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Commodity Risk: The impact of Oil volatility and Hedging strategies on Firm Value

Thesis Supervisor

Professor Stefano Di Colli

Candidate

Riccardo Del Maestro

224561

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Introduction – The April 2020 Oil Price Drop

Commodities, because of their apparent simple nature, may superficially seem boring and trivial if one does not have enough knowledge about the markets they trade in and their dynamics. They become much more interesting when you acknowledge that they are the most volatile asset traded in financial markets and because of their volatile nature can have an impact on the value of firms that deal with them, both as buyers and as sellers. It only gets better when one discovers the wide range of financial instruments and derivatives that are used to trade commodities and the techniques that exposed firms use to reduce the risk deriving from the price fluctuations of these apparently simple and innocent objects.

This thesis starts from the very bottom of financial theory, by explaining first what risk is, how it is measured and how it is managed, then by exploring the types and mechanics of the markets for commodities and the numerous instruments and strategies that are related to commodities trading and hedging. Once these dynamics have been made clear, the dissertation proceeds by analyzing the most influential questions that commodity-dealing firms have about the risk caused by commodity price movements: To what extent does commodity risk impact the equity value of my firm? How does the use of commodity risk management instruments impact the value of my firm?

More specifically, the empirical studies that are going to be examined will provide a comparison of these two impacts across different industries, however, particular attention will be dedicated to crude oil and other petroleum-derived products. This is so because of very recent developments in the crude oil market have drawn substantial attention from the media to themselves.

On April 20^{th}, 2020 U.S. Oil prices broke through rock bottom by heading into negative territory for the first time in history. The West Texas Intermediate (WTI) traded as low as -$40.32 a barrel in a day of massive market turmoil. This scenario is strictly related to the concurrent Coronavirus outbreak, an infectious disease that forced the world population to quarantine measures inside their homes. This implied that people started to work from home and avoid contacts with other individuals, thereby causing a drastic fall in Oil demand. As a consequence, Oil storage facilities were so full that producers were willing to pay to just get it off their hands and have someone take it away with some extra money. Previous efforts by OPEC to cut back on production by 10% globally were not effective, causing further political instability in the U.S., which backed the supply cut by the organization.

With this being said, commodities such as Oil do have an impact on many different entities and their effect can spread enough to affect the entire world economy. This event has provided the main inspiration for the topic chosen in this thesis.

Finally, a regression model to estimate the impact of Oil price fluctuations on Equity share returns during the COVID-19 outbreak is proposed, on the basis of similar studies.

1. Risk

1.1 Risk definition

In finance, risk can be defined as the probability that actual results will differ from expected results. For example, the return on an investment may turn out to be lower than expected, sometimes even resulting in a loss. However, risk works both directions: a riskier investment may potentially bring about a higher return than a safer one. The relationship between risk and return is a cornerstone of financial theory: the higher the risk borne by an investor the higher the potential return from the investment. This is why safer assets such as Treasury Bonds have lower rates of return than Corporate Bonds, the formers are safer because they are issued by governments which can pay back their debt by collecting taxes from their citizens, the latter are issued by corporations which are generally seen as riskier because they depend mostly on their own business and hence have a higher chance to become insolvent. In the same way as a commercial bank charges a higher interest rate to customers who have a low credit score and are more likely to default on their loan payments, so investors require a higher rate of return to invest in riskier corporate bonds (that is, lend money to companies).

There are many different types of risk, depending on the factor causing its existence. In this thesis however, the focus is on Commodity risk: "The financial risk on an entity's financial performance/ profitability upon fluctuations in the prices of commodities that are out of the control of the entity since they are primarily driven by external market forces. Sharp fluctuations in commodity prices are creating significant business challenges that can affect production costs, product pricing, earnings and credit availability" (Deloitte, 2018).

1.2 Risk measurement

"Risk plays a key role in the decision-making process of both investors and companies, so it is important that the risk associated with an investment can be quantified. Risk is measured by the *standard deviation* (σ) of returns of a share, calculated using either historical returns or the expected future returns" (Watson, Head, 2007). Alternatively, *variance* (σ^2) which is the square of the standard deviation, can be used to quantify risk as well. Both measures indicate the deviation of the returns of an asset from the *mean return* ($\bar{r}$), which is the expected value of the return in the probability distribution of returns:

$$\bar{r} = \sum_{i=1}^{n} p_i \times r_i \qquad Var(r_i) = \sum_{i=1}^{n} p_i \times \ (r_i - \bar{r}\ ) \qquad StDev(r_i) = \sqrt[2]{Var(r_i)}$$

Variance reflects both upside risk, when returns exceed the expectations and downside risk, when returns fall short of expectations. This confirms what was stated about risk in the previous paragraph (risk works both directions…). Variance and standard deviation are in fact symmetric measures of dispersion.

Nevertheless, these measurements do not provide the most insightful information to investors, particularly those more interested in the chance of realizing a loss than in volatility. As a matter of fact, investors care more about the lower tail of the distribution, which represents returns below expectations. For this purpose, the *semi-variance* can be calculated:

$$sv_r = \frac{1}{T-1}\sum_{t=1}^{T}(\min[0; r_t - \bar{r}])^2$$

As it represents asymmetries and downside risk in the distribution of returns. Notice that this measure works well with asymmetric distributions and the fact investors may have different targets which may differ from $\bar{r}$. If so happens, the mean return can be substituted with an individual target r^* to reflect downside risk according to individual preferences.

Another method that can be used to account for losses and in case of skewed distributions is *Value at Risk (VaR)*. It is the loss corresponding to a very low percentile of the entire return distribution, such as the 5th or 1st percentile return. It is reported as a metric into bank regulations and closely regarded by risk managers. Basically, it can be thought of as another name for the *quantile* of a distribution, which is the value below which lie *q%* of the possible values. For example, the meaning of the commonly estimated 1% *VaR* is that 99% of returns will exceed the VaR, and 1% of them will be worse. Hence, the 1% *VaR* may be viewed as the cut-off separating the 1% worst-case future scenarios from the rest of the distribution. In case the returns are normally distributed (and more than 30 observations of returns are gathered) the *VaR* is determined in its entirety by the mean and standard deviation of the distribution (Bodie, Kane, Marcus, 2018):

$$VaR = \bar{r} - z\sigma$$

Where $\bar{r}$ is the mean return, z is the *z-score* corresponding to the confidence level chosen (2.33 in case of 99% confidence) and σ is the standard deviation.

By linking the risk of a portfolio to the co-movement between individual assets in that portfolio, Harry Markowitz changed the way risk is commonly perceived. He did so by proving that the variance of a portfolio can be written as a function of what portion of the funds is invested in each security (weight, *w*) and the variability (variance, σ^2) of the individual securities but also of the *correlation* ρ between the securities (Damodaran, 2007):

$$E(r_p) = w_A r_A + w_B r_B \qquad \sigma_p^2 = w_A^2\sigma_A^2 + w_B^2\sigma_B^2 + 2w_A w_B \sigma_A \sigma_B \rho_{AB}$$

$$or\ equivalently, \qquad \sigma_p^2 = w_A^2\sigma_A^2 + w_B^2\sigma_B^2 + 2w_A w_B \sigma_{A,B}$$

Where $\sigma_{A,B}$ is the *Covariance* between assets A and B, as the correlation is simply the covariance of the standardized variables.

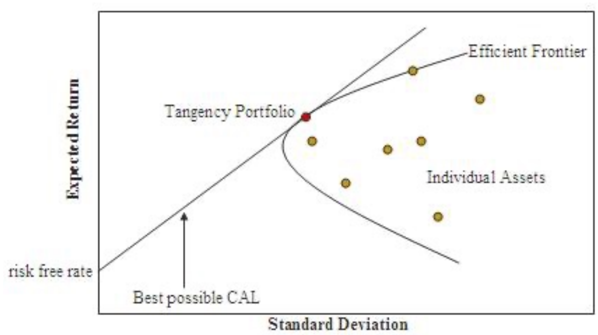
Markowitz's statement about the importance of correlation in determining portfolio variance can be proved if we consider a portfolio that contains a large number *n* of securities and compare the number of variance and covariance terms:

$$\sigma_p^2 = \sum_{i=1}^{n} w_i^2\,\sigma_i^2 + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} w_i\,w_j\sigma_{i,j}$$

In fact, there are *n* variance terms and $n^2 - n$ covariance terms. Hence, as *n* becomes very large the contribution of variance terms to the variance of the portfolio return goes to zero while that of the covariance terms goes to the *average covariance*.

Markowitz then derived the *efficient frontier*, a set of optimal portfolios for different combinations of risk and return. His approach reduces investor choices down to two dimensions: *expected return* and *variance*. What Markowitz's theory put more emphasis on, is not the volatility of single assets, but their co-movement with the entire portfolio. It does so because diversifying by incorporating assets that move independently from one another into the portfolio, reduces overall risk. In a perfectly diversified portfolio, the *specific risk* of the assets is eliminated so that the portfolio is subject to *systematic risk* only, deriving from market movements. The renowned CAPM originates from this assumption. (Damodaran, 2007).

Figure 1 - Markowitz's Efficient Frontier



On the x-axis the standard deviation that is the variability of returns, a proxy for risk; on the y-axis, the expected return of the portfolio.

Source: www.wikipedia.com

In the Capital Asset Pricing Model (CAPM), the expected rate of return of a risky asset depends on the rate of return of a risk-free asset and on the responsiveness of the risky asset to market movements. This model lies on several assumptions, such as the existence of a completely risk-free asset, markets being in equilibrium and all investors holding well-diversified efficient portfolios.

$$E(r_j) = r_f + \beta(E(r_m) - r_f)$$

Where β is the ratio of the covariance of the asset with the market portfolio (a portfolio containing all risky assets traded in the market, representing the market as a whole) to the variance of the market portfolio and $(E(r_m) - r_f)$ is the *market risk premium*, which is the excess return of the market portfolio on the risk-free asset.

Stephen Ross' 1976 Arbitrage Pricing Theory (APT) on the other hand, does not focus on efficient portfolios. Instead, it assumes that stock returns depend both on macroeconomic influences (*factors*) and on other events specific to that company or entity (*noise*) and that no arbitrage activity is profitable, following the Law of One Price (two financially equivalent assets must have the same price). It is a multi-factor model:

$$E(r_j) = a + b_1(r_{factor1}) + b_2(r_{factor2}) + b_3(r_{factor3}) + \cdots + noise$$

The factors can be chosen at will, in our case we could choose an oil price factor, in other cases interest rate factors and so on. Some stocks will be more sensitive to a particular factor than other stocks. For example, Royal Dutch Shell shares may be more affected by oil price changes than, say, Tesla shares. If factor 1 captures unexpected changes in oil prices, b_1 will be higher for Royal Dutch Shell. Notice that every asset still bears systematic and non-systematic risk and that the latter can still be diversified away. Hence, diversified investors ignore the *noise* when deciding whether to buy or sell a stock.

APT conveys the idea that the expected risk premium on a stock depends on the risk premium of each factor and on the stock's sensitivity to each factor:

$$Expected\ risk\ premium = r - r_f = b_1(r_{factor1} - r_f) + b_2(r_{factor2} - r_f) + \cdots$$

Notice how a value of zero for each *b* in the formula would cause the expected risk premium to be zero. This checks out because a well-diversified portfolio arranged to have zero responsiveness to every macro factor is basically risk-free and therefore is priced to offer the r_f interest rate. If we assume that such a portfolio offered $r > r_f$, investors could make a riskless arbitrage profit by borrowing risk-free and using these funds to buy the diversified portfolio. Conversely, if this portfolio offered $r < r_f$, investors could make a riskless profit by short-selling the diversified portfolio and investing in a risk-free asset.

Chen, Roll and Ross (1986) developed a further multifactor model following the macroeconomic factor approach of the APT:

$$r_i = r_f + b_{IP}IP + b_{EI}EI + b_{UI}UI + b_{CG}CG + b_{GB}GB + \varepsilon_i$$

Where:

- $IP = \%\Delta IP$ percentage change in industrial production
- $EI = \%\Delta EI$ percentage change in expected inflation
- $UI = \%\Delta UI$ percentage change in unexpected inflation
- $CG = \%\Delta CG$ percentage change in excess return of long-term corporate bonds over long term government bonds
- $GB = \%\Delta GB$ percentage change in excess return of long-term government bonds over short-term government bonds

The Fama and French (1993) Three Factor Model uses (other than the excess return on the market portfolio, R_M) selected factors reflecting firm fundamentals that seem to proxy for exposure to systematic risk, as of empirical evidence. These factors are chosen on the basis of how well their underlying variables have been in predicting average returns according to past evidence and for this reason, may be capturing risk premiums:

$$R_{it} = \alpha_i + \beta_{iM}R_{Mt} + \beta_{iSMB}SMB_t + \beta_{iHML}HML_t + \varepsilon_{it}$$

Where:

- SMB = Small Minus Big (excess return of a portfolio of small stocks on a portfolio of large stocks)
- HML = High Minus Low (excess return of a portfolio of stocks with a high book-to-market ratio on a portfolio of stocks with a low book-to-market ratio)

Liew and Vassalou (2000) have shown how these two factors are linked to more fundamental sources of risk, as they anticipate the business cycle. In their empirical analysis, they consider the two risk factors, *SMB* and *HML*, in several countries in the period 1978-1996. For each country, they calculated the mean of the two risk factors in years preceding *good* GDP growth and in years preceding *bad* GDP growth. The differences of both factors (*Good State – Bad State*) turned out to be positive, indicating that these factors take larger values in years preceding good growth than in years preceding bad growth. This proves how the performance of HML and SMB is linked to future economic growth, so the hypothesis of Fama and French (1993) is supported by these results.

Fama and French's three factor model is considered a benchmark within the class of multi-factor models introduced by Robert Merton's Intertemporal CAPM. Other models using macroeconomic variables may capture different sources of systematic risk other than the market portfolio such as: liquidity, exchange rates, inflation rates, commodity prices, yield curve slope and momentum. These could also be added to the Three Factor Model or could replace its factors, according to specifications.

1.3 Risk management

Now that we have defined what risk is, we examine more in depth the concept of risk management and the main reasons why firms may need to carry out this practice. However, before we get into the core of this topic, we briefly regard the historical developments of risk management.

The very first documented risk management practice dates as far back as to ancient Egypt (Froot, Scharfstein, Stein, 1994). In the Old Testament it is told how the Pharaoh bought and stored large quantities of corn after having dreamt about food shortages and being told by Joseph that his dream could actually be a prophecy for seven years of prosperity followed by seven years of starvation. The Pharaoh's response to this "risk" is actually the first documented case of risk management. In the Middle Ages, a futures-market-like infrastructure arose: people could reserve a certain quantity of agricultural output to be bought at a predetermined price and future date. Another form of risk management was also documented in ancient Rome, where simple insurance policies were developed in form of mutual aid associations.

Risk management is thought to have roots in gaming too, according to some historians (Rhodes, 2015). Ancient people began to play with dice and bones which more than two thousand years ago turned into chess and checkers. Galileo (ca. 1630) provides significant evidence that the study of dice games evolved into probability theory. Roughly from the same period, we have evidence of a six-letter correspondence between Pascal and Fermat about chance in these types of games, which is widely regarded as having laid the foundations for probability theory.

The term *risk management* as we mean it today originated in the 1950s, with this concept likely being first introduced by Russell B. Gallagher. From the 1960s, an increasing interest in the subject was witnessed among scholars, as can be seen from the increasing number of publications regarding risk management in that decade. To get to the broader definition we use today, scholars engaged in debates to agree on the nature of this then-new subject. It is interesting to look at how the definition has evolved over time, starting from the one on the first actual textbook on the subject, Mehr and Hedges (1963) "The management of those risks for which the organization, principles and techniques appropriate for insurance management are useful", McCahill (1971) instead viewed it from an insurance perspective, as "activities undertaken to prevent an unexpected loss" others like Bannister and Bawcutt (1981) define risk management by emphasizing on the “management” part: “the identification, measurement and economic control of risks that threaten the assets and earnings of a business or other enterprise”, Crockford (1982) gives a more practical definition: “The stages of risk management correspond to the process of problem definition, evaluation of possible solutions and selection of the most appropriate which becomes central to all management decisions”. However, if we reduce the scope of risk management and see it as applied to different situations, it becomes difficult to come up with a single definition encompassing all the different aspects of this practice.

Let us now deal with the substance of risk management. Risk management has the main purpose of ensuring the firm has access to enough cash to make value-augmenting investments (Froot, Scharfstein, Stein, 1994). This statement is a direct consequence of the fact that the value-creation depends on the amount of successful investments a company is able to make, which ultimately depends on their financing decisions. In a classic Modigliani-Miller world with perfect capital markets, financing decisions do not impact value creation, and by consequence, risk-management strategies should have no influence either.

Companies would ideally tend to use their retained earnings or other internal sources of cash to invest in projects, because this way they would be less exposed to risk and their cost of capital would drop as a consequence. In reality though, they need a source of external financing and can choose among debt and equity. The former requires fixed and possibly costly obligations, which could potentially lead to financial distress. The latter does not have such stringent payment obligations as the company decides how much to pay out as dividends, still, it involves the liability of being judged by the market, as the value of the company is publicly traded in secondary markets once shares are issued and could potentially be struck by significant value swings, thereby impacting both company value and the ability of the firm to raise funds by issuing new shares. Seen from this perspective, and given the preference for firms to use their own funds to invest, risk management provides a useful tool to keep these funds from being taken away by risk.

As we have previously seen, there are multiple types of risk which can be classified into two main categories: unsystematic risk, affecting only an industry or company and systematic risk, affecting the market as a whole and measurable using methods such as the CAPM. Some companies and industries may have larger exposures to certain types of systematic risk than others. For example, because large multinational companies operate in many different countries each using its own currency, they bear more exchange rate risk than local firms. Oil companies bear oil price risk as oil constitutes their main output and directly affects their profits. Airline companies bear oil price risk as well, however, it affects the price of one of their inputs so it directly impacts on their costs. In both cases, risk management can protect both companies from having cash shortages deriving from revenue decreases in the former case and cost increases in the latter.

A key component of risk management is hedging, a technique consisting in making investments to reduce the risk of adverse price movements in an asset. This definition links hedging back to the fund imbalance motive explained earlier. Managers when constructing a hedge need to carefully consider what portion of the funds they want to devote to hedging purposes, based on the imbalance that the risk factor is expected to cause. This is crucial because if they were to hedge too aggressively the result may be counterproductive, if instead they chose to hedge too little, the company exposure to risk would be excessive causing it to impact the cash balances of the firm. Firms may also want to consider carrying out a cost-benefit analysis to determine whether hedging benefits exceed hedging costs or not (Damodaran, 2007).

According to financial literature, the factors influencing company hedging decisions, namely, whether to hedge or not are mainly three: corporate tax liabilities, managerial risk aversion and transaction costs associated to financial distress (Smith, Stulz, 1985). Hedging helps to shield the company from paying higher taxes by reducing the pre-tax firm value, resulting in a higher post-tax firm value, as long as the hedging cost does not offset the gain. Hedging also provides an insurance to debtholders as they know the company may be able to pay them through their hedging operations. Hedging is also strictly linked to managerial risk aversion, especially when managers have an interest in performing well (for example, when they own shares in the firm) or, in the opposite case, they may choose not to hedge and take risks to exploit their compensation bonuses in case of favorable outcomes and increased firm revenues.

As hedging consists in acquiring financial assets that help to reduce the variability of firm cash flows, the main hedging instruments need to be introduced, more detailed information on this topic will be provided in the second chapter. These financial contracts are called “derivatives” because their value depends on an underlying asset. Examples of derivatives are: forwards, futures, options and swaps. They are relevant because most risk management operations are carried out by trading these financial instruments on organized exchanges or over-the-counter.

Because hedging is such an important part of risk management, they are often considered as the same thing. However, hedging is just one way to manage risk. Before introducing other methods companies use to manage risk, one point should be made clear: some firms have a comparative advantage in taking risks, others do not (Stultz, 1996). Corporations often engage in selective hedging, that is, determining the extent to which they hedge exposures on their timing and judgment of future price movements and not systematically. They also focus primarily on short-term transactions and larger firms have been shown to use derivatives to a greater extent than small firms. Further insights about this finding will be provided in the third chapter.

Moreover, if a hypothetical firm using Oil intensively in its production processes were to acquire private information from its suppliers about future oil prices its management would most likely hedge the firm exposures according to the information they are provided from its stakeholders. That is, when they get no news about the market they may choose to hedge 50% of its Oil purchases to protect itself from financial distress. Were they to receive news about an upcoming bullish market from its suppliers they may go up to a full coverage 100% hedge by taking long positions in Oil futures, for example. In case they were convinced by purchasing managers that the market will head downwards in the upcoming months their hedge would probably be divested down to, say, 20%. If we place this argument into an Efficient Market Hypothesis (strong form) setting however, the argument would not make sense as all prices would reflect all publicly and privately available information. This scenario obviously pertains to an "ideal world", as in reality managers still happen to be involved in financially-successful insider trading practices and regulation still provides punishment for this behavior. A more plausible scenario would be that the private company information may not be better than that of the market.

Anyway, what the company should focus on when considering risk management practices is determining its source of comparative advantage, as the same operating activity in one firm may not provide the same comparative advantage in risk-bearing for another firm (Stulz, 1996). For instance, a FOREX trading room can make money by taking very large positions if it has access to information before other firms and make money if it has a large customer base that allows it to profit from bid-ask spreads. As evidence (and intuition) suggests, trading rooms realize profits mostly from the bid-ask spread and their large number of customers, at a lower risk too. Hence, following a comparative advantage reasoning, the room must prioritize the building and maintenance of their customer base by investing in it rather than investing in FOREX positions and acquisition of exclusive information.

There is a method called *risk-taking audit* that management can use to determine when to take risks and when not to. It consists of examining the risks the company is exposed to, assessing which of these can be "self-insured" over a business cycle, determining what is the comparative advantage in the hedged, semi-hedged or unhedged positions of the firm and finally considering which risk management activities have consistently added value without introducing extra sources of volatility.

Now, return to the hypothetical company using Oil as an input in its production process and suppose it has valuable private information suggesting it how to hedge, or better, speculate and earn massive profits trading oil. These abnormal profits are still not a sure thing, there is always a chance the firm will experience significant losses, and these may endanger the company operating activities, the extent to which they do so depends on its risk management policy, capital structure and financial health (Stulz, 1996).

On the basis of what has been explained so far, companies may choose different tools to manage risk for many different reasons, as hedging is just one of them. Hedging is finance-oriented while other risk management practices are more strategic and cross-functional. The former serves to protect from downside risk, the latter may be used to exploit the upside (Damodaran, 2007).

Risk management consists of three phases: risk estimation, risk evaluation and risk control. There are, specifically to price risk management, three broad categories of risk management strategies: Sourcing strategies, Contracting strategies and Financing strategies. Examples of sourcing strategies are: commodity substitution, purchase timing, supplier switching and vertical integration. Contracting strategies consist of escalator clauses, when supplier and buyer agree on a process in which price adjustments will be made; staggering contracts, where the company uses contracts for different quantities and time periods, creating a smoothing effect; passing price increases on to customers and piggyback contracting, which occurs when buying firms extend pricing and terms of a commodity contract to suppliers using the same purchased commodity. Finally, Financing strategies such as hedging and cross-hedging, the latter occurring when a company deals with low liquidity commodities and buys derivatives for other commodities that have commonalities with the materials used. Cross-hedging may have specific legal requirements that must be met, thereby limiting its deployment as a risk management tool. The factors influencing the choice among these risk mitigation strategies include: Product factors such as commodity differentiation, value of commodity with respect to cost; Buying organization factors like expertise and inventory availability; Supply chain factors such as final product price flexibility; External environment factors like market liquidity and PESTLE factors (Gaudenzi, Zsidisin, Hartley, Kaufmann, 2018).

Determining ex-ante which risk management strategy is best for a given firm is not an easy task but looking at past evidence may help to understand how this leads to create value for a firm. However, the main focus of this thesis does not lie on the factors influencing the choice of risk management tools but on how the changes in commodity prices and the risk management practices impact the value of the firm.

2. Derivatives

2.1 Commodity markets

In the previous chapter, we introduced the concept of risk: how it is perceived by individuals, how it affects companies, how it is measured and how it is managed. This chapter is centered around financial derivatives, which are the building blocks of a risk management practice called hedging. Because this thesis deals with commodity risk, namely, the variability of the cash flows of a company deriving from the price movements of a commodity the firm in question has some exposure to, the main dynamics of commodity markets must be introduced first.

A commodity market can be a physical or virtual marketplace used for buying and selling raw or primary products. The first form of commodity trading arose between 4,500 BC and 4,000 BC in the Sumerian civilization, where clay tokens representing the quantity of a given good were enclosed in a clay container to represent a pact to deliver the commodities (Banerjee, 2013).

Overtime and especially in recent times, commodity prices have become increasingly volatile, making companies and other investors become more aware of the risk they were incurring by trading commodities. From there, the need to hedge against these price fluctuations led to the creation of derivatives.

As a matter of fact, most hedging practices today involve trading instruments on commodity markets or over-the-counter providing cash settlements based on commodity price movements rather than contracts providing physical delivery of a particular commodity. The invention of derivatives made hedging more accessible and immediate to carry out. However, the existence of derivatives is not subordinated to commodities, they can be linked to all kinds of financial instruments such as stocks, bonds, currencies, interest rates and market indices. It now becomes easier to interpret the definition of a financial derivative: a contract that derives its value from the performance of an underlying asset or benchmark. The most frequently traded derivatives on commodity exchanges are futures contracts, other frequent commodity derivatives are forwards, swaps and options.

These financial risk management instruments are available as standardized or tailor-made contracts. Standard contracts trade for the most part on organized commodity exchanges while personalized contracts are traded over-the-counter (OTC), where the two parties can negotiate.

When dealing with exchange-traded standardized commodity contracts no negotiation about contract specifics between the parties is necessary, reducing transaction costs and speeding up the trading process. What allows hedgers on commodity exchanges to find a counterpart for their proposed sale or purchase of a contract is the presence of other hedgers and speculators who are looking to open an inverse position, thereby setting themselves on the opposite side of the transaction (also because of clearing houses, which will be dealt with later). Speculators, unlike hedgers, do not have any risk deriving from a physical transaction in a commodity but involve in this type of trading merely to realize profits from their forecasts about future market prices and for this reason are willing to bear price risk. Under certain conditions, there might be a third type of actor trading on the market: Arbitrageurs, individuals who aim to exploit asset mispricing between multiple markets that arise as a result of market inefficiencies.

Today, most trades taking place on commodity exchanges are ordered and finalized electronically, however, not too long ago most trading deals still occurred on the trading floor via open outcry. The floor trading process works as follows: traders place orders by calling a commodity broker, who in turn sends it over to a desk clerk, the desk clerk relays the order to a floor broker standing in the pit pertaining to the trading of the right commodity, the floor broker then makes sure the trade is carried out via a dealer or market maker, when the order is executed information is sent backwards to the trader. This process is far less efficient than electronic trading: it takes longer to execute trades, transaction costs are higher and information is less clear and direct to the trader. Despite this, open outcry trading is still heavily practiced on some commodity exchanges such as the London Metal Exchange (LME). Pit trading advocates also emphasize the advantages this practice has over electronic trading: floor brokers standing in the pit have a better feel of the action of the market and may reveal insights and advice to their customers; large and complex orders such as four-legged trades may be better executed by a floor broker than an electronic trading platform; in case of volatile markets electronic platforms may not be as reliable as pits, still, more sophisticated technology and additional requirements for electronic market makers may promote their reliability in the future.

Organized exchanges are subject to tailored government regulation and supervision, to assure their solvency and maintain solid standards. In OTC markets, contract specifications are not standardized: two market participants negotiate the terms of the contract such as quality, quantity, price, delivery date and other procedures to suit the requirements of both parties. The two parties are usually a trading house (such as a trading arm of a natural gas company) on one side and financial intermediaries (brokers and private banks) on the other. Because these contracts are personalized and traded on a principal-to-principal basis they are less easy to resell than exchange-traded ones. OTC markets are usually less transparent than Commodity exchanges, because trading in these markets involves taking on counterpart risk deriving from the possibility that the counterpart will not fulfill its obligations and are subject to fewer regulations, as they are directly related to physical trading and because most participants are large companies and banks that do not need as much protection as retail investors do on commodity exchanges (UNCTAD, 1998).

An indispensable condition for the proper working of organized commodity exchanges (e.g. futures exchanges) is *Liquidity*: this condition is ensured when there are a large number of participants providing a high volume of transactions. If a security is *liquid*, buyers and sellers can trade at low cost because of a narrow *bid-ask spread*, that is, the difference between the market price for buying a contract and the market price for selling it. If a security is *not liquid* enough and the *bid-ask spread* is too wide, price manipulation becomes easier, transaction costs increase, and prices may not reflect their intrinsic value and corresponding economic reality. Price manipulation does not occur in liquid or *deep* markets as they are able to withstand large bids without reacting with significant price fluctuations, thereby preventing losses for hedgers and preventing speculators from profiting at the expense of the former or other market participants.

Commodities can be classified into two main categories: *hard commodities* are typically those that need to be mined or extracted – such as gold, silver, crude oil and natural gas – whereas *soft commodities* are agricultural products or livestock – such as corn, coffee, cotton, sugar, wheat and pork. Alternatively, they can be classified according to uses: *Agricultural* – such as corn, wheat, soybeans, lean hog, live cattle – *Energy* – such as crude oil, natural gas, coal, electricity, weather and emissions – *Metals* – such as gold, silver, copper, platinum and palladium.

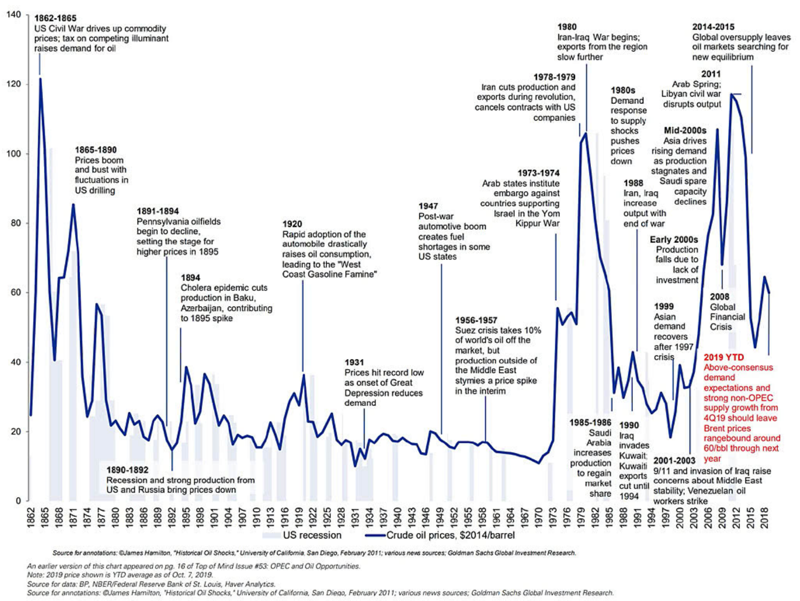
Crude oil is the most largely traded commodity in the world, with global demand amounting to about 80 million barrels a day (Hull, 2015). There are two main benchmarks representing it on commodity markets: the *Brent*, which trades at the London International Petroleum Exchange (now Intercontinental Exchange, ICE) and represents the price of Oil extracted from the North Sea, near Northern Europe; the *West Texas Intermediate* (WTI) instead, trades at the New York Mercantile Exchange (NYMEX) and is a benchmark representing the price of Oil sourced in North America. These two oil benchmarks used to trade roughly at par, more recently though the gap between the former and the latter increased because of two main reasons: an increase in North American Oil production and geopolitical tensions in the middle east. In addition, Brent Oil is more expensive because of higher transport costs as the WTI is transported mainly via pipeline. Futures and options for these two varieties of oil trade on their respective organized exchanges, while forward and swap contracts are traded OTC.

Commodities and in particular energy commodities are one of the most volatile assets. As Oil price volatility is a central topic in this thesis, it is necessary to mention the factors influencing Oil prices. Obviously, like any other good or asset, it is influenced by supply and demand. However, here are the specifics:

- *The Organization of Petroleum Exporting Countries* (OPEC) is a consortium of 13 oil exporting nations, among which Saudi Arabia, Iraq, Kuwait and The United Arab Emirates. They are so crucial in influencing oil prices as they control almost 80% of the world oil supply and they do so by increasing or decreasing production.

- *Natural Disasters* can cause both supply and demand shocks: Hurricane Katrina struck southern US oil storage facilities back in 2005, affecting 20% of US oil supply and drove oil prices up by $13; the 2020 Coronavirus pandemic on the other hand, forced the world into quarantine, social distancing and work-from-home solutions causing the demand for oil to drastically fall.
- *Politics* have caused oil prices to fluctuate several times in the past, especially in the Middle East, home of some of the major owners of worldwide oil reserves: in July 2008 the price for a barrel rose to $128 due to spreading fears among consumers about Iraq and Afghanistan wars.
- *Production Costs* when oil is relatively cheap to extract, as is the case for Middle East oil, the price should be under control all else equal. However, if the Middle East were to run out of their oil reserves, consumers would have to switch to more expensive Canadian oil, as Canada faces higher production costs.
- *Storage Capacities* may hurt oil price stability in case of an overestimation of demand, simply put if too much oil stays unsold and demand is unexpectedly low, producers are going to have to lower the price to free up storage space, this was another crucial factor influencing the April 2020 price drop.
- *Interest Rates* have been shown to have negative correlation to oil prices, as interest rates rise costs for manufacturers and consumers rise as well, which in turn reduce the amount of time and money spent driving and vice-versa. However, these two factors are not correlated exclusively as there are so many other reasons why oil prices change, so the rule does not always hold.

Figure 2 – Historical Crude Oil Prices with Explained Shocks



Every commodity exchange specializes in providing contracts on different commodities, below a list of the main world commodity exchanges:

Table 1 – Main world commodity exchanges

Exchange	Abbreviation	Location	Major commodities
London Metal Exchange	LME	London, UK	Metals
Chicago Board of Trade	CBOT	Chicago, US	Agricultural, Energy, Metals
Chicago Mercantile Exchange	CME	Chicago, US	Metals, Soft
New York Mercantile Exchange	NYMEX	New York, US	Energy, Metals
European New Exchange Technology	EURONEXT	FR, BEL, PT, NED, UK	Agricultural
Dalian Commodity Exchange	DCE	Dalian, China	Agricultural, Plastics, Energy
Multicommodity Exchange	MCX	Mumbai, India	Metals, Energy
Intercontinental Exchange	ICE	US, Canada, China, UK	Agricultural, Energy, Emissions
Africa Mercantile Exchange	AfMX	Nairobi, Kenya	Energy, Metals, Soft
Tokyo Commodity Exchange	TOCOM	Tokyo, Japan	Energy, Metals, Rubber, Soft
Dubai Mercantile Exchange	DME	Dubai, UAE	Energy
Australian Securities Exchange	ASX	Sydney, Australia	Energy, Agricultural

Source: Author's elaboration

2.2 Forwards

Forward contracts are deals signed by two parties to conduct a financial transaction at a future (forward) point in time. The buying party takes a *long position*, the selling party takes a *short position*. The price is agreed upon when the contract is stipulated and it is called *delivery price*. The actual payment occurs at maturity and the outcome depends on the delivery price: if it is below the *spot price* (the market price of the underlying security at maturity) the buyer gains from the transaction and the seller suffers a loss; in case the delivery price is above the spot price, the buyer loses from the transaction and the seller makes a profit. This way, the two parties are able to protect themselves from adverse price changes by locking in the price for a future transaction. However, markets keep moving and if spot prices differ from delivery prices at maturity, they determine winners and losers. Still, both parties know the price in advance and eliminate risk.

These contracts are traded OTC and they do not involve a cash transfer when the contract is signed (except for transaction fees). The seller of the commodity must deliver the product at maturity and the buyer has the obligation to pay at maturity but pays no money upfront. Because of their non-standardized nature, they are mostly used for hedging purposes rather than speculation. For example, a trader or a producer buying or physically holding a spot long position in cotton can shield adverse cotton price movements by selling forward an equivalent amount of cotton at a predetermined forward price. This hedging strategy is called *forward cover* and it serves to stabilize the amount of revenue from a future sale by locking in the price. Nevertheless, the only warranty that can insure the fulfillment of the contract lies in the reputation of the parties, as the counterpart may fail to either carry out product delivery or execute the delivery price payment at maturity.

The payoff of a *long forward* is given by the difference between the spot price at maturity (S) and the delivery price (K):

$$P_L = S - K$$

The payoff of a *short forward* is the opposite, as it is the counterpart of the long forward contract:

$$P_S = K - S$$

Figure 3 - Payoff from the purchase of a forward contract

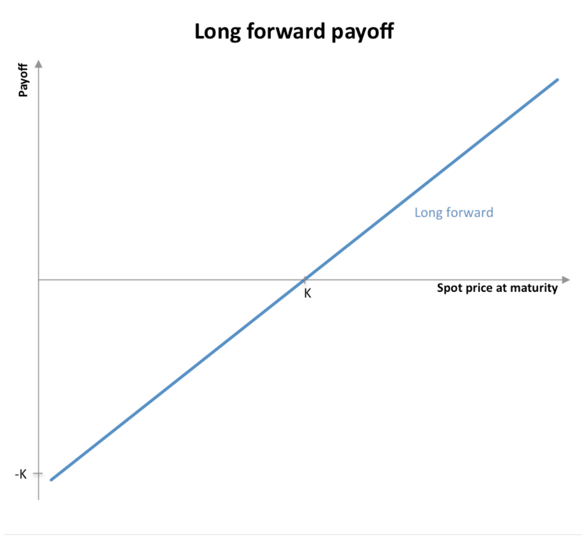
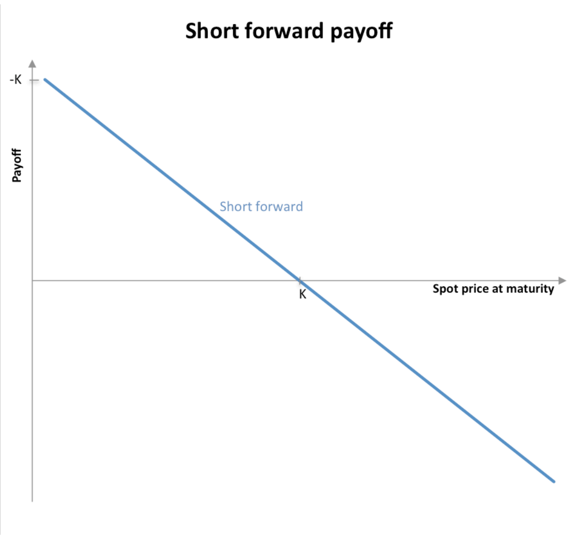


Figure 4 - Payoff from the sale of a forward contract



Source: commons.wikimedia.org

These two graphs show how the value of any of the two contracts is zero when it is signed, because the spot price is locked in the contract for the delivery date and assumed to be equal to the delivery price. The financial instrument is then periodically *marked to market* to determine its value. When the payment is carried out, the spot price at maturity is crucial in determining the value of the contract according to the above formulas.

2.3 Futures

Futures contracts, similarly to forward contracts, are agreements establishing the purchase or sale of a given quantity of a commodity at a pre-arranged price, to be settled at a future date. The main difference with forwards lies in the fact that they do not automatically imply physical delivery of the product in order to satisfy the contract terms and are traded on commodity exchanges. The usual outcome involves the balancing of the negotiation by or at maturity with an equivalent reverse transaction. The initial sale and corresponding purchase of the contract can occur at different times, as long as they cancel out. Because these instruments are traded on organized exchanges, clearing houses mark them to market on a daily basis to make sure price information is readily available to market participants. Clearing houses also ensure contracts are *closed out*, this allows traders to immediately find a counterpart for their futures contract because the clearing house acts as one.

The same cotton producer holding a long position in cotton from the previous example can construct a *cover* using futures by going short on a futures contract and then buying it back to close out the position when he sells the physical good. This way, he receives the market price from the physical sale, if it is below the price written in the futures contract he can compensate this loss with the higher futures contract sale he carried out earlier. This happens because meanwhile, the futures contract price has declined too, following the market price of the underlying commodity. In the opposite situation, the higher profit realized from the sale of the physical good is offset by the higher price to be paid for the futures contract.

Nevertheless, practical hedging with futures does not guarantee the previously explained offsetting of profits or losses. This is due to *basis risk*: the risk that the price of the physical commodity does not match the behavior of the price of the corresponding futures contract quoted on the exchange. This happens because of various factors: the country to which a company exports may differ from the one where the futures contract is negotiated, hence creating substantial price differences; price movements in the customer market may deviate from those on the futures exchange, for instance because the futures market could be manipulated; the company may be forced to *cross hedge* the exported product because it may not be available in commodity markets, by trading a similar commodity; the futures contract could trade in a currency differing from the one used in the physical transaction and finally, the available delivery date of the futures contract may diverge from the timing needs of the hedger resulting in the contract to be closed or expire early.

Another characteristic of futures contracts is that they may be leveraged. That is, the hedger may trade a contract using a *margin*, which allows any trader to buy or sell a contract using a lower amount of funds than required and borrow the rest of the required funds from *broker's call loans*. The practice works as follows: there are *initial margins* to be deposited to partially pay for the sale or purchase of the contract, these margins represent a fraction of the value of the underlying contract, the broker sets a *maintenance margin*, which is a margin percentage below which a *margin call* will be issued. The margin call requires the trader to add new liquidity into the margin account, if the margin call is not complied with the broker may sell part or all of the securities in the account and use the proceeds to repay an appropriate part of the loan and recover the percentage margin by bringing it to an acceptable level. On organized exchanges, margins are determined by brokers and other intermediaries, instead on OTC markets they are determined by direct negotiation between the parties.

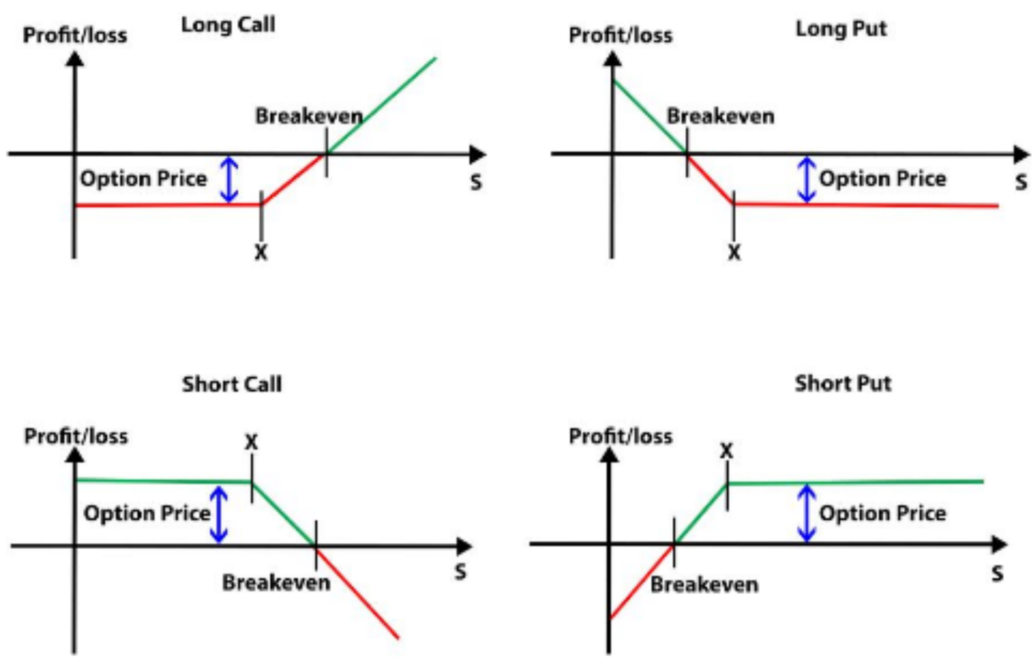
2.4 Options

Options are derivative instruments that serve the purpose of shielding their buyers against unfavorable price movements while preserving the possibility of profiting from favorable ones (UNCTAD, 1998). They give the right, not the obligation, to purchase or sell an asset at a pre-arranged price, the *strike price*, on (or by, depending on the option category) a specified date called *maturity* or *expiration*. Unlike forwards and futures, buying or selling an option involves a payment to the counterpart called *premium* to be paid at the outset, which becomes the only cash outflow if the option is not exercised. A *call option* permits to buy the underlying asset at a pre-set price and it is suited for those who believe that the market will head upward as it allows to purchase the asset at a lower price in the future, thereby protecting the holder against price increases. A *put option* allows to sell the underlying asset at a pre-set price is suited for those who believe that the market will head downward because it allows to sell the asset at a higher price in the future, so that the holder is insured against price decreases. The two basic categories of options are *European options*, which may be exercised only at maturity and *American options*, which can be exercised at any time preceding the maturity date and on maturity itself. There is also a less common, third kind of options called *Exotic options*. Exotics usually trade OTC and differ from traditional ones in their payment structures, expiration dates and strike prices. Some examples of exotic options are Chooser options, Compound options, Binary options and Spread options.

Options related to commodity markets give the right to buy or sell a certain quantity of physical commodity or to buy or sell an amount of futures on a commodity. Exchange-traded options have the same maturity date as the underlying futures contract; OTC options on the other hand, can have longer maturities (up to five years). OTC option buyers face counterpart risk while sellers do not: sellers cash in on their premium when the deal occurs, buyers depend on whether the sellers will meet their commitment when they decide to exercise their option.

These instruments become particularly useful compared to futures when supply is uncertain. For example, if a fixed-price deal has been scheduled and has been covered with a futures contract, the party holding the contract may be left with a loss-making futures position if the physical leg of the transaction is not finalized. When options are used instead of futures in contexts like this, the losses are limited to the upfront premium paid at the beginning. (UNCTAD, 1998)

Figure 5 – Payoffs of the main traditional option strategies



On the horizontal axis we find S, the spot price of the underlying asset when the option is exercised; on the vertical axis the payoff from the option strategy; X is the strike price; Option Price is a synonym for the premium paid and the Breakeven point occurs when the spot price offsets the premium paid at inception. Source: blog.quantinsti.com

As shown in the graphs above, the main option trading strategies are four: *long call, long put, short call* and *short put*. The formulas behind these payoffs are as follows:

Table 2 – Call and Put option strategies with corresponding payoffs

Payoff	**Long**	**Short**
Call	max (S-X;0)	min (X-S;0)
Put	max (X-S;0)	min (S-X;0)

Source: Author's elaboration

More sophisticated option trading strategies are *strips*, *straps*, *spreads*, *straddles* and *strangles* and originate from the combination of options with underlying assets. More on these in the following paragraphs.

Before moving on to the next topic, a crucial relationship that ensures options are correctly priced needs to be introduced. It is termed the *put-call parity condition*. For starters, we consider two portfolios: Portfolio A contains a *European call* and a *zero-coupon bond* (ZCB) providing a payoff K at maturity; Portfolio B contains a *European put* and one unit of the underlying asset, such as a stock. We furthermore assume that the share does not provide any dividend payment and that the strike price K and maturity T are equal for both the call and the put.

Table 3 - Values of Portfolio A and Portfolio B at time T under different scenarios

Portfolio values at time T		$S_T > K$	$S_T < K$
Portfolio A	Long Call option	$S_T - K$	0
	Zero-coupon bond	K	K
	Total	S_T	K
Portfolio B	Long Put option	0	$K - S_T$
	Share	S_T	S_T
	Total	S_T	K

Source: Hull, 2015

As we said, the ZCB will be worth K at time T and if the stock price turns out to be greater than K, it will be convenient to exercise the option. This will cause the portfolio to be worth $(S_T - K) + K = S_T$. If the stock price turns out to be less than the strike price the call option will expire and portfolio A will be worth just K.

In portfolio B, the shares will be worth S_T at time T. If the share price falls short of the strike price of the put option, portfolio B will be worth $(K - S_T) + S_T = K$ and the option will be exercised. If the stock price rises up past the strike price of the put, portfolio B will be worth just Kas the put option will be worth zero.

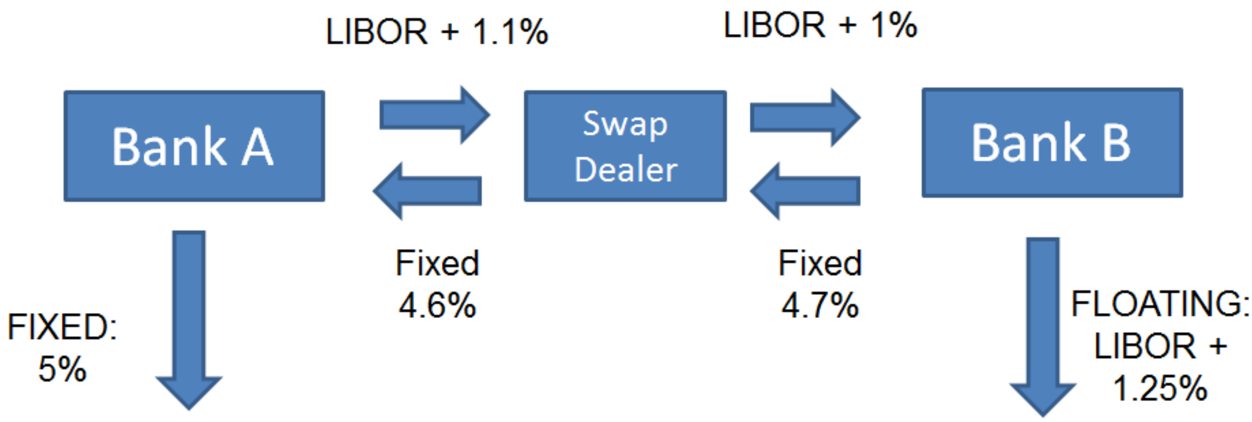
Notice how both portfolios are worth the same in each of the two scenarios, $\max(S_T, K)$. We can state that because portfolios are worth the same at time T, they must have the same price today. If this condition were not to hold, arbitrageurs could take advantage of the mispricing by short selling the overpriced portfolio and buying the underpriced one. The present values of the components of portfolio A are *c* and Ke^{-rT}, the components of portfolio B today are worth p and S_0. By consequence, $c + Ke^{-rT} = p + S_0$ is the *put-call parity condition* for European options with the same strike price and exercise date. Notice however that this relationship does not hold for American options because they can be exercised before maturity as well. (Hull, 2015).

For the sake of completeness and precision, to derive the same condition for European futures options we consider the same portfolios with the exceptions that portfolio A contains an amount of cash equal to Ke^{-rT} instead of a zero-coupon bond and portfolio B contains a long futures contract and an amount of cash equal to F_0e^{-rT}, where F_0 is the futures price, instead of a long position on another asset and the options are the same but written on a futures contract as an underlying. With an analogous reasoning, the put-call parity condition for European futures options becomes: $c + Ke^{-rT} = p + F_0e^{-rT}$.

2.5 Swaps

Swaps are OTC-traded price risk management instruments that allow producers and consumers to effectively fix the prices they deal with in the medium to long-term. Their mechanism is entirely financial as no physical delivery of commodities is expected. As other derivatives however, their existence is not strictly dependent on commodities but can be linked to all kinds of assets, rates and indices. Swaps can also be viewed as more complex forwards because they involve multiple payments at many different dates, while forwards establish an agreement for a single payment at a future date. Widely used types of swaps are: *interest rate swaps* and *currency swaps*. An interest rate swap (IRS), for example, can be simply regarded as a series of *forward rate agreements* (FRA). The standard IRS arrangement is termed *plain vanilla* swap, which involves two counterparts: one paying a fixed rate on the basis of a *notional* to the other party and the latter paying a variable interest rate on the same notional to the former for a given number of times over a certain period. Variable interest rates are usually *interbank offered rates*, such as the London Interbank Offered Rate (LIBOR) or the European Interbank Offered Rate (EURIBOR), these rates are the average rates at which selected banks in their respective money markets are able to borrow from each other. Because both LIBOR and EURIBOR are offered rates and hence are not based on actual transactions, they can be easily manipulated. It so happened in London in 2012, where panel banks deflated their offered rates to appear more financially solid, this led to a scandal and law prosecution. The EONIA rate (European Over Night Index Average) is the weighted average rate at which European banks lend at each other based on actual transactions, thus allowing to solve the problem of rate manipulation.

Figure 6 – Dynamics of Plain Vanilla Interest Rate Swaps



With this mechanism, Bank A pays LIBOR + 1.5% instead of 5%; Bank B pays 4.95% instead of LIBOR + 1.25% and the Financial Intermediary earns 0.2%. All percentages refer to the same underlying notional. Source: analystprep.com

Similarly, in currency swaps, parties exchange interests and principal payments on debt denominated in different currencies. Unlike in IRS, the principal is not a notional but an amount to be exchanged along with interest obligations.

Commodity swaps analogously, can be visualized as a series of forwards at different maturities but with the same delivery price, whose underlying is a commodity. There are two prices defining a *commodity swap* agreement: one is variable and expressed as a function of a readily available price index, such as the price of a futures contract; the other is fixed at the time of the swap agreement.

Figure 7 – Dynamics of Commodity Swaps

Source: UNCTAD, 1998

In practice, because commodity swaps are a purely financial transaction, they allow producers and consumers to hedge their price exposure without interfering with their business activities, such as production and procurement. Notice that only net amounts are actually paid: when the reference prices are higher than the fixed ones payments by the producer are delivered to the dealer and from the dealer they are owed to the consumer, in case the reference price is lower than the fixed price the payments are delivered by the dealer to the producer and by the consumer to the dealer (UNCTAD, 1998).

These particular swap deals usually occupy very wide time frames and can be used in absence of similar exchange traded products, for example, if a certain commodity is not traded on organized exchanges. They are attractive to investors too, because they provide hedging and protection at the same time for the company, ensuring a constant stream of cash flows. Moreover, they are attractive from the company's perspective as well, due to their tailor-made nature, absent or less strict margin calls, low administrative burden and the presence of a long-term, known and reliable counterparty.

On the other side, commodity swaps have flaws too: deals require high set-up costs, positions may be difficult to reverse due to the long-term nature of these contracts, the fair value of the contract may be difficult to determine because of small or absent correspondent exchange traded products and market activity and the possibility of benefiting from favorable price movements may be lost.

2.6 Commodity bonds and loans

Commodity bonds and *commodity loans* are a complex kind of financial instruments. Swaps are often included in commodity-price-linked loan and bond agreements and as such, they are primarily linked to investment projects and debt rescheduling rather than price risk management. Still, because instruments with price risk management features are often enclosed into these deals they are still useful to provide more coverage from unfavorable price fluctuations to lenders and borrowers. Thus, they can be seen as media that ease access to capital (UNCTAD, 1998).

Commodity-linked loans connect the payment of interest and/or principal to the price of a commodity or a basket of commodities. The loan is paid off with value-equivalents of a commodity instead of variable or fixed interest rates payments.

Commodity bonds are bonds whose yield to maturity is tied to the price of the underlying commodity. The commodity bond principal and coupons to be paid back are calculated based the commodity price, as opposed to fixed amounts and rates. Examples of commodity bonds are: *forward-type bonds* have principal and/or interest payments linked to a commodity price or index; *option-type bonds* let the holder of the bond exercise an option to buy or sell a certain amount of the designated commodity at the predetermined price at or by maturity; *commodity convertibles* or *indexed bonds* leave the bond holder free to choose between receiving the nominal face value or the commodity amount at maturity. Forward-type bonds are more suited for risk-hedging, Option-type bonds work best at reducing the cost of financing because of their smaller coupons.

When commodity producers borrow at a fixed rate, they are inevitably exposed to price risk as the price of their output may drop below their break-even cost of production. Producers that borrow at a floating rate are in an even worse situation, as they bear the risk of interest rate increases while being simultaneously exposed to commodity price risk. Commodity bonds and loans come handy in these cases as they provide a hedging solution against interest rates: for a producer, when the commodity price rises, the commodity-linked debt becomes costlier to repay, in conformity with the increase in revenues, when the opposite situation occurs, that is, the price of the commodity drops, the debt becomes cheaper to repay. This framework, obviously, does not allow to profit from favorable price changes but provides a reliable one-to-one hedging strategy while making access to capital easier. Commodity-linked debt instruments may help to reduce the loss in value of the shares of listed companies too, as investors are less worried about commodity price risk affecting firm revenues. The goal is to place all service obligations and commodity revenues under the same roof, so that their effects offset in any scenario and reduce the general level of risk to the producer.

Among the advantages of using Commodity bonds and loans we find: their long-term and tailor-made nature, the fact that no initial cash transfer is required to the issuer and the repayment and interest amount being positively correlated to the borrower's own risk (the price of the commodities they deal with). Some disadvantages are: lenders still evaluate whether to lend or not based on the borrower's creditworthiness which might as well depend on other factors, the commitment of a pretty complex firm network for bringing the issue to the marketplace and a corresponding high volume of transactions needed due to significant costs related to the issue.

2.7 Hedging and trading strategies

We now dig deeper into the specifics of hedging and trading with derivatives by examining the main strategies applied by firms that have exposures to commodities. Obviously, the focus will be on Oil and Gas hedging strategies as they are two closely related commodities and constitute the main topic of this thesis. These strategies mainly involve *Futures* and *Options*, it is convenient to start with *Futures* as they are the oldest way to trade commodities along with Forwards and also because they have many similarities.

The two standard futures hedging strategies to protect from commodity price risk have been anticipated in the previous pages, they are: the *short hedge* and the *long hedge*.

A *short hedge* involves taking a short position in a futures contract, it is appropriate for oil and gas producers who own these commodities and are looking forward to selling them at a future date or for producers who know they will own some in the future. As an example, suppose it is March 1st today and an oil producer has just agreed a trade to sell 1 million barrels of crude oil at the market price of June 1st. The possible gain to the producer amounts to $10,000 for every 1 cent increase in the market price of oil over the next 3 months, the possible loss amounts to $10,000 for every 1 cent decrease in the market price of oil over the same time span. Suppose that on March 1st the market price of oil is $80 a barrel and the futures price for June delivery is $79 a barrel. Each futures contract represents the delivery of 1,000 barrels, so the producer can hedge its entire exposure by selling 1,000 oil futures. If the producer decides to do so, he will have secured $79 million in future revenue and disposed of risk from further price decreases by giving up $1 million in "possible" future revenues, due to the delta with the current market price of $80 a barrel. The company gains $\$79 - \$P$ if $P < \$79$ and loses $\$P - \$79$ if $P > \$79$ per barrel with such a futures contract. Notice however, that the producer gives up the possibility of profiting from price increases and ends up with approximately $79 million, regardless of any price development. (Hull, 2015)

A *long hedge* conversely, consists of taking a long position in a futures contract and it is suited for companies that have planned a future purchase of a certain amount of a commodity. Suppose that it is again March 1st and a copper manufacturer knows he will demand 100,000 kg of copper on June 1st to start the production of machinery to meet the requirements a certain contract. The spot price of copper is $3.40 per kg, the futures price for May is $3.20 per kg. The manufacturer can hedge its exposure to copper price risk by taking a long position in as many as needed futures contracts on the nearest commodity exchange. By doing this, the manufacturer locks in the price of $3.20 per kg, shielding its cash flows from being impacted by copper price increases. In fact, the fabricator gains $100{,}000 \times (\$P - \$3.20)$ if the spot market price P is above $3.20 from the futures contract, in case P is below $3.20 he loses $100{,}000 \times (\$3.20 - \$P)$. However, because the physical transaction is carried out in terms of the spot market price, the futures contract payoff and the transaction even out. Still, the manufacturer gives up the possibility of saving from price decreases to protect from price increases. (Hull, 2015)

Cross hedging was also briefly introduced earlier, it is a technique used by hedgers when the asset the company is dealing with and whose price they need to be hedge is not available as a futures contract or another standardized hedging tool. As an example, consider an airline that is willing to hedge against the price of aviation gasoline because of recent concerns about its market. Because jet fuel futures are not traded on exchanges, they may rely on exchange-traded heating gas oil futures to hedge their exposure, as they witness their co-movement to jet fuel prices. More examples and deeper insights on the aviation industry will be provided in the third chapter.

When dealing with cross-hedging, setting up a *hedge ratio*, h (i.e. the ratio of the volume of the position taken in futures to the volume of the actual exposure) of 1 may not always be the optimal choice. The hedger should choose h to minimize the variance of the value of the hedged position. The minimum variance hedge ratio h^* has been shown to be equal to the ratio of the standard deviation of the change in the spot price S to the standard deviation of the change in the futures price F times the correlation coefficient between the two, both during a period of time equal to the life of the hedge (Hull, 2015):

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

This ratio represents the slope of the best-fit line from a linear regression of ΔS against ΔF. Notice how if $\rho = 1$ and $\sigma_S = \sigma_F$ the hedge ratio is exactly 1, this occurs because the futures price precisely mirrors the spot price. If the standard deviation of the futures price were to double, the hedge ratio would halve to 0.5. The R^2 of this regression measures how effective the hedge is, as it is the proportion of variance that is eliminated by hedging. All parameters need to be estimated from historical data.

In cases where the expiry date of the hedge occurs at a further point in time than the delivery date of other available futures contracts, the hedger can roll the hedge forward by closing out the current futures contract and taking the same position in a new futures contract with a later delivery date. This procedure can continue repeatedly, and it is known as *stack and roll* (Hull, 2015).

Table 4 – Example of rolling a commodity hedge forward

Date	Apr. 2018	Sep. 2018	Feb. 2019	June 2019
Oct. 2018 futures price	88.20	87.40		
Mar. 2019 futures price		87.00	86.50	
July 2019 futures price			86.30	85.90
Spot price	89.00			86.00

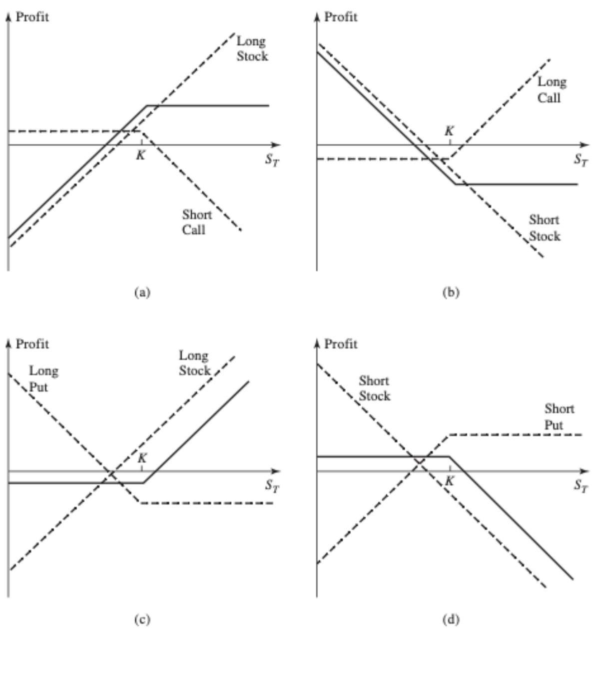
Source: Hull, 2015

Suppose it is April 2018 and a company realized it will sell 100,000 barrels of oil in June 2019 and decides to hedge oil price risk with a hedge ratio of 1. We also suppose that the present spot price is \$89 and that only contracts for the first six months have sufficient liquidity to be traded. The oil company then decides to roll the hedge forward periodically as shown in Table 4: the October 2018 contract is shorted in April for \$88.20 and closed out in September at \$87.40, for a profit of \$0.80 a barrel and it keeps doing so and realize profits until June 2019, when the physical sale occurs. The oil producer gains (88.20 – 87.40) + (87.00 – 86.50) + (86.30 - 85.90) = 1.70 per barrel of oil from rolling short futures contracts. Meanwhile the spot price of oil decreased from \$89 to \$86. Notice how the hedge did not cover completely the price drop, this is because the company has a monthly exposure to the underlying asset and uses futures contracts that do not compensate entirely as their prices are below spot market ones.

Nevertheless, stack and roll strategies do not always work this well, they could actually lead to cash flow pressures. It was the case of Metallgesellschaft (MG), in the early 1990s: they sold a heavy volume of 5- to 10-year heating oil and gasoline fixed price supply contracts to its customers at 6 to 8 cents above market prices and hedged simultaneously their exposure with long positions in short-term futures that were rolled forward. Then the price of oil fell, and futures positions alerted for margin calls, imposing significant short-term cash flow pressure on the firm. While MG risk managers argued that the short-term cash outflows would eventually be offset by cash inflows from the long-term fixed-price contracts that were previously stipulated with their customers, MG senior managers and bankers became concerned about the significant cash shortage. In the end, the company had to close out all hedge positions and also agree with its customers to not perform the fixed-price contracts. This operation resulted in a $1.33 billion loss for MG. The cash flow timing mismatch of the two sides of the hedge was the determining reason for the loss as it could not be bore further by the firm. The bottom line of this story is that potential liquidity issues should always be accounted for when building a hedge.

The basic *option* trading patterns and strategies have been introduced previously in this chapter (*long put*, *long call*, *short put* and *short call*). Let us now introduce more complex options strategies, which mainly involve combining these instruments along with other assets such as stocks or, in this case, oil-and-gas-related assets, physical holdings or planned holdings in these commodities. A *covered call* is a strategy consisting of a short position on a call combined with a long position in an asset, the long position "covers" from the payoff on the short call. A *reverse covered call* involves a short position in the asset combined with a long position on a call, to protect from price increases that would make the short position have a negative payoff. A *protective put* requires a long position on a put option and a long position on the underlying asset, simply to protect the long position from price decreases with the offsetting payoff of the put. Finally, a *reverse protective put* consists of a short position in a put option combined with a short position in the underlying asset.

Figure 8 – Profit patterns of a: (a) covered call; (b) reverse covered call; (c) protective put; (d) reverse protective put



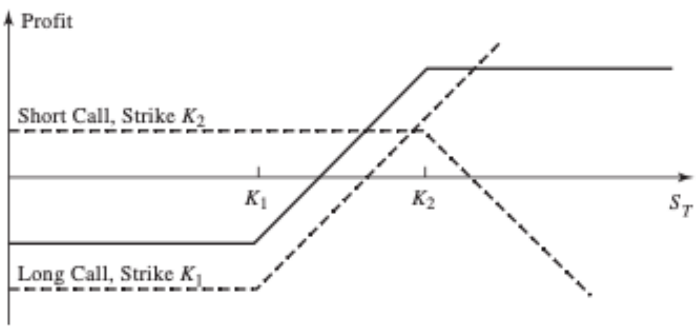
Source: Hull, 2015

A *costless collar* is implemented by selling one out-of-the-money covered call and simultaneously buying one out-of-the-money protective put, with the same expiry. It is appropriate for agents who own at the same time a long position in the underlying asset. The purchased put should have a strike price below the current market price of the underlying, the sold (or written) call needs to have a strike price above the price of the underlying. The put protects from downward price movements of the underlying and the call generates a premium that offsets the premium paid to buy the put. This strategy can have little to zero cost if set up so that the strike prices are equidistant from the current price of the asset owned.

As an example, consider an oil and gas producer who is trying to hedge its December Brent crude oil production with a producer's costless collar and they ideally need to hedge against prices trading below $40 per barrel. Hence, they buy a $40 December Brent crude oil put for a premium of $2 per barrel and sell a $60 December Brent crude oil call, again, for a premium of $2 per barrel, so that it perfectly offsets the premium paid on the put. This leaves the producer with a $40/$60 costless collar with the lower number being a floor and the higher acting as a ceiling. The company incurs a hedging gain if prices drop down below $40 and a hedging loss if they rise above $60. Both gains and losses will eventually be offset by physical sales. If the price stays in the interval $40-$60, neither hedging gain or loss will be incurred by the firm and they will still be able to sell their output at the market price. However, it should be reminded that dealing with options also means buying on margin, that in situations of volatility can involve margin call requirements, which could be rather difficult to meet.

Spreads involve taking multiple positions in two or more options of the same type (e.g. two calls or two puts). A *bull spread* consists of buying a European call and selling a European call on the same asset for the same expiration date, with the strike price of the sold call necessarily being strictly higher than the strike price of the bought call. The value of the short call is always lower than the value of the long call, because a call price decreases as the strike price increases. The graph representing the payoff is summarized below.

Figure 9 – Payoff from a bull spread using call options



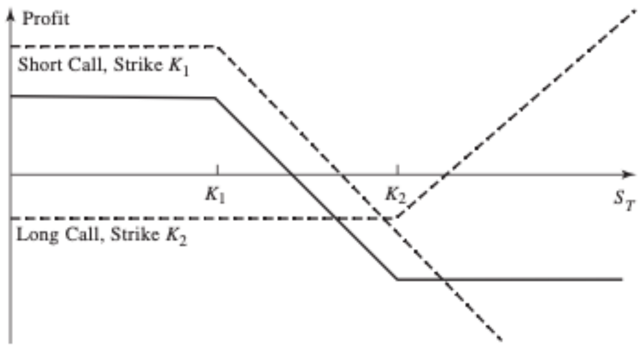
Source: Hull, 2015

This strategy limits both upside and downside risk, the trader here sacrifices upside profits in order to obtain the price of the short option with a higher strike price. There are three types of bull spreads, from most aggressive to most conservative: type one is when both calls are initially out-of-the-money, type two is when one call is initially in-the-money and the other call is initially out-of-the-money, type three is when both calls are initially in-the-money.

Bull spreads can also be set up with European puts, for example by going long on a put with a low strike price and going short on a put with a high strike price. However, it should be noted that put bull spreads involve a positive up-front cash flow to the investor and an either negative or null payoff.

A *bear spread* is fit for investors who, contrary to bull spread investors, hope the asset price will decrease. They involve buying a European put and selling a European put with the strike price of the long put higher than the strike of the short put. This strategy requires an initial cash outflow as the price of the put sold is less than the price of the put purchased.

Figure 10 – Payoff from a bear spread using call options

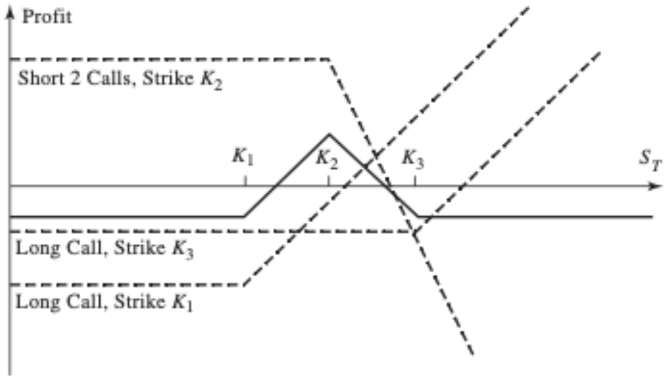


Source: Hull, 2015

A *box spread* is obtained by combining a bull call spread with two strike prices with a bear put spread with the same two strike prices. Its payoff is always the difference between the short call strike price and the long call strike price. If the price of the box spread differs from the present value of this difference, there are arbitrage opportunities in the market: if it is lower it is convenient to buy the box; if it is higher it is profitable to sell it. Notice that this strategy too holds for European options only.

A *butterfly spread* requires taking positions in options with three different strike prices. For instance, one could buy a European call with a low strike price, a European call with a high strike price and sell two European calls with another strike price enclosed by the highest and the lowest among the two options bought. The payoff of this strategy is shown below.

Figure 11 – Payoff from a butterfly spread using call options

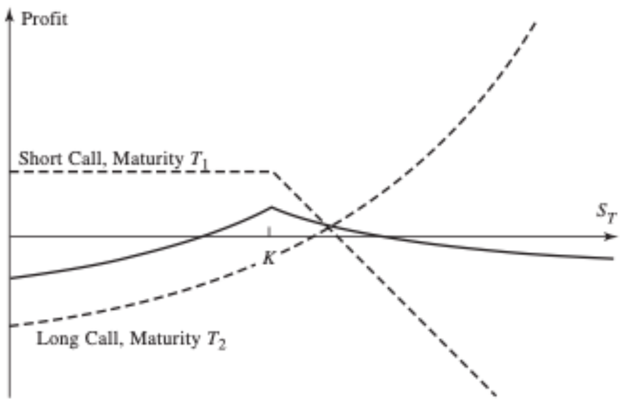


Source: Hull, 2015

This strategy leads to a profit when the spot price of the underlying asset keeps close to the strike price of the sold calls (around K_2 in Figure 11) and results only in a small loss if the spot price deviates significantly from K_2. This strategy requires an initial small cash outflow and can be carried out using puts too referring to the same conditions and structure of the call butterfly spread.

A *calendar spread* differs from the previously explained strategies because it does not require all the options to expire on the same day. In a calendar spread all options have the same strike price but different expiration dates. This strategy involves selling a European call with a certain strike price and buying another European call with a farther maturity date and the same strike price. Usually, longer maturity options are more expensive, so this strategy requires an initial investment too. In the graph below, the payoff has been drawn under the assumption that the long position with the long maturity is closed out at maturity of the short call.

Figure 12 – Payoff from a calendar spread using two call options, calculated at the short call maturity date



Source: Hull, 2015

Notice how this strategy provides a similar payoff to the butterfly spread, in fact, the financial agent profits when the price of the underlying fluctuates closely to the strike price of the options. However, an eventual loss caused by a deviation of the price of the asset from the strike price neighborhood causes a greater loss compared to the butterfly strategy. The costs and possible profits of this strategy depend on the strike price and on the initial spot price of the asset. It is most profitable and cost-effective to start such a strategy when the spot price is close to the strike price, because the shorted option costs a small amount or zero and the purchased option is quite valuable, resulting in a significant profit.

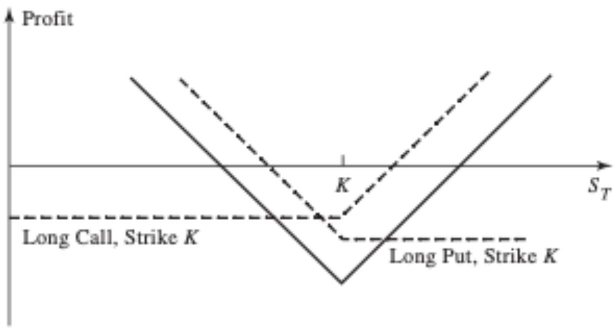
This strategy is suitable for put options too (buy long-maturity put, sell short-maturity put) and results in a similar outcome.

There are spreads involving options with different strikes and same expiration date (bull, bear), spreads with same strike and different expiration dates (calendar) and other spreads, termed *diagonal spreads* that involve options having different strikes and expiration dates.

Let us now introduce *combinations*. A combination is an option trading strategy that involves taking a position in both calls and puts on the same stock (Hull, 2015).

To generate a *straddle*, a European call and a put with the same strike and expiration date must be bought. A *bottom straddle* is suited for investors who expect significant volatility in any direction of the price of the underlying asset. This strategy allows to profit whenever this occurs, it leads to a loss when the spot price of the asset keeps close to the strike price of the options. A *top straddle* is exactly the opposite: the investor profits when the price keeps close to the strike and loses a large amount of money when the price deviates, it is set up by selling a call and a put with the same strike and expiration date. Notice that straddles are actually a very risky strategy.

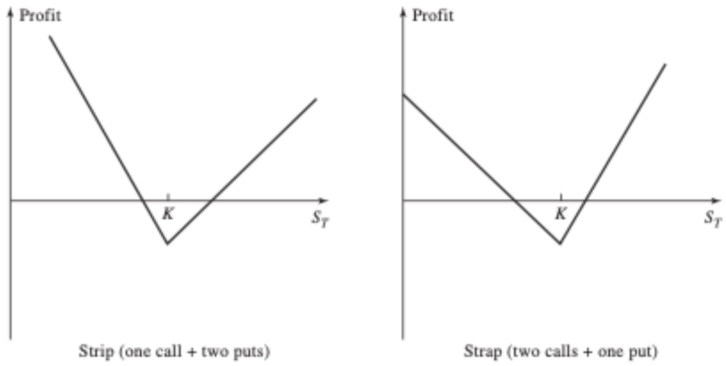
Figure 13 – Payoff from a bottom straddle



Source: Hull, 2015

A *strip* is a strategy which involves going long on both a European call and two European puts with the same strike price and expiration date. A *strap* instead, requires buying two European calls and one European put with equal strike price and expiration date. If an investor constructs strips, she believes that that there will be significant volatility in the price of the underlying asset, with a decrease more likely than an increase. In a strap, the investor still bets on significant volatility, this time though, he expects the price to be more likely to increase than to decrease. Notice that these two strategies, even though to different extents, ensure profits both from upside and downside asset price movements.

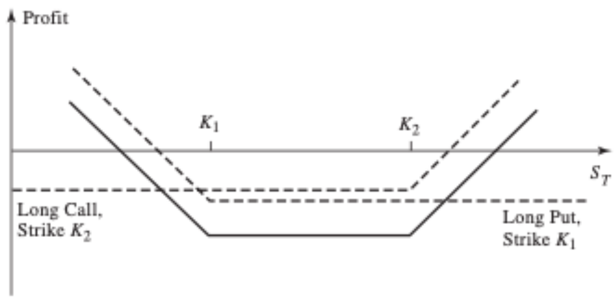
Figure 14 – Payoff from a strip and a strap



Source: Hull, 2015

A *strangle*, or *bottom vertical combination*, is a strategy where the investor acquires a long position in a European put and a long position in a European call with the same expiration date but different strike prices, with the strike of the call being higher than the strike of the put. The payoff is similar to that of a straddle, as both bet on an big move in the price of the underlying asset. However, in a strangle the price has to move farther than in a straddle for the investor to realize a profit. Conversely, the downside risk is lower in a strangle with respect to a straddle. Notice also that the farther the two strike prices are apart, the lower the downside risk and the farther the asset price has to move for a profit to be made.

Figure 15 – Payoff of a strangle



Source: Hull, 2015

If the strangle is sold instead of bought, it is termed a *top vertical combination*. It is appropriate when the investor believes that large asset price movements are unlikely but also involves a significant amount of downside risk if the asset price were to make large fluctuations as the potential loss is unlimited.

3. Relevant studies on Commodity Risk

3.1 Relationships between Commodity Risk and Equity Share Price

The first topic that is going to be addressed in this chapter is about how commodity price fluctuations affect the value of the equity of listed firms which have a certain degree of exposure to these commodities. Exposure measures how sensitive equity value is to changes in the underlying asset, which in these cases are commodities. To measure it, most researchers use an *augmented market model*:

$$R_{i,t} = \alpha_i + \beta_i R_{m,t} + \gamma_i R_{b,t} + \varepsilon_{i,t}$$

Where the return on stock i for the period t, $R_{i,t}$, is regressed on the return on the market portfolio, $R_{m,t}$, represented by a market index, which acts as a control variable for all the systematic risk factors that may have an impact on the stock return; and on the return on a commodity index, $R_{b,t}$, chosen according to the commodity being studied. The β_i coefficient captures the sensitivity of the stock return to changes in the market as a whole, while the γ_i coefficient actually measures the exposure to commodity price risk. Intuitively, one might expect a producer of the commodity to have a positive γ_i, because the price of the commodity is positively related to their profits; while a commodity user, who utilizes it as an input in its production process has its profits negatively related to the price of the commodity, as it is a cost to them. A firm having a γ_i equal to zero or not significantly different from zero has no exposure to commodity price risk.

This topic is going to be addressed by comparing multiple studies, among the most relevant ones, which deal with these phenomena in different industries. Particular attention will be drawn to the similarities and divergences of exposures across industries and the factors causing them.

The topic of commodity price risk gained substantial interest between the late 1990s and the beginning of the 2000s: earlier on, most exposure literature focused on other sources of risk such as exchange rates, as they were considered more relevant because of the greater impact they could have on the cashflows of multinational companies and because of their higher volatility. Following this reasoning, it seemed reasonable to bring more attention on those.

However, as previously anticipated with the Oil example in chapter two and also according to most research (see Bartram, 2005), commodity prices have fairly recently started to exhibit more volatility than most equities, interest rates and exchange rates. This raised research interests towards topics regarding the impact of commodity price fluctuations on company cash flows and value. Overall though, because a lower amount of corporate cash flows is dependent on commodities than on, say, exchange rates, commodity price exposures do not seem to be more significant than other exposures. This implies that the impact of price fluctuations of these instruments may turn out to be small compared to firm size, thereby appearing less attractive as a research topic. As a consequence, research focuses on highly commodity-dependent industries such as mining, oil extraction and agriculture.

In some cases, when exposures affect costs to a small extent companies are able to *pass-through* the subsequent price increases to other companies or customers; most frequently though, companies adopt hedging practices to prevent costs from increasing and stabilize revenues.

Based on what has been said so far, one might expect firms which directly operate with commodities to have the highest exposures. However, these companies are at the same time the most likely to be aware of their significant exposure and therefore the first to hedge the risks away (Bartram, 2005). Indirectly exposed industries on the other hand, such as a chemical company looking to decrease the exposure of its sales of pesticides to demand uncertainties coming from the agricultural sector or international hotel chains trying to hedge against oil price risk, as changes in jet fuel prices impact the airline industry and hence may decrease the amount of tourists; find a hard time to calculate and foresee risk and hence are less likely to hedge it away. If these two scenarios balance out, given that the former group may hedge and the latter may not, the relevance of the exposures could become similar.

Let us start analyzing Bartram (2005), a study on the commodity exposures of 490 German non-financial firms, which can provide an insightful starting point to more industry-specific studies. The sample companies were picked so to reflect the impact on different industries, such as: agriculture, public utilities, mining, chemicals, rubber, plastics, industrial machinery, paper production, retail trade, wholesale trade, electrical equipment, transportation, real estate, manufacturing and diversified conglomerates. The market index used is the CDAX, derived from the main German stock exchange (Deutsche Börse AG), which accounts for dividends and stock splits, just like the stock price series. Other than single Commodity prices, five Goldman Sachs commodity price indices (GSCI) were used. These five indices allowed to group commodities by categories: agricultural, energy, industrial metals, precious metals and livestock. Subsequently, these indices were value-weighted according to the worldwide production of the respective commodities. The analysis is based on continuously compounded monthly returns.

The percentage of companies with significant commodity price exposure range roughly between 5% and 15% per industry, while foreign exchange exposure typically ranges 5%-20% as of previous studies. These results confirm the hypothesis that commodity price risk does not have a greater impact on company cash flows than exchange rate risk or interest rate risk. This occurs because the higher volatility of commodities but their lower impact on the average company cash flows, compared to the relatively lower volatility of exchange rates or interest rates but relatively higher impact on the cashflows of a company balance each other out.

As a further proof, the exposures to commodity risk of the sample listed companies are smaller compared to those of foreign exchange and interest rate risk from previous studies. Therefore, commodity exposures are not economically and statistically more relevant than other financial risk sources.

Tufano (1998) analyzes the gold price risk exposures of 48 North American gold mining companies during the period January 1990 to March 1994 and their effect on the equity share returns of these firms. He also shows how the corresponding exposure coefficients are affected by factors such as the cost structure, leverage and risk management policies of the firms. North American gold mining firms are particularly well suited for an exposure analysis: the product is homogeneous, the exposure framework is pretty straightforward, data on risk management practices is easily accessible and the gold market is both liquid and volatile.

The analysis begins by estimating a model equivalent to the augmented market model that was introduced at the beginning of this chapter, with the return on the market portfolio being represented by a daily return on the CRSP NYSE/AMEX/NASDAQ composite value weighted index and the return on gold specifically, as opposed to the many different commodity returns used in the previous study. Notice how this study uses high-frequency daily returns to account for non-stationarity of exposures, as exposures have not been stable enough over the declared time span.

Quite unsurprisingly, gold mining companies present a positive gold price exposure: a 1% change in the return on gold causes the average (and median) share of gold mining firms to move by roughly 2%, hence the sample presents an exposure coefficient of about 2.

The paper studies how exogenous firm-specific factors influence these exposures by building three theoretical models: a *fixed production model*, a *flexible production model* and a *fixed production model with hedging*. In the first one, the firm has a fixed production schedule that stays unaltered and does not have a financial risk management policy, its market value is calculated as follows:

$$V = \sum_{i=1}^{N} \frac{[Q(P - C) - F](1 - \tau)}{(1 + r)^i}$$

It assumes the firm owns *R* gold reserves, mined over *N* years at a rate of *R/N* or *Q*, has *F* fixed costs, *C* variable costs, acts as a price taker, so it is able to sell gold at the market price *P*, incurs taxes τ and its cost of capital is r. Once the market value *V* is calculated, the exposures (in this case indicated by β) are the percentage change in firm value for every unit percentage movement of gold price:

$$\beta = \frac{\partial V/V}{\partial P/P} = \frac{PQ}{Q(P-C)-F}$$

So, the beta decreases as gold prices and reserves rise (as N is held constant) and increases as marginal processing costs C and fixed costs F increase, so financial leverage and operating costs enhance the exposure of the firm.

The second model, flexible production, considers the existence of real options, which allow firms to temporarily or permanently halt production if events such as a massive drop in gold prices occur. It views these companies as holding call options on gold, with strike price being their marginal costs, so that they can adjust or retain their reserves and production according to market conditions. This model was developed because ignoring real options would result in an overstatement of the exposures. Using this framework confirms that the gold beta decreases as volatility increases as well and also measures the impact of interest rates on the betas, however results are mixed.

The fixed production model with hedging considers the scenario in which the firm chooses to sell forward its production to hedge against gold price drops. In this case, the exposure would drop to zero but the impact of the cost of the forward sale operation needs to be evaluated as well:

$$\beta = \frac{\partial V/V}{\partial P/P} = \frac{(1-\alpha)PQ}{Q[(P-C)+\alpha(P-W)]) - F}$$

In this model, the firm has sold forward a fraction α of its future annual output Q with a forward contract providing a payment W per ounce of gold at maturity. This framework assumes all firms face the same contract terms and credit risk is ignored.

If the firm does not hedge at all, α is zero and the equation becomes identical to the one of the first model. In all other cases as the hedged portion increases, the exposure becomes smaller. The contract price W instead, is inversely related to the exposure. Overall, this model proves that gold exposures and gold prices are inversely related.

In the empirical analysis, the paper regresses beta on a number of j factors, after having made several adjustments on the coefficient in terms of autocorrelation. Among these factors we find the price of gold and its volatility, hedging levels, interest rates, leverage, production, cost structure and forward prices. Other than confirming again the negative relationship between gold price volatility and the gold beta, it shows how hedging decreases the exposures of the firms by 0.78 at a minimum to a maximum of 0.96. This implies that investors incorporate the impact of hedging practices of the firm into their valuations. According to theory, sales of higher forward price contracts usually results in lower exposures, however, evidence is mixed with this data. Leverage, production (and hence firm size) and ancillary business activities are found to be positively related to exposure. Cost structure instead, is not found to have a relevant impact on the betas.

In conclusion, the paper confirms the utility of the theoretical models developed above, particularly the fixed production ones, as the empirical results coincide with the predictions of these models. Their only limitations regard the fact that they do not account for the effect of production and firm size on exposures and their inability to adjust to financial flexibility of firms by leading to overestimated results. Lastly, the importance assigned by capital markets on firm and market-specific information for more accurate valuations is highlighted.

Jin and Jorion (2006) switches the focus on the Oil and Gas industry by studying the impact of hedging and price fluctuations of these two commodities on the value of 119 U.S. firms involved with their exploration and production on a time span ranging from 1998 to 2001. Other oil-and-gas-related activities carried out by these companies include refining, processing and marketing. However, before assessing this effect they need to verify the exposures of these firms.

The types of exposures borne by the single firms are similar to each other, this makes the sample homogeneous and minimizes spurious correlation among the variables such as hedging ones. Nonetheless, the hedging ratios of the industry are various, making the analysis of this sector more engaging. The empirical model chosen is again the augmented market model, with the monthly return on NYMEX WTI Crude Oil (or natural gas) and the monthly return on the S&P500 as independent variables.

By applying the model to the sample firms, the exposures resulted positive for 92% of the oil firms and 95% of the gas firms and significant overall. A 1% increase in oil prices led to a 0.28% increase in the share price, the same increase in gas prices led to 0.41% increase in the share price, these results are similar to those of other studies. Then, hedging and reserves variables are added to the model and, as expected, the former reduce the sensitivities to commodity risk and the latter increase them.

Now, let us switch the perspective by looking at how commodity users are affected by commodity risk. For example, airline companies make great use of oil-derived jet fuel. Other than very volatile fuel costs, what makes this industry so appealing are its low profit margins, which derive from a very competitive environment which makes it difficult for airlines to raise ticket fares when the fuel costs increase. This is the main reason why airlines develop both financial and operational hedging strategies.

Financial hedging is the standard type of hedging we have dealt with so far in this thesis, for aviation companies hedging contracts are usually arranged OTC because aviation fuel is seldom traded on organized exchanges. To avoid the uncertainties involved with OTC markets, aviation firms often *cross hedge* their fuel needs with comparable futures contracts on commodity exchanges such as gasoil, heating oil or crude oil, whose prices historically have a positive correlation with kerosene or other jet fuel prices. Still, this process does not come without basis risk, deriving from situations where the price of jet fuel does not perfectly match the one of its publicly traded substitutes. The *crack spread* measures exactly the gap between crude oil spot prices and jet fuel spot prices and it tends to increase during periods of high crude oil price volatility. As a bottom line, these firms face a tradeoff between the disadvantages of OTC markets and the basis risk of similar exchange-traded instruments.

Operational hedging involves *real options*: practices involving tangible-asset-related investments projects carried out as a response to changes in technological, economic or market conditions. An example applied to the aviation industry and fuel price risk could be fleet diversification: when fuel prices are high and the demand for flights gets lower as a consequence of rising prices, smaller aircraft can be a good solution to adjust to lower demand and to save up on fuel because of lower fuel requirements.

Berghofer and Lucey (2013) address exactly these types of questions by studying the impact of these variables on exposure coefficients and share returns of a sample of 64 airlines of which 20 are Asian, 24 are North American and 20 are European over a period of 10 years, ranging 2002-2012.

Their model follows a two-step procedure and slightly differs from the initial augmented market model:

$$R_{i,w} = \alpha_i + \beta_{i,y} R_{mkt,w} + \gamma_{i,y} R_{JF,w} + \delta R_{USD,w} + \varepsilon_{i,w}$$

The return on the stock is regressed on the return on the market portfolio, the natural logarithm of the weekly return on jet kerosene prices and the natural logarithm of the change in the weekly trade-weighted U.S. dollar index, plugged in because this study deals with airlines from three different continents operating in different currencies. The coefficients $\beta_{i,y}$ and $\gamma_{i,y}$ represent the market risk factor and the jet fuel risk factor for airline i in year y respectively.

The second step involves regressing the yearly jet fuel risk exposure $\gamma_{i,y}$ on a series of financial and operational hedging variables and other control variables:

$$\gamma_{i,y} = \alpha_0 + \alpha_1 (HDGPER_{i,y}) + \alpha_2 (HDGMAT_{i,y}) + \alpha_3 (ADI1_{i,y}) + \alpha_4 (LNTA) + \alpha_5 (LTDA) + \alpha_6 (LNDIS) + \alpha_7 (LF) + \varepsilon_{i,y}$$

Where HDGPER is a financial hedging variable consisting of the percentage of the hedged fuel requirements of the following year, HDGMAT is the highest hedging maturity the firm has in months. ADI1 is an operational hedging variable that accounts for fleet diversity and is constructed as follows:

$$ADI1_i = 1 - \sum_{j=1}^{N} \frac{(No.of\ aircraft\ model_j)^2}{(Total\ no.of\ aircraft_j)^2}$$

N is the number of aircraft model airline *i* possesses, where similar models with a different number of seats are counted separately. LNTA is the natural logarithm of total assets and is used to account for firm size, LTDA is the long-term debt to assets ratio and accounts for leverage, LNDIS is the natural logarithm of average flight distance and it is a variable that accounts for various factors: fleet diversification, because the longer the distance covered by airplanes, the lower the chance for an airline to diversify its fleet; tankering, that is, the practice of carrying fuel on the outbound flight to avoid buying it at destination because of possible higher price; and price differences between flights due to distance, as domestic flights can be more expensive than long distance ones.

Overall, the exposure coefficient resulted negative, with 68% of observations being so and averaging -0.131. North American airlines exhibited the most significant observations, followed by Asians and European. Risk exposure has also been shown to diminish as volatility decreases, in fact, among the reasons why North American airlines are the more struck by exposures than airlines from the other two continents there are the impact of the 9/11 terroristic attacks on the U.S. airline share returns and the much less strict hedging policy carried out by North American airlines over the years. Moreover, higher leverage, load and size result in higher exposures, just as fleet diversification does. No significant difference in exposures has been found between companies hedging with different percentages of fuel or periods, however, based on the results of this study, operational hedging seems significantly more effective than financial hedging in this industry.

Treanor, Rogers, Carter and Simkins (2014) found a similar jet fuel exposure coefficient in their study on a sample of publicly-traded aviation companies during the period 1994-2008. Their average coefficient of -0.1179 is in line with many other studies such as Carter et al (2006) and the previously mentioned one.

Their approach to the study of the impact of input price risk on equity share returns is slightly different than the one seen in Berghofer and Lucey (2013):

$$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 JetFuel_t^{(h)} + \gamma_2 JetFuel_t^{(l)} + \gamma_3 JetFuel_t^{(m)} + \varepsilon_{i,t}$$

Other than the usual return on the market portfolio, we find three independent variables being used to account for jet fuel price changes, taking a value different from zero when the jet fuel price is in their quartile and zero otherwise. The first one (h, as in high) represents the percentage change in these prices when they fluctuate in the fourth quartile, the second one (l, as in low) is activated when prices are in the first quartile, the third one (m, as in medium) works when prices are between the first and fourth quartile.

Quartiles are determined based on daily data on the same period. With this model they also confirmed the hypothesis that exposure coefficients are a function of jet fuel prices and as such they move together: airline jet fuel risk during days in which input prices are in the highest quartile is roughly four times higher than the risk when jet fuel prices are in the lowest quartile.

They also tested the hypothesis whether exposures to jet fuel prices are the same with rising or falling prices with this model:

$$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 JetFuel_t^{(r)} + \gamma_2 JetFuel_t^{(f)} + \varepsilon_{i,t}$$

Where (r) represents daily changes in prices when these are rising and (f) when they are falling, when one variable is nonzero the other one is null, as the situations are mutually exclusive. Average exposures resulted to be of -0.116 for rising prices and -0.074 when prices are falling, however, they argue that the highest exposure coefficients are reported in periods of moderate volatility, when prices lie within the interquartile range.

Situations of high or rising fuel prices or excessive exposure also cause airlines to hedge more than their fuel requirements, according to this study.

3.2 Relationships between Risk Management Instruments and Firm Value

In order to measure the impact of the use of commodity risk management instruments on the value of a firm, most studies use the following model:

$$LnQ_{i,t} = \alpha + \beta_1 Hedge_{i,t} + \sum_{j=2}^{N} \beta_j \, Controls_{i,t} + \varepsilon_{i,t}$$

The dependent variable is the natural logarithm of *Tobin's Q*, the most widely used proxy for firm value in research to date. Promoted by James Tobin, Nobel laureate in Economics from Yale University but first cited by Nicholas Kaldor in 1966, is based on the intuition that the market value of all listed companies combined could be equal to their replacement cost. It is computed as the ratio between the total market value of the firm to the total asset value of the firm, however, different versions of it exist to facilitate its computation and data gathering. For example, sometimes it is just computed as the equity market value divided by the equity book value, based on the assumption that the market and book value of liabilities are equivalent. What the Q ratio tells us, is whether the firm is undervalued or not: a Q above 1 implies that the firm is overvalued, as the cost to start the same business over today is lower than its market value, a Q below 1 implies that the firm is undervalued, as the cost to start the same business from scratch today is higher than its current market value. The independent variables of this model are Hedge, which can be a dummy that takes value 1 if the firm hedges and 0 otherwise or directly the percentage of hedged input or output; and Control variables regarding different aspects of the firm, such as size, expressed with the natural logarithm of total assets, debt, credit rating, liquidity and dividend policies. Notice that relevant control variables vary by industry.

In a world without asymmetric information, transaction costs or taxes, risk management would be irrelevant to the value of a firm. The hedging instruments would not be able to provide additional value to firms and would not carry a positive risk premium, plus, shareholders could cancel any risk management operation proposed by the firm by implementing the opposite transaction at the same cost.

However, capital markets are not perfect and often do not carry the aforementioned characteristics. This creates imperfections that allow for hedging to actually be able to lower the volatility of earnings, speculation to provide a positive risk premium and arbitrage to profit by eliminating asset mispricing.

Jin and Jorion (2006) tests exactly whether these hedging activities actually have an impact on the value of U.S. Oil and Gas producing companies by using a sample of 119 of them. To do so, they first estimate the deltas of the hedging activities of all firms, by assigning a $\Delta = 1$ to long hedging positions and a $\Delta = -1$ to short hedging positions, then they multiply each delta by the notional amounts of every active contract and sum them all up to get total deltas for both commodities. Indeed, all firms have been shown to have deltas below or equal to zero, as their purpose is to hedge and not to speculate. Next, the deltas are divided by the production of the following year or by the reserves to obtain relative measures *DeltaProduction* and *DeltaReserve* respectively, where the former represents the portion of future production that is hedged and in the latter the extent to which current reserves are effectively hedged. The Q ratios are computed in three different ways, and have been shown to be positively correlated among each other:

$$Q1 = \frac{BV\ total\ assets - BV\ common\ equity + MV\ common\ equity}{BV\ total\ assets - BV\ proved\ reserves + NPV\ proved\ reserves}$$

$$Q2 = \frac{BV\ total\ assets - BV\ common\ equity + MV\ common\ equity}{BV\ total\ assets - BV\ proved\ reserves + MV\ proved\ reserves}$$

$$Q3 = \frac{BV\ total\ assets - BV\ common\ equity + MV\ common\ equity}{BV\ total\ assets}$$

Where BV stands for *book value*, MV for *market value* and NPV for *net present value*. The analysis proceeds by testing the hypothesis about whether firms involved with hedging activities have higher Q ratios and no systematic difference in Q ratios was provided by the analysis between hedgers and non-hedgers. However, consistent with previous studies, hedging firms have been shown to be double or triple the size of non-hedging firms.

To better assess the effect of hedging on firm value, the study proceeds by adding control variables to isolate the impact of hedging:

$$Q = \alpha + \beta \times HedgingDummy + \sum\nolimits_{j\gamma_j} Control\, variable_j + \varepsilon$$

$$Q = \alpha + \beta \times DeltaProduction + \sum\nolimits_{j\gamma_j} Control\, variable_j + \varepsilon$$

$$Q = \alpha + \beta \times DeltaReserve + \sum\nolimits_{j\gamma_j} Control\, variable_j + \varepsilon$$

With the hedging dummy taking value 1 if the company hedges and 0 otherwise and the other two variables being calculated as previously explained. The control variables included were taken from Allayannis and Weston (2001) and they are: *Firm size*, because large firms, as of previous literature and tests, are more likely to engage in hedging than small ones, this variable is expressed as the logarithm of total assets; *Profitability*, expressed as the return on assets (ROA) ratio, because profitable firms are more likely to have a grater Q ratio; *Investment growth*, as the more investment opportunities there are in the future the higher the Q will supposedly be, calculated as capital expenditures (CAPEX) over total assets; *Access to financial markets*, a dummy taking value 1 if the company paid dividends in the year and 0 otherwise, it is expected to have a negative impact on Q as limited access to financial markets means less hedging and as a consequence, the pursuit of investment projects with very high net present value (NPV) only, on the other hand, dividends could be viewed as a positive impulse to shareholders which could imply a positive impact on the value of the firm; *Leverage*, to account for the possible relation of indebtedness and firm value, calculated as book value (BV) of long-term debt to market value (MV) of common equity; *Production costs*, these are obviously expected to have a negative impact on Q.

This model yielded the following results: both oil and gas hedging program have a slightly negative impact (coefficient) on firm value, but is deemed non-significant; investment growth proved to have a positive impact on the value of oil and gas firms, according to all three types of Q ratios and all three models; production costs, as expected, have a negative impact on the value of the company; both size and leverage have shown positive signs on average, other variables such as profitability and dividends have not shown consistent effects. In conclusion, hedging has no impact on the market value of oil and gas firms, it is likely to be so because managers act for personal utility maximization rather than for maximizing shareholder value.

In contrast to Jin and Jorion's conclusions, Adam and Fernando (2006), in the same year found opposite evidence that contradicts the classical risk management literature too, which claims that all derivative transactions have zero intrinsic net worth. By studying the gold mining industry using a sample of quarterly observations of 92 North American firms from this industry over a 10-year time period (1989-1999), they prove that these companies realize both cash flow and value benefits from using derivatives. They claim that these benefits come from risk premia attached to these instruments and that these premia are crucial in determining if and to what extent firms use these instruments. Their reasoning starts with a relatively simple example: a commodity producer selling a fraction h of its good forward at t with delivery at a future date T, the per-unit expected risk premium of selling it forward is expressed as follows:

$$E_t[R(t,T)] = F(t,T) - E_t[S(T)]$$

Where *F(t,T)* is the forward price and $E_t[S(T)]$ is the expected spot price at T. If the expected risk premium is zero, the producer will hedge a portion h^{fund} depending only on hedging needs. If the expected risk premium is greater than zero, the producer will hedge $h > h^{fund}$ to take advantage of the positive premium. Instead, if the expected risk premium is negative, the producer will choose $h < h^{fund}$ as the forward agreement has negative expected value. This is to show how h moves together with the expected risk premium.

Positive cash flows realized by trading derivatives using this rationale are caused by increases in the market risk exposure borne by the firm, as the risk premium ultimately depends on systematic fundamentals. This results in an increase in shareholder value only if shareholders do not adjust immediately their required rate of return from holding shares in the firm, if they could anticipate this scenario, shareholders would not be provided with added value.

To tell whether cash flow benefits actually turn into shareholder value benefits, the study proceeds by estimating the augmented market model, finding no significant effect on the market beta by the return on gold. Furthermore, they regress the market beta on hedge ratios and other controls such as size and leverage to test whether hedging gold price risk causes shareholders to require a larger rate of return for holding firm shares. No evidence of any impact of hedging on the stock market beta was found. Hence, because shareholders cannot observe any change in the stock market beta caused by hedging, the cash flow gains from hedging activities are actually converted in shareholder (and hence, firm) value gains. They also claim it is reasonable to expand these results and apply them to any industry, and not restrict them just to the gold mining one, as there is extensive literature confirming the presence of risk premia in a number of commodity markets.

In contrast, based on their findings, *selective hedging*, a hedging approach based on the managers' judgment about the market which impacts the timing during which risks are hedged, has been shown to provide only small benefits to firms.

Treanor, Rogers, Carter and Simkins (2014) study a sample of listed U.S. airlines in the period 1994-2008 and find that a higher amount of hedging as a result of higher exposures does not imply any firm value premium. They find a value premium only when the portion of future jet fuel requirements hedged increases on its own, without any stimulus from higher exposures.

First, they determine whether the sample companies change hedging plans as a consequence of fuel exposure changes:

$$PerHedg_{i,y} = Price_y + JetFuel_y + StDev_y + \sum Controls$$

Where the dependent variable is the percentage of fuel requirements for the following year that are already hedged at the end of the current year, *Price*, *JetFuel* and *StDev* are exposure variables which can be alternatively substituted by *Exposure*, a yearly average of the exposure proxies of each airline computed using quarter by quarter observations. Both *CAPTSAL*, the ratio of CAPEX to sales, and *LnQ* are control variables, to account for more frequent and intense hedging by larger firms, on the basis of what has been shown in previous studies. Other control variables include long-term debt to total asset ratio and the natural logarithm of the BV of total assets, to account for the effect of leverage on hedging; cash flow to sales ratio and cash holdings to sales, as companies generating more cash and disposing of a higher degree of liquidity are supposed to be less constrained to spend money on investments; Standard & Poor's credit ratings are included as well to account for more or less likely financing issues; *FUELPASS* to account for fuel pass-through agreements, it is in fact a dummy that is activated if the firm has such agreements.

Price and *JetFuel* coefficients turned out to be positive, as expected, and more significant than coefficients from control variables regarding firm-specific features (with the exception of *LnQ*, which has a significant positive impact on hedging). This suggests that hedging practices are more driven by changes in the exposure environment than by changes in firm fundamentals.

To justify their finding, they create a new variable $PerHedgXExposure_{i,y}$, which is simply the product of *PerHedg* and *Exposure*, to test whether the two variables have a combined effect on firm value. A very negative value for the coefficient of this new variable would indicate that investors value hedging when exposure is larger, as the exposure coefficient is negative on average.

However, by running many different models including new variables, the coefficient of the combined variable always turns out to be nonsignificant, this is probably due to a model misspecification. As a result, to build a new model, they introduce the concept of *selective hedging* as occurring when the *PerHedg* variable changes across periods and expect the combined variable to have a positive impact on the Q ratio as exposures or fuel prices increase. They test the structure of this new framework by looking at the differences in the coefficients between *Selective Hedgers*, those airlines which are constantly changing and timing their hedging policy, as shown by the variability in the *PerHedg* variable, and *Passive Hedgers*, airlines that do not change their hedging policy over time and do not have much variability in their *PerHedg*. The final model resembles that of similar studies relying on Tobin's Q to account for firm value:

$$LnQ_{i,y} = \alpha + \beta_1 PerHedg_{i,y} + \beta_2 HedgerType_{i,y} + \beta_{3-12}(ControlVariables_{i,y}) + \varepsilon_{i,y}$$

HedgerType is crucial to justify the results, as it describes the hedging strategy of the firm and is computed in two manners. It can be the standard deviation of *PerHedg*, *StdHedg*; or the product of the change in *PerHedg* and a variable indicating the years when the industry is highly exposed to fuel prices *DHedgXExpYear*. In addition, *DHedgPXExpYear* accounts for the positive change in the airline hedging activity in years characterized by large exposures, taking value zero otherwise; *DHedgNXExpYear* accounts for negative changes in the airline hedging activity in years when exposures are high.

Results yielded interesting conclusions: the positive and significant coefficient on *PerHedg* calls for the existence of a hedging premium; the negative nonsignificant coefficient on *StdHedg* suggests that increasingly varying the hedging strategy will not affect firm value, or else affect it negatively; coefficients on *PerHedg* and *DHedgXExpYear* are positive but insignificant, possibly because changing hedging strategy when the exposures are high does not affect firm value; *DHedgPXExpYear* has a negative insignificant coefficient, owing to the hypothesis that increasing hedges in highly exposed years does not have a positive effect on firm value and decreasing hedges could actually impact negatively the value of the firm; *DHedgNXExpYear* has shown a positive and significant sign, meaning that firms would face a -6.1% value drop by loosening fuel hedging policies when exposures are high; finally the *PerHedg* coefficient is positive and significant, showing how more hedging corresponds to higher firm value. One thing is for sure, what the average firm should not do based on these data, is change its hedging strategy over time as it is more likely to result in harm than good. In conclusion, firms with more stable hedging strategies are likely to be valued more by shareholders, rather than those which hedge more as the exposures increase.

3.3 The Coronavirus regression

In this section, which concludes the third and last chapter of this thesis, I propose an empirical model that could be suited to estimate the impact of the Crude Oil Risk on the Equity Share Prices of listed firms.

It can be applied directly to *upstream oil companies* (involved with the exploration and production of crude oil) and *downstream oil companies* (involved with refining and distribution of final, readily usable products such as diesel fuel and gasoline), but also to *oil users* like airlines or industrial firms.

More specifically, this model has the objective to estimate the impact of the massive WTI Crude Oil price fluctuations that were witnessed in the period around April 2020, as a consequence of oil demand uncertainties due to the outbreak of the COVID-19 pandemic, on the Value of North American listed firms that bear exposures to this commodity.

To fit the purpose, I needed a model that could account for this impact based on daily frequency data and in a short time frame, to try and capture the effect of the massive price drop of the WTI index, when it hit negative territory for the first time in history on April 20th, 2020.

I was inspired by one of the models developed in Tufano (1998), which studies the gold mining industry:

$$R_{i,t} = \alpha_i + \beta_i R_{m,t} + \gamma_i R_{Gold,t} + \varepsilon_{i,t}$$

Where $R_{i,t}$ is the daily return on stock i including dividends, $R_{m,t}$ is the return on the market portfolio and $R_{Gold,t}$ is the total return on gold. β_i represents the responsiveness of stock i to daily market movements and is used to control for changes in equity indices that may affect the shares, independently from gold. γ_i is the actual exposure of firm i to gold price risk and it determines the impact on its share returns.

On the basis of Tufano's model, the model for Oil price risk becomes:

$$R_{i,t} = \alpha_i + \beta_i R_{m,t} + \gamma_i R_{WTI,t} + \varepsilon_{i,t}$$

With the only differences being $R_{m,t}$, the daily return on the S&P500 market index, $R_{WTI,t}$, which is the daily return on the WTI Crude Oil price index and γ_i, being this time the exposure to gold prices. This model is designed for quarter observations of daily returns, as a consequence I decided to center the analysis on April by studying the March-May 2020 time frame.

The only case in which this model can actually be applied correctly, provided that the chosen firms trade on exchanges every working day during the same hours, is in case of non-stationary exposures over the period. If this is not the case, it is more formally correct to use weekly or monthly observations as it leads to less biased results (Tufano, 1998).

4. Conclusions

The two main objectives of this thesis were: analyzing the market phenomenon of commodity price volatility and what it implies in terms of value for exposed firms and assessing the implications on firm value of the way firms usually respond to this occurrence.

In order to do so we laid solid theoretical foundations by describing all the facets of risk in the economic and financial field, with particular emphasis on the classical literature on its measurement and the main views on its management. We have also witnessed how risk management is a continuously evolving, multilateral subject as it does not consist of financial hedging only. However, the attention on hedging instruments and strategies was essential for interpreting the results of the empirical studies.

To assess the first objective we examined exposures, that is, the impact of commodity price changes on equity share returns. From the empirical studies we examined we can draw the following conclusions:

First, on the basis of what was successfully highlighted by Bartram (2015), we can confirm that the higher volatility of commodities with respect to other financial sources of risk does not directly imply that commodity exposures are more relevant than other types of exposures, as the quantity of cash flows depending on commodities are, on average, lower than those affected by other variables such as exchange rates or interest rates. Thus, for the average multinational firm, the two forces balance out so that equal attention should be dedicated to both issues.

Second, based both on Tufano (1998) and Jin and Jorion (2006), we can confirm that commodity price increases cause significant value increases for both Oil and Gold producers, as the exposures resulted positive. Furthermore, hedging actually reduces exposures on average and works as a great tool to protect from output price drops. By contrast, leverage, production and firm size have been found to increase exposures.

Third, for Oil-derived products users such as airlines exposures resulted negative, as expected. (Berghofer and Lucey, 2013), (Treanor, Rogers, Carter and Simkins, 2014). Also, factors such as leverage, firm size and fleet diversification have been found to increase the absolute value of their exposures. Conversely, financial hedging has proven less effective at reducing exposures than operational hedging for this industry. For this sector, higher commodity prices and volatility imply higher negative exposure on average, however, moderate volatility maximizes exposures.

To assess the second objective, we look at the sign of the hedging coefficients, which allows to tell whether hedging practices increase or decrease firm value. The studies yielded slightly different results:

Jin and Jorion (2006), confirm that hedging does not have an impact on the firm value of Oil and Gas producers. It is likely to be so because managers act for personal utility maximization rather than for maximizing shareholder value.

Adam and Fernando (2006), confirm that hedging does not impact firm value as well, by studying a sample of Gold companies. However, they find an exception: the only case in which hedging impacts firm value is when shareholders are not able to observe changes in the firm market beta as a result of derivatives trading activities by the firm. Because these instruments carry systematic risk premia, the market beta of the company increases and if shareholders are not able to realize it has changed, they will not adjust their required rate of return and witness an increase in value.

Other factors positively impacting firm value have been found to be investment growth and leverage, higher production costs instead drive down the value of the firm, as expected. On the side of commodity users, hedging has a positive impact on firm value only when it is carried out as a consequence of higher exposures. (Treanor et al. 2014)

Finally, inspired by these studies and based on their experience, I proposed a model to measure the impact of the volatility of crude Oil on Equity share prices. To be left open for improvement and further research.

References

Adam, T., Fernando, C. (2006) – Hedging, speculation and shareholder value, *Journal of Financial Economics 81, pp. 283-309*

Allayannis, G., Weston, J.P. (2001) – The use of foreign currency derivatives and firm market value, *Review of financial studies 14, pp. 243-276*

Banerjee, J. (2013) – Origins of Growing Money, *Forbes India*

Bannister, J.E., Bawcutt, P. (1981) – Practical Risk Management, *Witherby, London*

Bartram, S. (2005) – The impact of commodity price risk on firm value – An empirical analysis of corporate commodity price exposures, *Multinational Finance Journal, 9, pp. 161-187*

Berghofer B., Lucey, B. (2013) – Fuel hedging, operational hedging and risk exposure – Evidence from the Global Airline industry, *International Review of Financial Analysis*

Bodie, Z., Kane, A., Marcus, A. (2018) – Investments, *McGraw-Hill Education, 11th edition*

Brealey, R., Myers, S., Allen, F. (2017) – Principles of Corporate Finance, *McGraw-Hill Education, 12th edition*

Carter, D., Rogers, D., Simkins, B. (2006) – Does hedging affect firm value? Evidence from the U.S. airline industry, *Financial Management, 35, pp. 53-86*

Carter, D., Rogers, D., Simkins, B., Treanor, S. (2017) – A review of the literature on commodity risk management, *Journal of Commodity Markets 8, pp. 1-17*

Crockford, G.N. (1982) - The Bibliography and History of Risk Management: Some preliminary observations, *The Geneva Papers on Risk and Insurance, 7, pp. 169-179*

Damodaran, A. (2007) - Strategic risk taking – A framework for risk management. *Wharton School Publishing*

Deloitte (2018) – Commodity Price Risk Management, A manual of hedging commodity price risk for corporates

Fama E., French K. (1993) - Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics, 33*

Froot, K.A., Scharfstein, D. and Stein J.C. (1994) - A framework for risk management, *Harvard business review*

Gaudenzi, B., Zsidisin, G., Hartley, J., Kaufmann, L. (2018) – An exploration of the factors influencing the choice of commodity price mitigation strategies, *Journal of Purchasing & Supply Management 24, pp. 218-237*

Hull, J. (2015) – Options, Futures and other Derivatives, *Pearson, 9th edition*

Hamilton, J. (2011) – Historical Oil Shocks, *University of California, San Diego*

Jin, Y., Jorion, P. (2006) – Firm Value and Hedging: Evidence from U.S. Oil and Gas Producers, *Journal of Finance, 2, 893-919*

Liew, J., Vassalou, M. (2000) – Can book-to-market, size and momentum be risk factors that predict economic growth?, *Journal of Financial Economics, 57, 221-245*

McCahill, F.X. (1971) – Avoid losses through risk management, *Harvard Business Review*

Mehr, R., Hedges, B. (1963) – Risk Management in the Business Enterprise, *Irwin, Homewood (IL)*

Mishkin, F., Eakins, S. (2018) – Financial Markets and Institutions, *Pearson, 9th edition*

Rhodes, A. (2015) – A brief summary of the long history of risk management, *Ventiv Tech*

Smith, C., Stultz, R.M. (1985) – The determinants of Firms' Hedging Policies, *Journal of Financial and Quantitative Analysis, 20, pp. 391-405*

Stock, J., Watson, M. (2015) – Introduction to Econometrics, *Pearson, updated 3rd edition*

Stultz, R.M. (1996) – Rethinking risk management, *Journal of Applied Corporate Finance, 9, pp. 8-25*

Treanor, S., Rogers, D., Carter, D., Simkins, B. (2014) – Exposures, hedging and value: New evidence from the U.S. airline industry, *International Review of Financial Analysis, 34, pp. 200-211*

Tufano, P. (1998) – The Determinants of Stock Price Exposure: Financial Engineering and the Gold Mining Industry, *Journal of Finance, 53, pp. 1015-1052*

United Nations Conference on Trade and Development, UNCTAD (1998) – A survey of commodity risk management instruments

Watson, D., Head, A. (2007) – Corporate Finance Principles & Practice, *Pearson, 4th edition*

Web references

www.analystprep.com
www.blog.ventivtech.com
www.blog.quantinsti.com
www.commodity.com
www.investopedia.com
www.mercatusenergy.com
www.wikipedia.org