VaR). According to Ahn et al. (1999), for an entity facing only price, risk the optimal option hedging strategy is represented by minimizing the VaR of the hedged position. However, the choice of VaR in the hedging framework is arguable. VaR is a single percentile of the position's probability distribution and it does not provide any information on the size of the loss exceeding such a level Thus, VaR is unable to capture tail risk. That in some circumstances may be big enough to liquidate the whole company. (Bajo et al., 2014)

To capture the tail risk there is another approach called conditional VaR (cVaR) or "Expected Shortfall" (ES). This risk measure carries a number of advantages relative to VaR. First and the most important, cVaR predicts both the size and the probability of experiencing losses greater than a given level. Second, cVaR enjoys subadditivity which is not the case with VaR. It has been seen that the literature, regulators and the financial industry are abandoning the simplistic VaR methodology in favor of more accurate measures such as cVaR. Moreover, the Basel Committee suggested switching the bank quantitative risk metrics from VaR to Expected Shortfall. (Bajo et al., 2014)

4.1.5 Problems related to optimal hedging level

According to Gay et al. (2003), the overhedging problem is overlooked in the risk management literature. Overhedging problem exist when a company has sold (bought) more linear derivatives than the realizing output (procurement). As a result of overhedging, the company faces bigger derivative gains or losses than the underlying position creates. In contrast, when using long position of options, the maximum loss at the end will be the amount of premium(s). Thus, as the risk of overhedging (in other words, quantity risk) increases, the optimal amount of linear hedging contracts decline, but to maintain protection against unfavorable price changes, the amount of non-linear contracts increase.

Fisher and Kumar (2010) stated that companies should only hedge exposures that actually threaten them. They found out that it is still relatively common that companies hedge risks for which they are not exposed to. A key solution for this problem is that hedging should be implemented in a close co-operation with business units. Business units may also hedge irrelevant exposures if they aren’t familiar with risk management techniques and derivative instruments used. Thus, it is important to have risk management professionals involved in the hedging process.

4.2 Operative hedging

Risk management does not necessarily rely on derivatives. This paper focus on derivative hedging but some other ways of risk management are shortly discussed.

Corporates can in some circumstances hedge their commodity price risks in operative way. They might negotiate fixed prices for their sales and purchase contracts, or buy raw materials into the storage in advance. Buying a raw material in to the storage when the sales are priced will hedge against price movements, but it is not necessarily wise if the storage costs of the raw material are high. Some companies might be able to pass on increased raw material prices to their customers, thus have no impact on their profit margins despite the volatile markets (Mercatus Energy Advisors, 2012).

Another way to manage risks without derivatives is liquidity buffers. Liquidity buffers can be used as a risk reserve. This means that company collects earnings instead of paying them out as dividends to cover possible negative surprises in future cash flows. Liquidity buffers are out from the shareholders' wealth, as earnings are not paid to the shareholders as dividends. (Nance et al., 1993)

4.3 Financial derivatives

Financial derivatives are alternative for operative hedging. Market participants buy or sell their physical commodities in the physical market through their regular channels. Alongside, they can hedge their physical risk exposures by using financial derivatives in the futures or over the counter (OTC) markets. Financial derivatives are financial contracts where parties agree on trade related to derivative instrument on an asset instead of trading the asset itself. There are four main types of derivatives: futures, forwards, swaps, and options. These are presented closely in the following subchapters.

4.3.1 Futures and forward contracts

Futures and forwards are contracts which involve an obligation to buy or sell an asset at a certain time in the future for a certain price. The difference between futures and forwards is that futures are exchange traded and standardized with certain delivery months and certain size of a contract. For example, in crude oil markets one contract is 1,000 barrels of crude oil and the deal cannot be made for smaller amount of oil. In addition, futures contracts are guaranteed by exchange clearinghouse and there are daily settlements to prevent credit risks. Daily settlement is handled through margin accounts. Forward contracts, in contrast, are derivatives which are traded in the over-the-counter markets, which means that the buyer and the seller agrees the terms of the forward contract, i.e. price, contract size, and maturity by themselves. Due to this flexibility, OTC market has become much larger than the exchange-traded market in terms of the total volume of trading. The disadvantage of the OTC market is the credit risk, which arise if the counterparty fails to execute the contract. Margin calls can be used also in the OTC markets to mitigate credit risk. Both futures and forwards can require settlement in cash or by physical delivery. In practice, only a small percentage of contracts result in a physical delivery because parties generally close their futures positions before the maturity. Closing the position is done by entering the opposite transaction in the market that is offsetting the position (i.e. buying back or selling the same amount of futures before the maturity date).

As stated earlier the consumer has two options to purchase needed commodity. She can buy the commodity either immediately or in the future. In the first case, the consumer should finance the purchase in cash, i.e. facing financing costs. Additionally, the holder of the commodity must pay insurance and storage costs. In the second case, the consumer pays in the future (when the commodity is needed), thus saving the previously-mentioned costs. This cost-of-carry determines the price for futures contract, which is the cash price today plus the cost-of-carry. The formal equation with continuously compounded interest rate is as follows:

$$F_0 = (S_0 + U)e^{rT} \tag{2}$$

Or if the storage costs are presented in percentages, then:

$$F_0 = S_0 e^{(r+u)T} \tag{3}$$

Where

$F_0 = Futures\ price$

$S_0 = Spot\ price$

$U = the\ present\ value\ of\ all\ storage\ costs$

$u = the\ storage\ costs\ per\ annum\ as\ a\ proportion\ of\ the\ spot\ price$

$r = the\ annual\ risk\ free\ interest\ rate$

$T = time\ to\ maturity\ (in\ years)$

One more commodity specific component should be taken into account when valuing futures contracts: the convenience yield. It is the benefit of the consumption commodity holder, which refers to the availability of the commodity in question as discussed earlier in this thesis. When incorporating the convenience yield in the former equation we will get:

$$F_0 = S_0 e^{(r+u-y)T} \tag{4}$$

Where y is the convenience yield in percentages

Hedging with futures or forward contracts can be seen as a price insurance, as the hedger takes an opposite position in the derivative market from that in the physical market, thus lock the prices and the profit margin. Consequently, the use of derivatives for hedging purposes eliminates the price risk of physical trade. The profits in one market are offset by losses in another (Labys & Granger, 1970).

A short hedge is the case where a hedger is long in the physical market and short in the derivative market. In contrast, a long hedge refers to the case, where a hedger is short in the physical market and long in the derivative market.

4.3.2 Swap contracts

Swap contracts can be seen as a different type of derivative, but actually those are just multiple cash-settled forwards, because a swap contract is an agreement to exchange cash flows in the future. A swap contract defines the dates when the cash flows are paid and the determinants for calculating the cash flows. (Hull, 2003)

Hedgers can use swaps in order to fix their cash flows to match physical position to ensure anticipated profits for a specific time. Moreover, in the commodity hedging also Asian style swaps are used. Asian swaps are swaps, whose floating leg depends on the average price quote of the predetermined calculation period. It is common that raw materials are purchased at average price of a delivery month or month before. This creates a need for hedging instruments that match this pricing mechanism.

4.3.3 Option contracts

Options are traded both on exchanges and in the over-the-counter markets. There are two types of options: call options and put options. Call option gives the option holder the right but not obligation to buy the underlying asset for a certain price at a certain date in the future.

Literature concerning commodity options is very limited, but some extension has been developed to take into account the stochastic term structure of commodities and the information costs associated with investing in commodities. Next the special characteristics of Asian options are discussed.

Asian style options are one of the so called exotic options and are widely used in commodity markets. Exotic options are options which offer different types of payoffs. An Asian option is an option where the payoff is based on the average price of the underlying asset during the life of a specified period of time. Asian options can be either calls or puts. (Chance, 2001 and Sandagdorj, 2005)

Asian style options written on average prices are effective hedging tools in commodity markets. Asian options have several advantages compared to European alternatives. For example, average price options are not so vulnerable to price manipulation because the payoff doesn't depend only on the price of maturity date. In addition, the averaging smoothens the high volatility characteristic of commodity markets, thus Asian options are also often cheaper than European options due to lower volatility. Especially, oil markets often use Asian derivatives to stabilize cash flows. The most-used pricing approach for Asian options relies on the assumption that the prices follow geometric Brownian motion. However, this model has two shortcomings. The first is the normality assumption of return distribution, which does not hold for return time-series of commodities. Second, no closed-form solution exists for the arbitrage-free price of options on arithmetic averages of lognormally distributed prices. (Fusai et al., 2008, Reinvall et al. 2014)

4.4 Optimal hedging instrument

If the market price cannot cover the cost of production for a long time, a producer may end-up to a bankruptcy. Therefore, hedging the sales price risk is one way to protect against unfavorable price changes. For example, oil producers hedge their positions against the risk of falling oil prices. Consumers in contrast, hedge their purchases against rising prices.

For example, Bartram (2006) investigated the use of derivatives in risk management activities. Bartram et al. (2009) found out that the use of derivatives has become a common practice for non-financial firms around the world. Especially in foreign exchange and interest rate risk management the derivatives are widely used, but in commodity price risk management using the derivatives is more concentrated in particular industries. They also noted that even though the non-financial corporates use derivatives in their risk management, it is not clear whether the full potential of derivatives is being realized and whether they are used appropriately. According to empirical evidence, non-financial corporates use derivatives mainly for hedging purposes rather than in speculative ways (Bartram, 2006).

However, hedging is not always profitable. There are several reasons for why hedging may be unsuccessful. Therefore, implementing price risk management should be an important part of the trading of commodities and using an appropriate derivative at an appropriate time is crucial to risk managers. Moreover, risk managers should be aware of the results of hedging. For example, futures and forward hedging locks in the prices, and hence, cuts also upside potential of the profits. In that case the risk and costs occur if the price of the underlying commodity changes against a risk manager’s expectation or if the risk manager chooses an inappropriate derivative. For example, an oil consumer who has a long forward position will lose if the price of oil decreases in the future. Unhedged competitor will gain advantage from the falling prices while hedger has locked the prices at the upper level. An oil producer who has a short forward position will lose if the price of oil increases in the future. (Sandagdorj, 2005)

Moreover, there is a problem called basis risk. The basis risk means that the price of a commodity eventually paid for in the cash market, are less than perfectly correlated with the prices of the available futures contracts. This results to the fact that naïve hedging strategy which aims to take an opposite position in a futures contract so that any potential change in physical position is offset by a change in futures position is violated.

It is argued that linear derivative instruments such as futures and forwards should be used when hedging linear exposures and vice versa. Gay et al, (2003) argues that optimal hedging portfolio when the corporate face only price risk consists of linear derivatives, but when the quantity risk exist, the use of linear derivatives should decline due to risk of overhedging. At the same time, the use of non-linear derivatives will come more attractive.

But linear derivatives can be used for delta hedge of non-linear exposures as well, thus delta hedging requires rapid and continuous adjustment of the derivative position as the risk factor changes, and moreover, the changes in risk factor should be small, as the hedge only works well for small risk changes (Bartman 2006). If linear derivatives are used for a static hedge of a non-linear exposure, the correlation between price and quantity risk affects significantly to the effectiveness of the hedge (Stulz, 2003) Taking these findings into account, linear derivatives are not the best choice for hedging non-linear exposures (Bartman, 2006).

Options, in contrast, are very versatile risk management instruments that can be used well to hedge various types of exposures, including linear and complex non-linear exposures. A static option position can hedge non-linear exposures significantly better than static linear derivative position including instruments such as futures and forwards (Stulz, 2003). Usually there is only a little uncertainty concerning corporate's short-term cash flows and therefore they can be hedged well with linear derivatives, but the longer the hedging horizon the bigger part of cash flows bear price and quantity risk which results in the non-linear exposure and can be more effectively hedged with options. (Bartman, 2006). In addition, the optimal hedging strategy depends on the correlation of price and quantity risk, as well as price and quantity volatilities. The corporates should use more non-linear hedging instruments, i.e. options, when they face small price risk and high positive or negative price-quantity correlation, or when they face large quantity risk. (Bartman, 2006)

Lien and Wong (2004) studied the use of currency options in the case where the contractor ultimately wins or loses the tender. As the outcome is independent of the exchange rate, hedging with options and futures can never eliminate all uncertainty, but intuitively, options being more flexible are likely to perform better as hedging instrument than futures. Contrary to majority of studies, Kulatilaka and Marcus (1994), argued that futures hedges often are more effective than option hedges even in the case where project acceptance is uncertain. In their opinion, options can be justified only as a min-max strategy aiming to minimize maximum losses as according to their study of minimum-variance hedge strategies, futures dominate options as a hedging instrument. Options can also be used as insurance against unfavorable market movements while keeping upside potential open. But this kind of insurance can't be seen as a hedge in variance minimizing sense, even though it protects the risk position against losses.

Bartman pointed out that also accounting treatment of different derivative instruments may have an important role when choosing between hedging instruments. As linear derivatives may cause significant gains or losses, the negative loss from the long option position is always limited to the premium payed. Even though linear exposure's opposite price fluctuation offset the gain or loss of linear derivative position, the management may see options more attractive at least in the situations when the underlying position would show significant gains. The elimination of the upside potential on the underlying asset when using linear hedging instruments can be seen as a price for protection the linear derivative offers when the underlying asset is losing value.

4.5 Commodity hedging strategies

In addition to so called naïve, 100% full hedge strategy, other strategies can be applied to hedging as well. There are several studies on commodity futures pricing that has shown abnormal returns based on various market signals. A momentum strategy is one of the simplest trading rules based on past returns on the asset. It has been first introduced in equity markets and means that one should take a long position in assets that has performed relatively well in the most recent past, and short position in assets that has performed relatively poorly. Thus, momentum strategy can be said to be "a bet that past relative performance will continue into the future" (Szakmary et al., 2010). During the 90's the momentum strategy in the equity markets was widely investigated and evidence about abnormal returns was documented. More recently, momentum strategies are being examined in commodity futures because of their possible diversification benefits for investors. Encouraging results have been shown for example, by Erb and Harvey (2006), and Miffre and Rallis (2007) according to whom momentum strategies in commodity futures earn impressive returns. (Szakmary et al., 2010)

Another recently examined commodity strategy is based on the slope of term structure of commodity futures prices. This strategy consists of taking long position in commodities showing backwardation (or positive roll-yields) and short position in commodities showing contango (or negative roll-yields). (Fuertes et al., 2015) This strategy is based on theory of storage and inventory considerations as well as hedging pressure hypothesis. Thus it is assumed that in commodity markets, producers are more vulnerable for price changes than consumers, thus willing to pay a premium for price stability. In addition, backwardated markets may imply scarcity in the commodity market in question and predict that prices will rise, thus giving rationale for a long position in that commodity. During the contango, the situation is reversed and the investor should short the commodity as the situation implies possible oversupply in the markets. The profitability of the traditional term structure strategy is evidenced by Erb and Harvey (2006), for example.

Kim and Kang (2014) extended traditional term structure approach to the dynamic term structure strategy which they call dynamic-slope strategy. This differs from static traditional strategy by incorporating the change of term structure in the strategy. This means that investor should take a long position on the commodity futures exhibiting dynamic backwardation and vice versa. Dynamic backwardation means the tendency of stiffening backwardation, i.e. the term structure becoming more negative, whereas the dynamic contango is opposite. According to Kim and Kang, dynamic strategy generates significant abnormal returns in excess of even the combined term structure and momentum strategies.

Combined strategies have become a popular theme to examine. Fuertes et al. (2010) introduced double-sort strategy that combines momentum and term structure signals. This strategy aims buying the backwardated past winners whose prices are expected to appreciate, while shorting the contangoed losers whose prices are expected to depreciate. The rationale behind the double-sort strategy is that return correlation between momentum and term structure strategies is low, and thus, it might be profitable to combine these two. According to Fuertes et al. (2010), the combined double-sort strategy was clearly superior, even though the individual momentum and term structure strategies also performed well.

Fuertes et al. (2015) further extended combined strategies to triple-screen strategy by incorporating idiosyncratic volatility as a third signal. They demonstrated that when applying the momentum, term structure and idiosyncratic volatility signals, which are non-overlapping, by buying commodity futures with high past performance, high roll-yields and low idiosyncratic volatility and shorting contrary contracts, Sharpe ratios are sizeable and outperform single strategies, as well as any of the double-screen strategies.

Moreover, there are different kinds of trend-following strategies other than momentum strategy. Szakmary et al. (2010) examined profitability of trend following strategies on a long term by employing monthly data for 28 commodities. They tested a dual moving average crossover and channel strategies. Aggregate results across markets showed significant profits and produced higher mean returns than momentum strategies. Even though it is usually necessary to pool results across markets to find a robust degree of statistical significance, their results showed positive mean net excess returns in 22 out of 28 markets.

All these investment or trading strategies presented here can be applied to hedging framework as well. In this study, three different hedging strategies based on term structure are formed and empirically tested. In addition, one competing strategy based on implied volatilities is evaluated, as well as naïve full hedge strategy.

5 DATA AND METHODOLOGY

The aim of the empirical test of this study is to evaluate the effectiveness of alternative commodity hedging strategies, more specifically, bitumen hedging strategies. For the beginning, this section presents the data used in the empirical testing. In addition, different strategies are explained and a rationale for choosing these particular strategies is presented. The methodology used in empirical tests is described in the last sub-section.

5.1 Data

The data includes daily USD spot and swap prices for bitumen. More precisely, the instrument used is HSFO 3.5% FOB Barges ARA (High Sulphur Fuel Oil, including 3.5% Sulphur, with delivery terms Free On Board in Amsterdam, Rotterdam or Antwerp). Prices are quoted per metric ton. Observation period covers nearly 5 years from March 2011 to January 2016. Swap prices covers maturities 1 month, 3 months, 6 months, 9 months and 12 months. These swaps' payoff depends on the difference between fixed price leg and floating price leg of which the latter is calculated as monthly average of the daily prices. In addition, for one hedging strategy, the implied volatility figures are used. As there are no quoted options for Fuel oil, implied volatilities for Gasoil (LGO) are used instead. Gasoil is the closest oil distillate to Fuel Oil thus it is assumed to imply Fuel Oil volatility pretty well. Volatility observations cover the same periods as well as the same maturities as the swap prices. The source of the data is Thomson Reuters Eikon platform. Full sample period includes 1243 observations for each contract although the usage of each contract data depends on the availability of realized values and varies between 1011 and 1243 observations.

5.2 Methodology

The purpose of this study is to examine different hedging strategies for a company using bitumen as a raw material in its production. The underlying risk position is assumed to be fixed in terms of price and quantity. Moreover, the price fixing is assumed to be based on bitumen forward prices prevailing at the time of pricing the construction project in which the bitumen is used. The physical bitumen for the production is purchased at monthly average price calculated from the daily quotations. This character gives a rationale for the use of Asian type hedging instruments, whose payoffs depend on the monthly average prices.

5.2.1 Hedging strategies

The hedging results are compared to the situation where no hedge at all is done. All alternative hedging strategies investigated are based on swaps as a hedging instrument, and only a decision to hedge or not to hedge vary between strategies based on different signals. Hedging strategies tested in this study are as follows:

- S1. Simple 100% full hedge strategy
- S2. Simple term structure strategy (100% hedge or no hedge)
- S3. Conservative term structure strategy (100% hedge or 50 % hedge)
- S4. Aggressive term structure strategy (100% hedge or no hedge)
- S5. Implied volatility strategy (100% hedge or no hedge)

Strategy 1 (S1) means that a company keeps continuously hedged the whole risk position. Once risk arises it will be hedged immediately by entering into swap contract, whose terms exactly match the underlying bitumen risk position. In other words, the reference rate, quantity, and timing are the same as the physical purchase in the future. Thus, the hedge ratio is 100%. This so-called naïve hedging strategy can be seen the most efficient hedging strategy in terms of mean-variance minimization as the future cash flow is certainly known and no risk about the amount exists. In this study it is assumed that there is no basis risk or counterparty risk in relation to hedging instruments used.

Strategy 2 (S2) is based on the slope of term structure of bitumen at the time when risk position arises. According to the theory of storage, the scarcity in commodity causes convenience yield to increase, which results in the term structure to incorporate the shape of backwardation. This further implies that prices will rise as there is a shortage of commodity. On the contrary, contango represents oversupply and the prices are expected to decrease. Term structure investing strategy is based on this pricing phenomenon and predicts excess returns when entering into long position in commodity facing backwardated term structure, and simultaneously, taking short position in commodity showing contango. This investing strategy is applied to hedging framework in this study. Strategy 2 incorporates term structure strategy in a very simple way. As backwardated markets predict prices to rise, backwardated markets imply need for hedging from consumer company's point of view, thus 100% hedging with swap contracts is entered into. In the contango market, prices are expected to fall which would be favorable to the consumer company. Thus no hedging is done when market shows contango.

Strategy 3 (S3) takes more conservative approach to the term structure hedging strategy. When market shows contango, the hedging decision is made similarly to Strategy 2, full 100% swap hedge. But instead of refraining from hedging in the contango market, 50% of risk position is hedged with swaps. This decreases the risk, but keeps some upside potential open for price dip.

Strategy 4 (S4) is more risky and relies loosely on dynamic slope strategy presented by Kim and Kang (2014). In their investing strategy the dynamic backwardation implies that the term structure is becoming more negative. In this study, the strategy is based on the steepness of the slope instead. Similar to Strategy 2, in this strategy the decision to hedge is either 100% or 0%, but the 100% hedging decision is only made when backwardation is more than 2%

compared to prevailing spot price, in other words, the forward price is less than 98 % of the spot price. In all other market cases, no hedge is done.

Strategy 5 (S5) differs from the earlier ones as the slope of the term structure does not define any hedging decisions. Instead, the implied volatility does. Implied volatility should predict the markets expectations of the future volatility of the commodity in question. If the implied volatility is relatively low, it is assumed that the variability of the future prices will be low, thus there is no need for hedging. In this hedging strategy the hedging decision is again either full 100% swap hedge or no hedge at all. At low implied volatility levels the decision is no hedge, whereas at high volatility levels the hedge ratio is 100%. To demonstrate what is low or high volatility, some descriptive statistics were investigated (see Appendix 1). According to statistics, the mean volatility vary between 21.5 - 24.6% and median between 22.3 - 24.7%, respectively. At its lowest, the volatility is around 12% whereas at its highest it was around 40 – 60%. Based on these figures, the volatility boundary in the hedging strategy was set to 20. So the Strategy 5 incorporates full 100% swap hedge when the implied volatility for the maturity in question is equal or more than 20% and no hedge is done if the implied volatility is less than 20%.

All the strategies presented are tested for several different maturities. Maturities included are 1 month, 3 months, 6 months, 9 months and 12 months.

5.2.2 Evaluation of hedging effectiveness

Two approaches to effectiveness of the hedging strategies are discussed next. According to literature, the risk averse hedger should minimize the uncertainty concerning cash flows. In other words, the strategy which minimizes the variance of the risk position’s returns should be chosen from the available hedging strategies. In this study the variability of hedged portfolio’s returns is measured for each hedging strategy. The variability is measured as a standard deviation of cash flows according to following equation:

$$\sigma = \sqrt{\frac{\sum(r-\bar{r})^2}{(n-1)}} \quad (5)$$

Where r is return from hedging strategy, and n is total number of observations.

However, the above-mentioned risk measure ignores the fact that positive returns are usually more than welcome. It assumes that all variations from the target value are undesired. Alternative way to measure risk is to use semi-deviation. (Felbel, 2003) Concerning this study, semi-deviation can be used to measure e.g. only negative returns, or negative deviations from mean value. The former is chosen to represent downside risk in this thesis because positive returns are seen favorable while negative returns form the risk. Equation used to measure *target absolute semi-deviation* (TASD) is as follows:

$$TASD = \sqrt{\frac{\sum_{i=1}^{n}|r_i - r_t|}{n}} \quad \textit{for all } r_i < r_t \quad (6)$$

Where r_i is return of hedging strategy for each return interval, r_t is target rate of return below which outcomes are considered risky (in this study 0), and n is number of observations in the whole distribution.

To eliminate all possible downside risk while keeping upside potential unaffected is impossible. There is always a trade-off between risk and reward. Next, the reward side is discussed more.

To test the effectiveness of the examined hedging strategies in terms of rewards, the excess returns of each strategy are compared to the no hedge situation. To do so, the no-hedge returns are calculated first. No-hedge returns are calculated as a difference between forward rate prevailing at the date when risk arises and monthly average spot rate realizing at the maturity. Assumption behind this is that pricing the bitumen in to the project is based on the forward rate at the signing date.

All hedging strategies are then calculated similarly based on the hedging rules described earlier and returns are compared to no hedge returns, resulting in excess returns. Excess returns are presented in relative terms.

5.2.3 Statistical significance

T-test was run to find out the significance of the test results. T-test assumes the student's distribution. Thus the before-mentioned problems in the distribution may cause some harm for the test. T-test measures if the tested mean values differ from zero. Hypotheses are as follows:

H_0 = Mean returns do not significantly differ from zero
H_1 = Mean returns significantly differ from zero

T-statistic is interpreted so that if p-value gets the value >0.05, then the H_0 is not rejected and the mean returns do not significantly differ from zero, whereas if $p < 0.05$ then H_0 is rejected and H_1 implicates that test results are significant and mean returns do differ from zero. Equation for T-test used in this study is following:

$$t = \frac{\overline{er}_i - \overline{er}_j}{\sqrt{SE_{eri}^2 + SE_{erj}^2}} \tag{7}$$

Where er_i is excess return of hedging strategy, er_j is excess return of benchmark portfolio, in other words zero in this study as the excess return of benchmark portfolio compared to the portfolio itself is always zero and SE is standard error.

The degrees of freedom for the test statistic are given as:

$$v = \frac{(SE_{ri}^2 + SE_{rj}^2)^2}{\frac{SE_{ri}^4}{n_i - 1} + \frac{SE_{rj}^4}{n_j - 1}} \tag{8}$$

In most cases, t-statistics obtained are relatively high.

6 EMPIRICAL RESULTS

This section presents the results of the empirical tests. Five alternative hedging strategies were investigated and compared to the no-hedge strategy. The performance of the strategies is evaluated by two measures, excess returns and variance of the returns. The first one indicate whether the hedging is economically effective compared to the no-hedge case. In other words, does the hedging strategy create positive excess returns for the company applying the strategy? The latter one concentrates more for risk minimizing perspective and implies whether the hedging strategy reduces the volatility of the returns or not. In addition to the volatility measures, the riskiness is also evaluated by downside risk only. The upside risk is seen as a favorable thing even though the revenues vary, but the below zero returns form the real risk. This downside risk is measured by target absolute semi-deviation.

6.1 Results of single strategies

This sub-section presents the results of the empirical study separately for each hedging strategy.

6.1.1 Simple 100% full hedge strategy

Strategy 1 represents the so-called naïve hedging strategy in which all risks are fully hedged with linear derivatives. This leads to the situation where all the future cash flows are known for certain (given that quantity risk does not exist). This is probably the most favored hedging strategy in the non-financial companies consuming commodities as a raw material in their production. In this study, the strategy is applied by entering to 100% hedge with OTC monthly average swaps on a day when risk arises. This leads to full hedge situation as the underlying risk position is priced based on the same monthly average prices in the future. From the risk minimizing perspective it follows that the variability of returns measured by standard deviation should be zero, as it is exactly the return expected. The same holds for downside risk measured by target absolute semi-deviation where $r_t < 0$. Thus, from the risk-minimizing perspective, it can be said that Strategy 1 is the best, or at least, one of the best if some other strategy results in the same risk metrics.

However, when investigating excess returns compared to no-hedge strategy from Table 1 below, it can be seen that in any for the maturities examined, the naïve hedging strategy do not outperform the no-hedge strategy.

Table 1: Excess returns of Simple 100% full hedge strategy

	1 month	**3 month**	**6 month**	**9 month**	**12 month**
Excess return	-2.08 %	-6.02 %	-10.21 %	-13.49 %	-16.69 %
Significance	6.4E-14	1.1E-33	7.4E-57	2.8E-72	1.9E-81

As shown in the Table 1, excess returns are negative for all maturities in Strategy 1. Furthermore, a magnitude of negative excess returns varies between -2.08% and -16.69% and increases for longer maturities. The results are extremely significant.

6.1.2 Simple term structure strategy

Strategy 2 is derived from the widely investigated investment strategy where investor should take a long position in commodity facing backwardated term structure while shorting another commodity showing contango. In this study the investment strategy is applied to hedging framework by incorporating only the first term of the investing strategy, as there is no intention to take any view concerning any other commodity than that being hedged. That is, to hedge only when the slope of the term structure of the commodity shows backwardation, and leaving position unhedged when contango is met. Furthermore, the strategy is static. When the hedging decision is made on a date when risk arises, no adjustments is done afterwards during the duration of the position even though the slope of the term structure changes. The strategy leads to either 100% swap hedge or 0% hedge ratio. Results are presented in Table 2 below.

Table 2: Excess returns of Simple term structure strategy

	1 month	3 month	6 month	9 month	12 month
Excess return	-0.75 %	-1.81 %	-2.69 %	-5.17 %	-7.65 %
Significance	1.2E-05	1.1E-08	5.4E-12	9.9E-23	3.3E-35
Std. deviation	7.66 %	13.28 %	17.05 %	17.85 %	20.49 %
TASD	10.40 %	9.93 %	5.43 %	2.02 %	0.80 %

The results show that the excess returns are very significantly negative for all maturities in Strategy 2, as they were also for Strategy 1. However, the magnitude of negative excess returns is smaller in this case. Thus, Strategy 2 seems to be more effective in terms of excess returns compared to Strategy 1 which indicates that term structure have explanatory power for future prices. However, no-hedge strategy would have, on average, outperformed the simple term structure strategy in the examined period. The excess return in Strategy 2 is at its lowest -0.75% for 1-month maturity and at its highest for 12-month maturity (-7.65%).

On the other hand, risk measures indicate that there is a remarkable risk associated with the returns. Standard deviation varies between 7.7% and 20.5% being smaller for short maturities and greater for longer maturities. These figures can be quite high for risk averting company as the effect on the profit margin can be severe. Interestingly, downside risk measure, target absolute semi-deviation, is even higher for 1-month returns than standard deviation, whereas it is clearly smaller for other maturities, especially from 6 months onwards.

6.1.3 Conservative term structure strategy

Strategy 3 is modified version from the Strategy 2 with the difference that the hedge ratio is either 100% or 50% instead of 100% or 0%. Decision rules are the same but hedge ratio differs: when term structure shows backwardation full hedge with swaps is entered into and when contrary situation, contango exist, the hedge ratio is 50%. This strategy represents the more sensitive hedger, who is not willing to take as much risk as the hedger in Strategy 2 where during contango the whole position is left unhedged. Instead of unhedge, the more sensitive hedger can hedge half of the risk position when the bet is for falling prices to benefit partly from possible favorable price movements while still keeping risk on acceptable level. Excess returns and risk measures for Strategy 3 are presented in Table 3 below.

Table 3: Excess returns of Conservative term structure strategy

	1 month	3 month	6 month	9 month	12 month
Excess return	-1.41 %	-3.92 %	-6.45 %	-9.33 %	-12.17 %
Significance	3.1E-12	2.1E-26	1.8E-44	6.7E-58	3.2E-72
Std. deviation	3.83 %	6.64 %	8.52 %	8.93 %	10.25 %
TASD	7.36 %	7.02 %	3.84 %	1.43 %	0.56 %

As can be predicted from the characteristics of Strategy 3, the results are somewhere between the strategies 1 and 2. This is due to the fact that hedging decision rules are the same than in Strategy 2, but the hedge ratio is higher in Strategy 3, thus closer to Strategy 1 which represents full hedge. Not surprisingly, the excess returns over no-hedge strategy are significantly negative for all maturities. Results are alike, statistically significant. Differently from Strategy 2, downside risk seems to be higher than standard deviation for both 1-month and 3-month maturities in Strategy 3, but decreases the longer the maturity, as is also the case for Strategy 2. However, both risk measures are lower than for Strategy 2.

6.1.4 Aggressive term structure strategy

Similarly to Strategy 3, Strategy 4 is modified version of Strategy 2 thus based on the slope of the term structure. Contrary to Strategy 3, this strategy is for the hedger who is willing to accept more risk than in Strategy 2. In this strategy the bet is on price increase only when backwardation is more than 2%. Therefore, hedging will be implemented only in that situation, but with 100% hedging ratio. If backwardation is equal or less than 2% or term structure shows contango, no hedge at all will be entered into. The results of Strategy 4 are shown in Table 4 below.

Table 4: Excess returns of Aggressive term structure strategy

	1 month	**3 month**	**6 month**	**9 month**	**12 month**
Excess return	0.20 %	0.75 %	0.28 %	-0.75 %	-2.81 %
Significance	9.2E-05	1.3E-08	0.18	0.02	1.5E-11
Std. deviation	9.43 %	15.79 %	19.10 %	20.71 %	23.35 %
TASD	14.17 %	13.73 %	7.52 %	4.35 %	3.34 %

This is the first strategy generating positive excess returns comparing to no-hedge benchmark position, shown by the results above. More precisely, positive excess returns are only achieved for short maturities from 1 month to 6 months and they are quite modest ranging from 0.20% to 0.75%. Moreover, the results for 6-month maturity are not statistically significant with p-value 0.18. Unlike the earlier strategies, the excess returns of this strategy do not decrease the longer the maturity is, but 3-month excess return is greater than 1-month excess return. Expectedly, risk measures indicate greater variability than in strategies 2 and 3 as Strategy 4 is more risky.

6.1.5 Implied volatility strategy

While Strategies 2, 3, and 4 are based on the slope of term structure, this strategy incorporates implied volatility as a decision variable in to the hedging decision. The rationale behind that is that implied volatility is a market estimate of future volatility, predicting thus the future turbulence in the markets. Strategy 5 applies full 100% swap hedge when implied volatility is equal or more than 20% and no hedge when volatility is less than this threshold. Once again, no superior profits compared to no-hedge case can be gained from this strategy either. Results are presented in Table 5 below.

Table 5: Excess returns of Implied volatility strategy

	1 month	3 month	6 month	9 month	12 month
Excess return	-1.59 %	-3.69 %	-5.05 %	-5.60 %	-4.63 %
Significance	3.1E-09	2.3E-17	1.0E-23	8.1E-23	2.0E-16
Std. deviation	2.62 %	8.75 %	14.01 %	16.52 %	21.01 %
TASD	5.17 %	5.45 %	3.70 %	3.48 %	4.43 %

Excess returns over no-hedge strategy are negative for all maturities like in strategies 1, 2, and 3. The pattern however differs from those strategies as the 12-month excess return in Strategy 5 is less negative than the 6- and 9-month excess returns. Interestingly, the excess returns are rather stable across maturities ranging from -1.59% to -5.60% while for other strategies excess returns vary more, except for Strategy 4. It is also noteworthy that the most negative outcome in Strategy 5 is only -5.60%, while in other strategies it is from -7.65% to -16.69%, except for Strategy 4 where it is only -2.81%. All results are statistically significant. In addition, also risk measures are relatively low compared to other strategies. Especially downside risk seems to be rather low resulting in TASD 5.45% at its highest for the maturity of 3 months. It is the lowest of the all strategies when comparing the highest TASD figures of each strategy. The same does not hold for the comparison of standard deviation.

6.2 Summary of the empirical results

The results of each strategy were presented separately in the earlier paragraphs but to give a broader view of the superiority of alternative strategies, the results are pooled together and compared to each others.

First, the riskiness of the strategies is evaluated. In Figure 4 the risk measures, standard deviation (σ), and target absolute semi-deviation (TASD), are shown for all alternative strategies with different maturities.

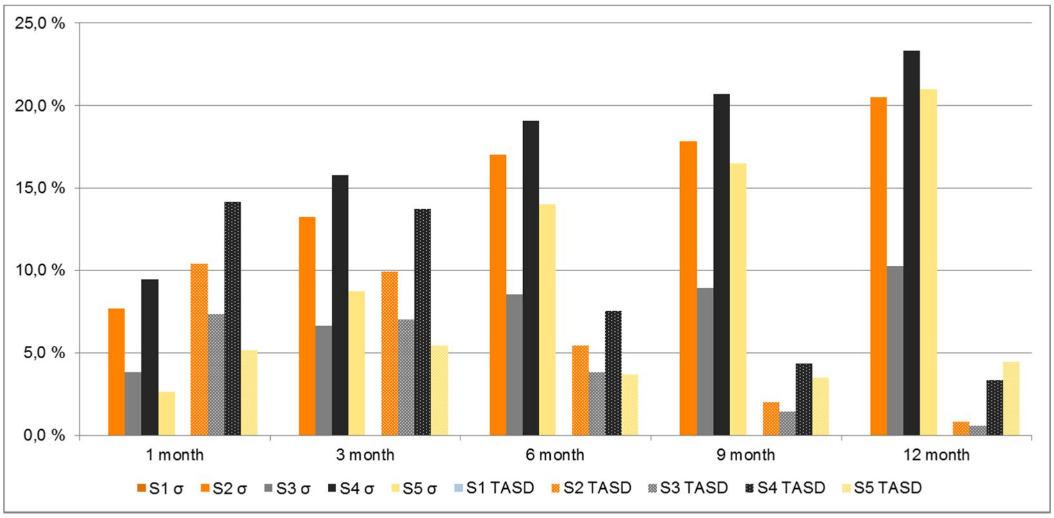

Figure 4: Risk measures of the alternative hedging strategies

The first and sixth columns in every maturity in Figure 4 are not visible indicating that Strategy 1 has zero standard deviation and target absolute semi-deviation as the expected return from the fully hedged risk position is known. Thus, no uncertainty exists in Strategy 1. The rest of the strategies have some uncertainty concerning future cash flows of the position and those figures are arranged in Figure 4 so that first columns with solid fill represent the standard deviation and the latter ones with pattern fill represent the downside risk measured with target absolute semi-deviation where target is 0.

It is true that from the risk minimizing perspective Strategy 1 is the best strategy to follow as all the uncertainty is eliminated by hedging 100% with perfectly correlated hedging instrument. The riskiest strategy seems to be Strategy 4 getting the riskiest figures in 9 out of 10 risk metrics/maturities. Only the downside risk measured for 12-month maturity for Strategy 4 is slightly better than for Strategy 5 which has the highest downside risk within that maturity. The riskiness of Strategy 4 was foreseen as the strategy is named to be “Aggressive term structure strategy” indicating more risk than moderate or sensitive hedging strategies. In that sense, the results are as expected. More surprisingly, within all the strategies except for Strategy 1, the target absolute semi-deviations do not differ notably from the standard deviations in short maturities of 1 and 3 months. Moreover, the downside risk measures are higher than standard deviations for 1-month maturity. Downside risk decreases remarkably for longer maturities and is clearly below the corresponding standard deviations. As all the variability in returns is not unwanted but the downside risk is in the interest of the hedger, the rest of the analysis is based on the excess returns and downside risk only.

Next, Figure 5 presents the excess returns for each hedging strategy and for each maturity.

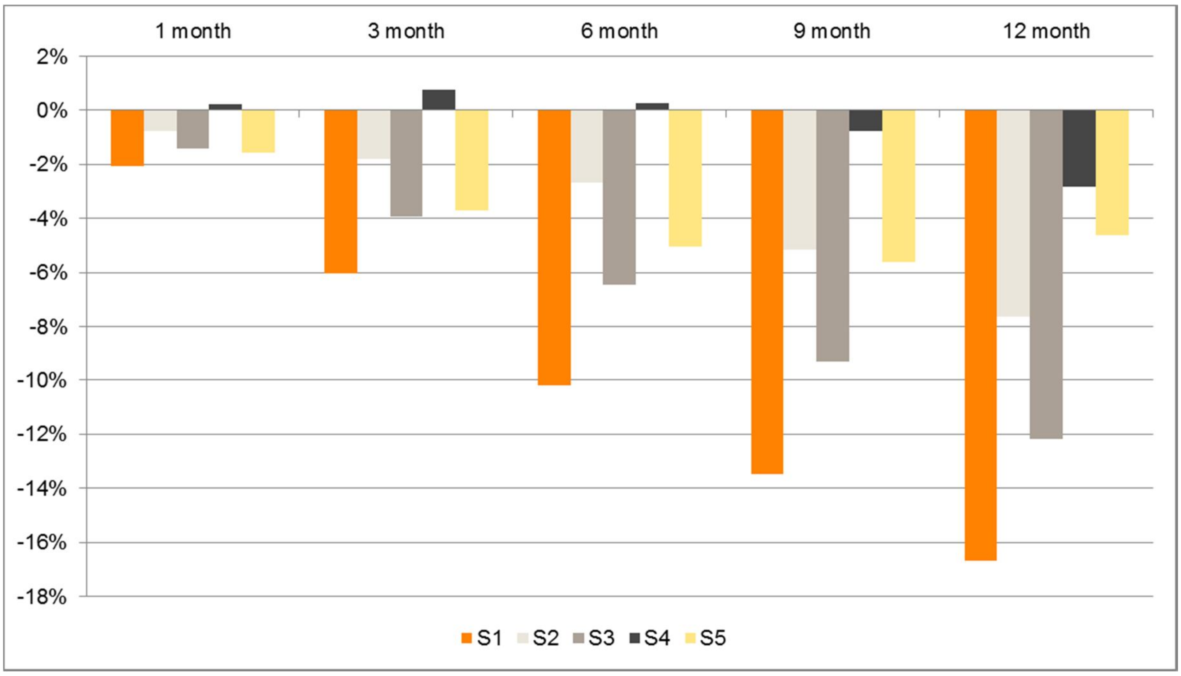

Figure 5: Summary of excess returns by strategy

It is remarkably clear that, on average, all the strategies fail to outperform the benchmark strategy which is to not hedge at all. Only Strategy 4 slightly beats the no-hedge strategy for maturities of 1, 3 and 6 months by creating small positive excess returns. It is also evident that negative excess returns tend to grow the longer the maturity is. This is true in all other cases except for Strategy 5 for 12-month maturity and for Strategy 4 for 3-month maturity.

Interestingly, Strategy 1 gets the worst excess returns in all maturities followed by the Strategy 3. Strategies 2 and 5 compete of the second and third best places having mixed results through the maturities. However, Strategy 2 outperforms Strategy 5 in 4 times out of 5, even though the longest 12-month maturity shows significantly contrary results.

When combining the results of riskiness and excess returns we will get the following Figure 6:

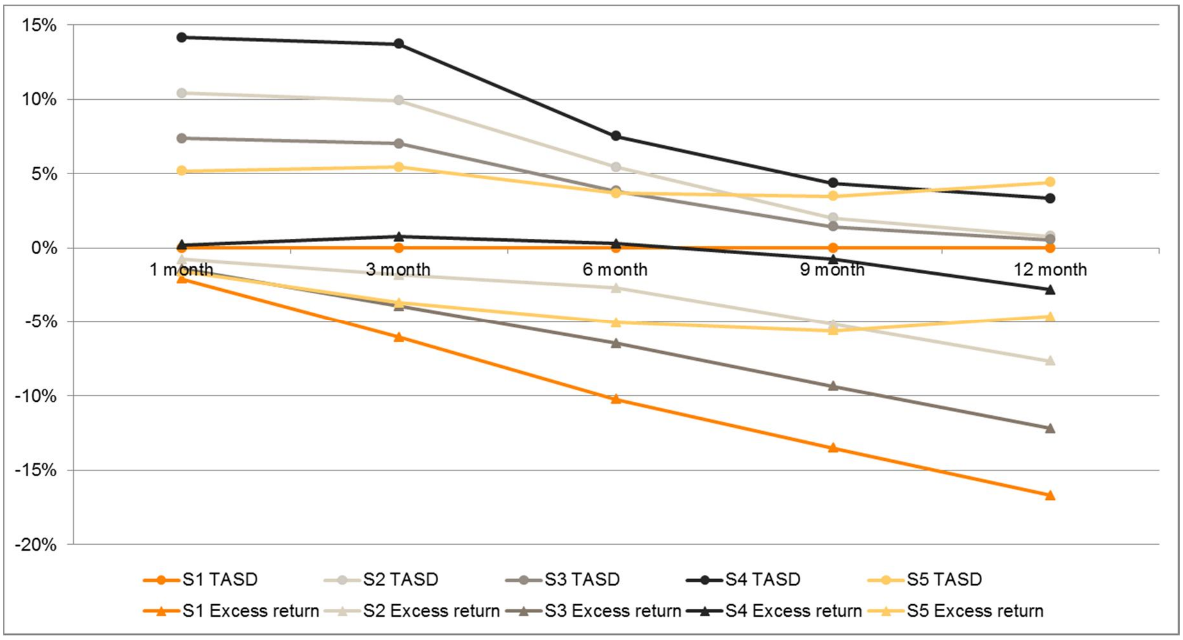

Figure 6: Combined results

It is noteworthy that the spread of excess returns increase, the longer the maturity is, whereas riskiness seems to behave reversely. Moreover, risk and return tend to increase hand in hand, in other words, the higher the risk, the better the return. The aggressive term structure strategy (S4) that generates the highest excess returns gets also the highest risk figures. And contrary, having the best risk measures, the full hedge strategy (S1) performs worst in the excess returns. All other strategies expect implied volatility strategy (S5) seems to follow this risk and return causality throughout different maturities. Implied volatility strategy gets more mixed results. It succeeds fairly well in short maturities 3 and 6 months getting the third best excess returns, while carrying only a risk less than the third riskiest strategy (S3). However, the results in the longer maturities take a new direction. In the 12-month implied volatility strategy (S5) cannot achieve the best excess returns despite carrying the biggest downside risk. Thus the results of implied volatility strategy are not consistent in all maturities.

6.3 Reliability, robustness and validity of the results and data

In this chapter the characteristics and quality of the data are discussed first. After that, the reliability, robustness and validity of the results are evaluated.

6.3.1 Quality of the data

Some problems arise due to the characteristics of the returns in this study. The descriptive statistic is presented in Table 6.

Table 6: Descriptive statistics

	N	Average	Median	Skewness	Kurtosis	t-value	Std. Error	p-value
Strategy 1								
1 month	1243	-2.08 %	-0.89 %	-0.64	2.15	-7.59	0.27 %	6.4E-14
3 month	1202	-6.02 %	-1.13 %	-0.95	0.44	-12.48	0.48 %	1.1E-33
6 month	1137	-10.21 %	-2.11 %	-1.10	0.11	-16.82	0.61 %	7.4E-57
9 month	1072	-13.49 %	-2.92 %	-0.78	-0.71	-19.43	0.69 %	2.8E-72
12 month	1011	-16.69 %	-4.25 %	-0.63	-1.19	-20.99	0.79 %	1.9E-81
Strategy 2								
1 month	1243	-0.75 %	0.00 %	-1.67	6.87	-4.39	0.17 %	1.2E-05
3 month	1202	-1.81 %	0.00 %	-2.12	6.69	-5.76	0.31 %	1.1E-08
6 month	1137	-2.69 %	0.00 %	-2.42	6.93	-6.97	0.39 %	5.4E-12
9 month	1072	-5.17 %	0.00 %	-1.74	2.33	-10.04	0.51 %	9.9E-23
12 month	1011	-7.65 %	0.00 %	-1.46	1.05	-12.87	0.59 %	3.3E-35
Strategy 3								
1 month	1243	-1.41 %	-0.69 %	-0.91	2.67	-7.04	0.20 %	3.1E-12
3 month	1202	-3.92 %	-0.91 %	-1.19	2.22	-10.89	0.36 %	2.1E-26
6 month	1137	-6.45 %	-1.77 %	-1.28	1.80	-14.62	0.44 %	1.8E-44
9 month	1072	-9.33 %	-2.50 %	-0.96	0.23	-17.06	0.55 %	6.7E-58
12 month	1011	-12.17 %	-4.22 %	-0.75	-0.47	-19.51	0.62 %	3.2E-72
Strategy 4								
1 month	1243	0.20 %	0.00 %	-1.52	64.34	3.92	0.05 %	9.2E-05
3 month	1202	0.75 %	0.00 %	-1.83	37.24	5.73	0.13 %	1.3E-08
6 month	1137	0.28 %	0.00 %	-2.59	20.65	1.34	0.21 %	1.8E-01
9 month	1072	-0.75 %	0.00 %	-2.77	11.83	-2.38	0.32 %	1.7E-02
12 month	1011	-2.81 %	0.00 %	-2.28	5.75	-6.82	0.41 %	1.5E-11
Strategy 5								
1 month	1243	-1.59 %	0.00 %	-0.81	2.86	-5.97	0.27 %	3.1E-09
3 month	1202	-3.69 %	0.00 %	-1.22	1.52	-8.61	0.43 %	2.3E-17
6 month	1137	-5.05 %	0.00 %	-1.87	3.20	-10.27	0.49 %	1.0E-23
9 month	1072	-5.60 %	0.00 %	-1.91	3.03	-10.06	0.56 %	8.1E-23
12 month	1011	-4.63 %	0.00 %	-2.32	4.63	-8.37	0.55 %	2.0E-16

First of all, kurtosis values in Strategies 2, 5, and especially in 4 are high. This is mainly due to strategies involving only hedge ratios of 100% or 0%. All the observations getting hedge ratio of 0% have zero excess returns as the return is exactly the same than no-hedge return used as the benchmark in this study. This leads to the situation where these strategies get several observations of exactly zero returns which increases kurtosis values. This can also be seen from the median values being zero for the above-mentioned strategies 2, 3, and 5.

Skewness values are also different from zero. Skewness gets negative values in all the strategies. This implies that the distribution is skewed to the left, in other words the tail on the left side of the probability density function is longer and/or fatter than the right side. However, skewness figures stay below 3.00, so it is not that serious problem for a test.

6.3.2 Validity and reliability of the results

There was a concern about possible bias in the results due to examining daily hedging behavior to monthly hedging periods even though that is the real-world practical situation. Figure 7 below demonstrates this problem.

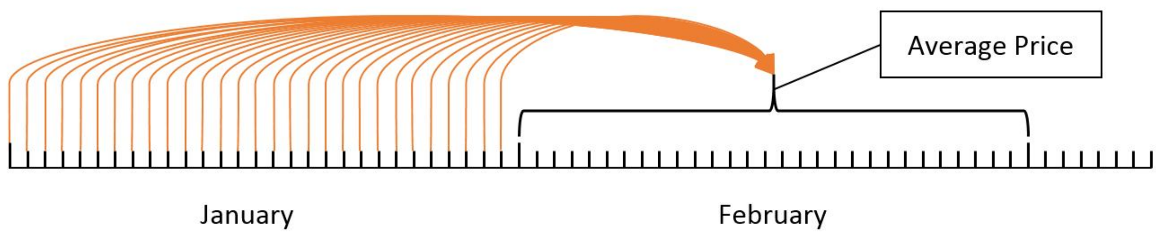

Figure 7: Problem related to the data

The concern was mainly related to 1 month figures as it is the closest month and the problem is assumed to be more severe with the nearest maturity. In this study, 1 month hedging period means hedging the forthcoming month and therefore, the period may actually be more or less than one month. For example, in January a risk position may arise any day from 1st to 31st, and in any of these cases, hedging is done for February calendar month (daily average price of February). It follows that on January first there might be less information about February prices than on January 31st. This phenomenon is tested by slice analysis. In other words, the sample data is sliced by the date of a month so that all 1st, 2nd, 3rd.... days are grouped to own subgroups and the same statistics calculated for these subgroups. These results are shown in Figure 8.

Figure 8: Slice analysis of the results

Most of 1 month figures are not statistically significant due to low N (23-44), but as can be seen from the Figure x above, 1-month average excess returns tend to get closer to zero when moving towards the hedging month. However, some strategies seem to suffer more from this phenomenon than others. Strategy 1 is most affected, while Strategy 4 is least affected. The effect is not as visible for longer maturities as assumed. More detailed results are presented in Appendix 2.

6.3.3 Robustness of the results

To figure out whether the test results are robust to different market conditions or not, the sample period is divided to sub-periods according to price development and volatility (see Figure 9).

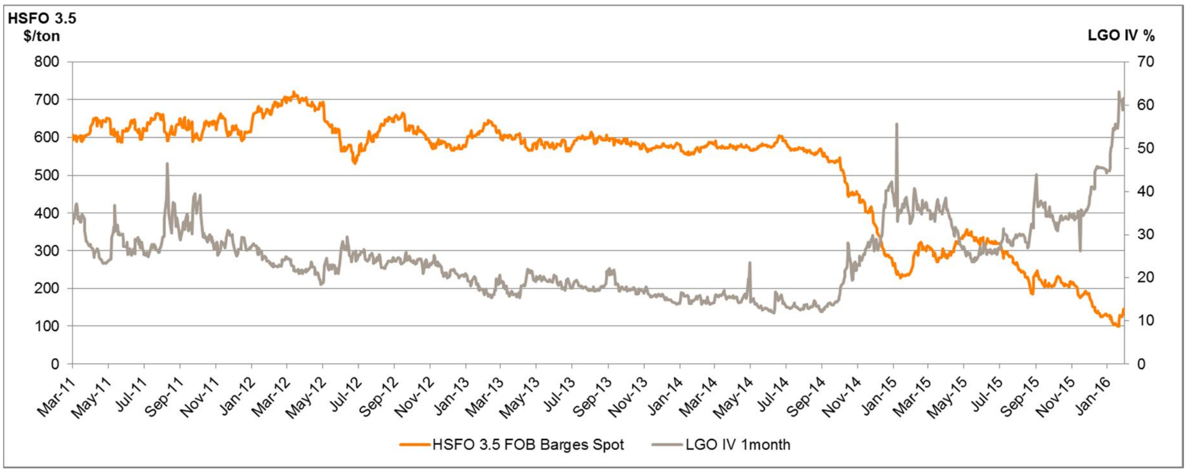

Figure 9: Price development and volatility

Three different sub-periods is examined on the basis of Figure 9:

1. Relatively stable period from the beginning of the sample period 1.3.2011 to 30.9.2014.
2. Even more stable period between 1.10.2012 and 30.9.2014.
3. Turbulent period from 1.10.2014 to the end of the sample period 29.1.2016.

The same tests were run for these three sub-periods as for the whole sample. The results are presented in the graphic form.

First the excess returns for each strategy and for each maturity are shown in Figure 10 for the above-mentioned three sub-periods and for the full sample period.

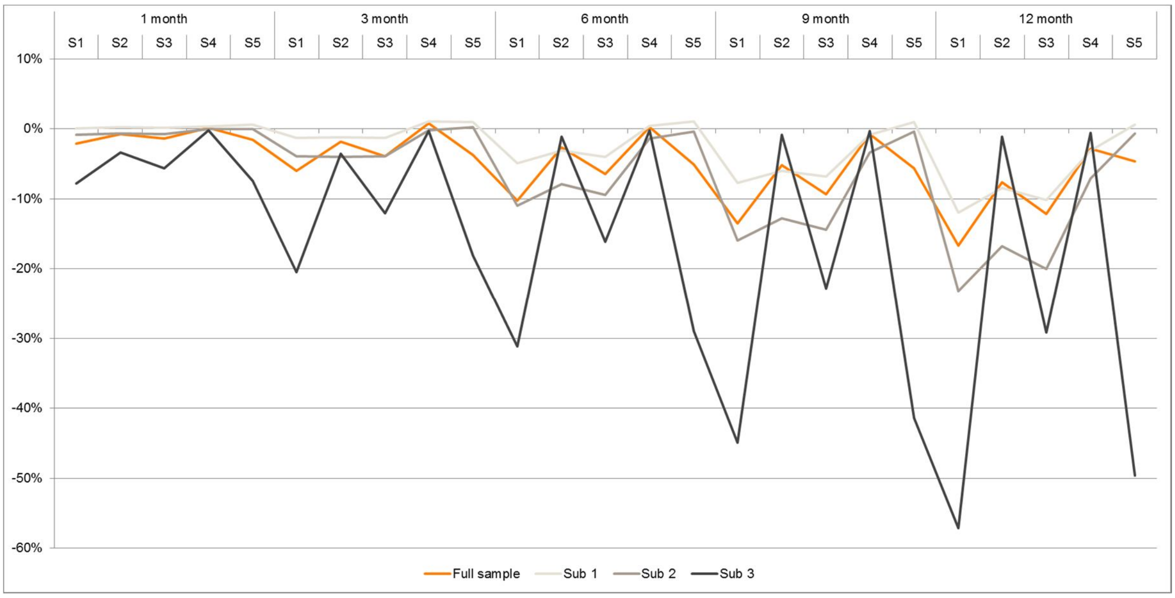

Figure 10: Excess returns by sub-periods

As can be seen from Figure 10, excess returns tend to have the same direction in all sub-periods compared to full sample period. In addition, the results for sub-periods 1 and 2, which represent relatively stable periods, follow the full sample results quite well, especially for shorter maturities. The most varying sub-period is the turbulent period covering the latest 16 months of the sample period. Particularly Strategies 1 and 5, but also Strategy 3 generate extremely negative excess returns compared to the full sample period.

The results are clearly a consequence of oil market crash during this turbulent period. Bitumen price has fallen more than 73% from October 2014 to the end of January 2016. Decline has been almost continuous excluding few short recovering periods. This means that in Strategy 1 where full 100% hedge is done in all market situations, the hedges create negative excess returns compared to no-hedge case when market declines, which is the case in sub-period 3.

Explanation also exists for extreme results from Strategy 5 in turbulent sub-period 3. Implied volatility incorporates the market uncertainty in a turbulent period, increasing thus implied volatility. In Strategy 5, the full hedge is executed when volatility is more than 20%, and during this turbulent sub-period, it leads to almost continuous hedging which again explains the extremely negative excess returns.

The results are very different when investigating from risk minimizing point of view. The downside risks are documented in Figure 11. As predicted, risk figures measured by target absolute semi-deviation, representing the positions' downside risk are quite different compared to excess returns. While strategies 1 and 5 faced extremely negative excess returns during the turbulent sub-period 3, the risk metrics are totally opposite. The downside risk of these strategies is zero for all maturities in sub-period 3. This is due to earlier-explained full hedge which is true for Strategy 1 in all market conditions, but leads to almost the same situation for Strategy 5, when market is turbulent and implied volatility increases. In contrast, by offering almost zero excess returns in sub-period 3, Strategies 2 and 4 meet higher downside risk than competing strategies in short maturities up to 6 months.

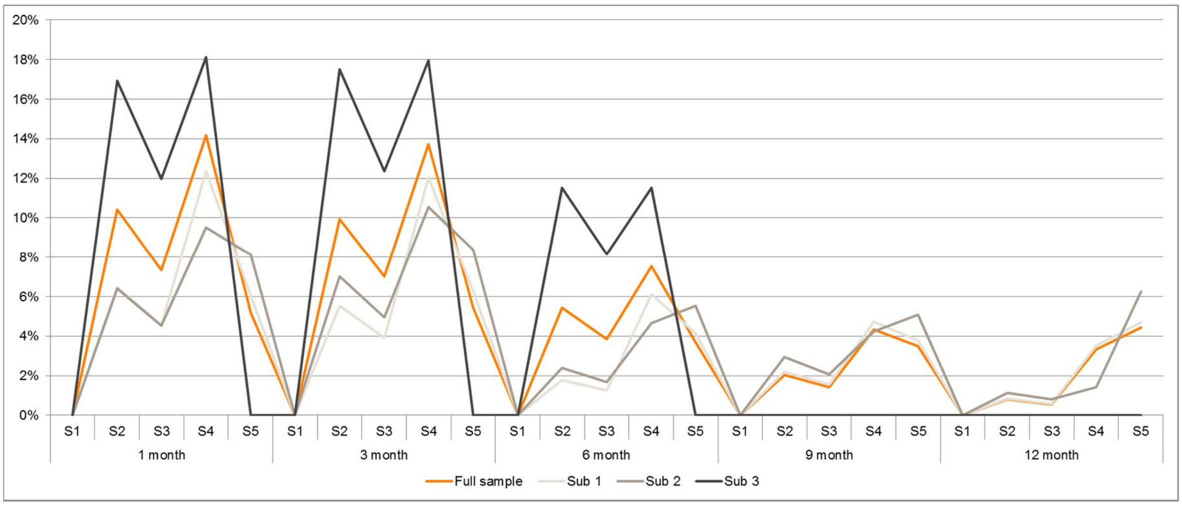

Figure 11: Downside risk by sub-periods

To conclude the robustness tests of the results, on average, during the relatively stable period the results are somewhat consistent with the full sample results. On the other hand, extreme market situations, like turbulence and falling prices during the latter part of the sample period, cause results to differ. Parallel, but opposite case is most presumable true when market steeply rises. In those turbulent or declining/rising market conditions, risk measures favor implied volatility strategy beside full hedge strategy. However, the excess returns compared to no-hedge case can be extremely negative or positive depending on the direction of the market development.

7 CONCLUSIONS

This thesis has investigated alternative hedging strategies for companies using bitumen as raw material in their production. Moreover, the aim is to find out whether there is a superior hedging strategy, among those examined in the empirical part of the thesis.

The theoretical part of the thesis reviews the existing literature to find suitable candidate strategies for empirical testing. Studies providing support for the so-called term structure strategies in investing context were found, and these strategies were chosen to be applied for hedging strategies.

Three different term structure strategies beside the so-called naïve hedging strategy and competing implied volatility strategy were examined by using the almost five year daily price data for bitumen. The effectiveness of these alternative hedging strategies was measured in terms of excess returns over no-hedge strategy and in addition, in terms of target absolute semi-deviation representing the downside risk of the strategy. All the tests were implemented for five different maturities: 1, 3, 6, 9 and 12 months.

The results show that in terms of excess returns any of the strategies tested does not outperform no-hedge strategy for any of the maturities examined. The results are rational, as the sample period includes first the relatively stable period followed by the period of oil markets' crash that started in the autumn 2014. At least partially due to sample period characteristics, no-hedge strategy was superior to any of hedging strategies examined. The stable sub-period without the market crash was also investigated, but the results were not remarkably different to those for the full sample period. The crash period alone indicated extremely negative excess returns for strategies of high hedge ratios, like for full hedge strategy (S1), implied volatility strategy (S5) in which the hedge ratio was high during the turbulent markets, as well as for conservative term structure strategy (S3) where the hedge ratio is never lower than 50%. However, the aggressive term structure strategy (S4) seems to be the best performing strategy within the five tested strategies in the thesis. This strategy even slightly outperforms the no-hedge strategy in short maturities from 1 to 6 months. In addition, the results for aggressive term structure strategy are robust within all sub-periods examined.

Despite the results presented above, it cannot be suggested to leave all the risk positions unhedged or go for the best performing aggressive term structure strategy in case the company is sensitive for uncertain cash flows. The full hedge strategy representing so-called naïve hedging gets the highest negative excess returns, but also the lowest risk metrics in this study. The target absolute semi-deviation (TASD) where the target return for position is set to zero, measuring the downside risk, is zero for the full hedge strategy. In other words, this strategy is the best in terms of downside risk indicating no risk at all. At the same time, the best performing aggressive term structure strategy gets the highest risk metrics among all the tested strategies in all maturities except for the 12-month maturity.

It is clearly evident that to be able to gain from favorable price movements a company must be ready to bear more uncertainty concerning returns. There is no such thing like free lunch in the world of hedging. The risk and return seem to increase hand in hand. For a sensitive company willing to have some upside potential in their returns, some moderately performing hedging strategy might be the right one. There is no need to choose either full hedge or extremely aggressive strategies because, for example, conservative term structure strategy generates less negative excess returns than the full hedge strategy, coupled with quite moderate risk level.

The choice of the applicable hedging strategy depends on the risk profile the company is willing to face. Therefore, the key element is the risk management policy of the company. It is good to remember that no sub-period of clearly rising markets was included in the sample period examined. Thus, the results including such a sub-period might differ significantly from the results obtained in this thesis. This gives rationale for further research around the topic with longer sample period including wider spectrum of market conditions. It would also be interesting to test the parallel option strategies. Moreover, the existence of quantity risk would create a whole new array for the applicable hedging strategies and instruments, and would be a valuable research topic for companies operating in project business and facing uncertainty in project acceptance during the tender phase.

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APPENDICES

Appendix 1: Descriptive statistics of Gasoil implied volatilities

	LGO IV 1 month	LGO IV 3 month	LGO IV 6 month	LGO IV 9 month	LGO IV 12 month
N	1 243	1 202	1 137	1 072	1 011
Min	11,8	12,0	12,4	12,4	12,4
Max	63,1	43,1	40,0	38,4	38,4
Average	24,6	24,0	23,3	22,3	21,5
Median	23,8	24,7	24,5	23,3	22,3

Appendix 2: Slice analysis of excess returns

Day of the month	N	Strategy 1 Average excess	Strategy 1 T-value	Strategy 1 Std Error	Strategy 1 p-value	Strategy 2 Average excess	Strategy 2 T-value	Strategy 2 Std Error	Strategy 2 p-value	Strategy 3 Average excess	Strategy 3 T-value	Strategy 3 Std Error	Strategy 3 p-value	Strategy 4 Average excess	Strategy 4 T-value	Strategy 4 Std Error	Strategy 4 p-value	Strategy 5 Average excess	Strategy 5 T-value	Strategy 5 Std Error	Strategy 5 p-value
1	38	-4.50 %	-2.32	1.94 %	0.026	-1.17 %	-1.14	1.03 %	0.262	-2.84 %	-2.19	1.30 %	0.035	-0.37 %	-0.61	0.61 %	0.545	-2.79 %	-1.54	1.81 %	0.132
2	41	-3.70 %	-1.82	2.03 %	0.077	-1.84 %	-1.26	1.46 %	0.214	-2.77 %	-1.72	1.61 %	0.093	0.14 %	0.56	0.24 %	0.580	-2.38 %	-1.23	1.94 %	0.226
3	42	-5.25 %	-2.71	1.94 %	0.010	-3.18 %	-2.04	1.56 %	0.048	-4.22 %	-2.58	1.64 %	0.014	-0.84 %	-1.08	0.77 %	0.285	-4.41 %	-2.33	1.89 %	0.025
4	42	-4.17 %	-2.39	1.75 %	0.022	0.11 %	0.13	0.78 %	0.894	-2.03 %	-1.83	1.11 %	0.074	0.53 %	1.58	0.33 %	0.121	-3.69 %	-2.15	1.72 %	0.038
5	41	-2.83 %	-1.69	1.68 %	0.100	-0.34 %	-0.34	1.01 %	0.737	-1.59 %	-1.31	1.21 %	0.197	0.86 %	1.92	0.45 %	0.062	-2.43 %	-1.48	1.64 %	0.148
6	40	-1.67 %	-1.00	1.66 %	0.322	-0.06 %	-0.07	0.97 %	0.947	-0.87 %	-0.73	1.18 %	0.467	0.42 %	1.59	0.26 %	0.119	-1.20 %	-0.76	1.59 %	0.455
7	41	-1.71 %	-1.10	1.55 %	0.277	-0.21 %	-0.29	0.70 %	0.772	-0.96 %	-0.97	0.98 %	0.336	0.58 %	1.92	0.30 %	0.062	-1.38 %	-0.94	1.47 %	0.353
8	42	-2.51 %	-1.58	1.59 %	0.121	-1.25 %	-1.20	1.04 %	0.236	-1.88 %	-1.58	1.19 %	0.122	0.47 %	1.58	0.30 %	0.122	-1.80 %	-1.20	1.51 %	0.239
9	42	-2.49 %	-1.36	1.83 %	0.182	-1.00 %	-0.82	1.21 %	0.417	-1.74 %	-1.26	1.39 %	0.216	0.22 %	0.84	0.26 %	0.407	-2.33 %	-1.29	1.80 %	0.203
10	43	-3.72 %	-2.22	1.68 %	0.032	-1.77 %	-1.40	1.27 %	0.169	-2.75 %	-2.01	1.36 %	0.051	0.21 %	1.42	0.14 %	0.163	-3.42 %	-2.06	1.66 %	0.045
11	44	-3.11 %	-2.11	1.47 %	0.041	-1.77 %	-1.77	1.00 %	0.084	-2.44 %	-2.17	1.12 %	0.036	0.28 %	1.43	0.20 %	0.160	-2.58 %	-1.79	1.45 %	0.081
12	43	-1.79 %	-1.12	1.59 %	0.268	0.09 %	0.08	1.20 %	0.940	-0.85 %	-0.65	1.31 %	0.522	0.19 %	1.23	0.15 %	0.226	-1.32 %	-0.85	1.56 %	0.402
13	43	-0.81 %	-0.52	1.57 %	0.607	-0.82 %	-0.80	1.03 %	0.429	-0.82 %	-0.69	1.19 %	0.495	0.32 %	1.59	0.20 %	0.119	-0.63 %	-0.40	1.55 %	0.688
14	42	-1.33 %	-0.96	1.39 %	0.344	-0.88 %	-1.12	0.79 %	0.270	-1.11 %	-1.14	0.97 %	0.261	0.26 %	0.62	0.42 %	0.538	-1.28 %	-0.93	1.37 %	0.356
15	42	-1.18 %	-0.77	1.53 %	0.446	-1.15 %	-1.16	0.99 %	0.252	-1.16 %	-1.01	1.15 %	0.317	0.51 %	1.62	0.31 %	0.112	-0.68 %	-0.45	1.50 %	0.653
16	42	-2.17 %	-1.43	1.52 %	0.160	-0.83 %	-0.90	0.92 %	0.376	-1.50 %	-1.37	1.10 %	0.179	0.23 %	1.42	0.16 %	0.162	-1.79 %	-1.20	1.49 %	0.237
17	43	-2.99 %	-2.23	1.34 %	0.032	-0.76 %	-0.99	0.77 %	0.327	-1.88 %	-2.01	0.94 %	0.051	0.12 %	1.00	0.12 %	0.323	-2.61 %	-1.98	1.32 %	0.055
18	43	-2.17 %	-1.57	1.38 %	0.124	-0.80 %	-1.02	0.78 %	0.313	-1.48 %	-1.55	0.96 %	0.129	0.24 %	1.41	0.17 %	0.165	-1.41 %	-1.04	1.35 %	0.305
19	43	-1.14 %	-0.75	1.51 %	0.456	-0.21 %	-0.27	0.80 %	0.788	-0.68 %	-0.66	1.02 %	0.511	0.18 %	1.26	0.14 %	0.216	-0.56 %	-0.38	1.48 %	0.708
20	43	-0.41 %	-0.28	1.44 %	0.779	0.01 %	0.02	0.66 %	0.985	-0.20 %	-0.22	0.92 %	0.831	0.17 %	1.00	0.17 %	0.323	-0.24 %	-0.17	1.42 %	0.869
21	41	-0.40 %	-0.31	1.32 %	0.761	-0.11 %	-0.13	0.85 %	0.895	-0.26 %	-0.26	0.99 %	0.795	0.26 %	1.00	0.26 %	0.323	-0.39 %	-0.30	1.30 %	0.765
22	41	-1.21 %	-1.00	1.21 %	0.322	-0.98 %	-1.36	0.72 %	0.182	-1.10 %	-1.26	0.87 %	0.214	0.00 %	N/A	0.00 %	N/A	-0.69 %	-0.59	1.17 %	0.559
23	43	-1.44 %	-1.01	1.42 %	0.318	0.00 %	0.00	0.78 %	0.999	-0.72 %	-0.73	0.98 %	0.468	0.42 %	1.38	0.30 %	0.175	-0.88 %	-0.64	1.38 %	0.528
24	43	-2.17 %	-1.56	1.39 %	0.125	-0.64 %	-0.75	0.86 %	0.457	-1.41 %	-1.39	1.01 %	0.171	0.15 %	1.00	0.15 %	0.323	-1.89 %	-1.40	1.35 %	0.168
25	36	-1.33 %	-0.99	1.34 %	0.328	-0.64 %	-0.71	0.91 %	0.483	-0.99 %	-0.96	1.03 %	0.345	0.19 %	1.22	0.15 %	0.230	-0.68 %	-0.53	1.27 %	0.598
26	36	-1.37 %	-0.93	1.48 %	0.360	-1.31 %	-1.62	0.81 %	0.114	-1.34 %	-1.32	1.02 %	0.196	0.12 %	1.00	0.12 %	0.324	-0.60 %	-0.42	1.42 %	0.674
27	41	-1.27 %	-1.09	1.16 %	0.281	-0.67 %	-1.03	0.65 %	0.307	-0.97 %	-1.21	0.80 %	0.235	0.10 %	1.00	0.10 %	0.323	-0.81 %	-0.72	1.13 %	0.476
28	41	-0.48 %	-0.44	1.10 %	0.664	0.79 %	0.95	0.83 %	0.347	0.15 %	0.17	0.91 %	0.867	0.12 %	1.00	0.12 %	0.323	-0.38 %	-0.35	1.09 %	0.729
29	37	-1.75 %	-1.39	1.26 %	0.173	-1.41 %	-1.65	0.85 %	0.108	-1.58 %	-1.63	0.97 %	0.112	0.21 %	1.00	0.21 %	0.324	-1.36 %	-1.11	1.22 %	0.272
30	39	-1.82 %	-1.43	1.27 %	0.160	-0.23 %	-0.34	0.67 %	0.736	-1.02 %	-1.20	0.85 %	0.239	-0.14 %	-0.48	0.29 %	0.631	-1.19 %	-0.97	1.23 %	0.339
31	23	-1.29 %	-1.02	1.26 %	0.319	-0.12 %	-0.22	0.57 %	0.831	-0.71 %	-0.88	0.80 %	0.388	0.00 %	N/A	0.00 %	N/A	-1.09 %	-0.87	1.25 %	0.396