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CORPORATE HEDGING WITH COMMODITY DERIVATIVES: A FOCUS ON CRUDE OIL SECTOR WITH AN EMPIRICAL HEDGING ANALYSIS ON A LARGE OIL PRODUCER: THE CASE OF CNOOC Ltd.

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INTRODUCTION

This research thesis aims to investigate the effectiveness of hedging with commodity derivatives as a tool to protect against risks to which an entity is exposed, with a focus on the crude oil sector. Specifically, the research questions this paper intends to answer involve the assessment of the practical effectiveness of using put options in offsetting crude oil downward price swings and whether the benefits of this methodology outweigh the costs. For a practical application, the company CNOOC Ltd., a leading oil producer with its headquarter in China, was considered.

The use of hedges is one of the primary objectives of risk management since the occurrence of unpredictable future events could have a detrimental impact on the company's financial and economic situation. This is even more true in the face of the growing uncertainty associated with the economic landscape and the succession of various economic crises over time, which have made firms more vulnerable to random phenomena. In view of this, the use of financial derivatives as instruments to generate a hedge against such risks and avoid huge corporate losses, has become crucial.

Derivatives constitute an ever-growing and rapidly expanding market in both advanced economies and emerging markets, thanks in part to the financial engineering activity that enables the creation of new instruments to meet the diverse needs brought about by an ever-changing economic sphere.

Among the broad class of derivative instruments, the most widely used are forwards, futures, swaps and options. The latter are the instruments used in CNOOC Ltd.'s hedging strategy, as will be discussed later. However, the functions for which derivatives are used are many, ranging from speculation, to arbitrage, to hedging, which is the object on which this elaboration is based.

In particular, the energy market represents one of the world's largest exchanges and plays a leading role in industrial growth and in powering the economy, hence, numerous derivatives are traded every day on the multiple marketplaces. Nevertheless, this research focuses on the crude oil market, illustrating its market data and its evolution over the years. It will illustrate the change in production, consumption, proved reserves, and the Reserves-to-production (R/P) ratio over the past decades, outlining how crude oil has grown considerably, given the increase in energy consumption in the face of globalization and ongoing progress.

To assess whether a hedging strategy is efficient in mitigating the risks associated with oil price fluctuations, it is crucial to grasp what are the key drivers of crude oil price determination. The impact of variables related to the macroeconomic scenario, the geopolitical environment, and the supply chain landscape will be considered, as they rank as the sources most responsible for price behaviour. An in-

depth analysis of the main characteristics of the black gold price will then be provided to highlight its main components, including the delivery price, crude benchmarks, pricing approaches, as well as possible hedging strategies related to this commodity.

These hedges are accounted for in different ways depending on the purposes for which the derivative instruments are used, i.e., in cash flow hedges, fair value hedges and net investment hedges, implying different effects on the company's Profit&Loss. Hence, an overview of accounting methods is provided in this work, illustrating the changes introduced by IFRS 9 and ASC 815.

The final part is devoted to the empirical analysis. A counterfactual analysis will be performed to test how much the company under analysis would have saved over the period 2017-2021 if it had entered into long put options with Brent oil futures contracts as underlying assets in each month. Long put options offset spot price decreases through payoffs generated by the difference between the strike price and the price of the underlying futures at the time these options are exercised, assuming they are in-the-money. A CNOOC Ltd. overview is provided, as well as the risks faced by the company. The main features of the methodology used, and the sample data will be presented. The hedging analysis will be performed, and the results reported and discussed in detail.

A discussion of the limitations behind this empirical analysis is explored, as well as suggestions for future research.

CHAPTER ONE

1.1 RISK MANAGEMENT AT CORPORATE LEVEL

From the perspective of the corporate world, and beyond, risk management has become an increasingly crucial and essential activity to ensure the continuity of the firm and to avoid the fall-out of random phenomena that can seriously threaten its financial health. This relevance of risk management was also highlighted in the past by Theodore Roosevelt, "Risk is like fire: if controlled it will help you; if uncontrolled it will rise up and destroy you". This shows how essential is to implement all remedies to cope with the unforeseen occurrence of unexpected and economically significant events (see Kujala P. and Lu L., 2018).

In particular, risk refers to the possibility that some uncertain future events may occur and adversely affect the company's performance and objectives, as well as create major damage in several aspects. Casual events do not always have a negative impact on the organization, since in some cases the occurrence of unpredicted events brings benefits or improvements from different perspectives. In any case, when we talk about risk management, we refer to the management of those incalculable future events that are classified as having the potential to affect the company in a detrimental manner, and for this reason they must be detected and managed with strategies and systems that allow reducing their degree of danger for the business.

The growing attention to the risk management, the need to improve the effectiveness of the business divisions that deal with risk management, the ability to prevent and avoid major economic damages, is mainly due to the increased risk in the economic and financial landscape that makes companies more vulnerable to random phenomena. This is due to the various crises that have occurred over time, suffice is to remember the crises of the 90s-2000s, the bursting of the Dot-com bubble[1], the crisis of 2007-2008, the sovereign debt crisis of 2011, which have highlighted the criticality not only of the various companies, but of the entire economic systems. Consequently, various regulatory changes have been introduced in order to increase the transparency and efficiency of markets and economic systems and to

[1] The Dotcom bubble is a speculative bubble that developed between the years 1997 and 2000 due to the general euphoria linked to the concepts of "progress" and "technological innovation" and the growing number of companies operating in the sector linked to the internet and technologies, convinced that they could generate high profits in the future (the so-called Dotcom). In reality, these companies were small and little capitalized, but they performed well since the internet and technology sector was heavily overestimated. When the bubble burst in the 2000s, due to market saturation, many large companies in the industry went bankrupt.

avoid the repetition of those events that have brought most of the world's economies to their knees. Hence, there is also an ever-increasing concern to manage risks in the best possible way, as well as an increasing strengthening of the risk management divisions and their modus operandi. This is also favoured by the development of ICT[2], which has made it possible to exploit cutting-edge and automated technologies and systems capable of managing risks with ever greater precision and validity.

However, random phenomena that are susceptible to affect the company's performance and create damages from a financial, managerial, and capital point of view are defined as business risks. These risks, which are the central focus of risk management objectives and efforts, can be classified in different kinds of ways. These differences will be conceptualized below:

- ***Internal and External Risks:*** External risks are all those events/phenomena that come from outside the company and can't be altered or influenced by it in any way. In general, external risks can be of a different nature, but this concept often refers to risks arising from the business cycle, interest rate movements, economic policy aspects and so on. It is relevant that even if these risks can't be influenced by the company itself, they can still be handled to reduce their potential negative impact.

On the other side of the coin, we have internal risks, which, unlike external risks, originate within the company. They are, therefore, all those risks that stem from the company's production system, decisions made by management, human capital, security, IT systems, etc. In addition, internal risks can be identified and managed during risk management activities, and they can also be modified and influenced internally, which makes them less difficult to control than external risks.

- ***Systematic and Diversifiable Risks:*** Another qualification of risks depends on whether they are systematic and therefore not diversifiable or whether they are diversifiable and thus not systematic. This categorization is based on the correlation between the economic effects of the risk and key macroeconomic and financial variables (see Floreani, 2004).

The concept of systematic and non-diversifiable risk was first discussed in the context of the Capital Asset Pricing Model (CAPM)[3], presented by Sharpe. In this context, systematic risk is defined as the volatility of a stock or portfolio of stocks relative to the market (See Nawazish M. and Simatupang D.D.,

[2] Information and communication technology, term used to indicate all systems and technologies for the management, transmission, collection of data and information

[3] The Capital Asset Pricing Model (CAPM) is a financial market equilibrium model that establishes a relationship between the return and risk of a financial asset, measured by a single risk factor called beta. The CAPM formula is: r=rf+B[rm-rf], where r is the return, rf the risk-free rate, B the beta and [rm-rf] the risk premium.

2004). However, systematic risk is that risk linked to sources of systematic risk, i.e., the main macroeconomic and financial variables, including interest rate trends, general economic trends, inflation, and those for which the diversification process does not allow elimination or significant reduction.

On the other hand, diversifiable or non-systematic risks are all those risks that do not depend on systematic risk sources and can be eliminated through diversification processes. It is important to stress that in order to define risk as diversifiable, it is sufficient that this risk can be eliminated by diversification and not that it has actually been eliminated.

- *Speculative and Pure Risks:* Risks can also be catalogued as speculative or pure, and this depends on the relationship between events and their consequences. When the occurrence of a given event can lead to both positive and negative effects, and thus the positive risk reflects the negative risk, we speak of speculative risks. In contrast to the latter, pure risk occurs when the possibility of the adverse scenario occurring is very low, just as the possibility of no harmful event occurring is high, but if such an event does occur, then the damage will be high and the benefit of the favourable scenario is hardly perceptible.

The pure risks also have some peculiarities that differentiate them from speculative risks:

- they occur suddenly
- they are characterized by an immediately observable manifestation
- economic effects occur in a very short time.

Speculative risks, on the other hand, are characterized by:

- a progressive realization over time
- their manifestation is not immediately observable
- the economic effects are determined with time.

The differences between these two categories are also reflected in the risk management process, since for pure risks the identification phase is of fundamental importance, while, for speculative risks the monitoring phase is the most relevant.

However, according to Floreani (2004), although there are such distinctions between the various types of risk, the latter has always been the subject of debate as to its meaning creating a lack of homogeneity in the literature and everyday language. Risk can take on different connotations depending on whom it is presented, and the word “risk” is often used to indicate a specific problem that needs to be solved.

Among the many definitions that can be attributed to risk, four approaches encompass almost all the different notions attributed to it. These approaches are:

- the traditional/insurance approach
- the statistical/financial approach
- the managerial approach
- the mathematical approach.

The first approach is based on the concept of evaluating risk as a potential future adverse event, caused by natural events or human actions, capable of threatening the economic and financial health of the enterprise. It is an approach that can be put into practice more easily when considering pure risks, i.e., those risks that arise from situations where there are only two possible scenarios. For speculative risks, given the equal possibility of upside and downside, the approach is more difficult to apply and requires an exhaustive consideration of all the positive and negative consequences that an uncertain event may cause, otherwise there would be a risk of arriving at erroneous estimates. In *the statistical/financial approach*, the risk is considered differently than in the previous approach and is measured as stochastic randomness. This means that the risk factor emerges when there is a possibility of a deviation of a variable from estimates and expectations. Although this approach is easier to apply for pure risks and more complex for speculative ones, it is the most widely used approach because it minimizes valuation and methodological errors. In *the management approach*, the risk is considered as the possibility that the occurrence of future unforeseen events may affect the strategic, operating, and financial objectives of the firm. Nevertheless, this approach has similarities with the statistical/financial approach as both consider the potential upside and downside that may emerge due to certain events. The difference between the two approaches lies in the fact that while in the statistical/financial approach the risk is assessed as the deviation from certain parameters, in the management approach this deviation is considered not concerning the expected values but with respect to the objectives set by the management. The advantage of this approach consists in the effectiveness of its applicability for both speculative and pure risks, although particular care must be taken to not treat targets as expectations. The last approach is *the mathematical* one in which risk valuation is done through the analysis of certain quantitative realizations to which probabilities of realizations are associated. Thus, the risk is defined as any random variable that is measured by certain risk measures, including expected value, mean square deviation, value at risk and asymmetry index. The main problem with this approach is that these risk measures

must be endowed with desirable properties, but these are closely related to the specific problems/risks that are to be solved, so there are no risk measures that are better or worse than others, but there are those that are more or less appropriate for risk assessment (see Floreani, 2004).

Therefore, the classification of business risks and different approaches are fundamental to the risk management process, because for each type of risk the decisions, processes and tools may be different, as well as the effectiveness of the measures implemented. In addition, depending on the risks to be considered and the area in which these risks may emerge, different approaches to risk management may be identified:

- entreprise risk management (ERM);
- project risk management (PRM);
- risk management tradizionale (TRM);
- financial risk management (FRM);
- risk control (RC).

Enterprise Risk Management (ERM) is the approach through which tools are implemented, according to a statistical/financial or managerial approach, in order to identify and eliminate strategic, operational, and financial risks that can jeopardize shareholder value and corporate performance. ERM considers both positive and negative aspects that could impact the company. The most significant process steps concern the adoption of preventive, hedging, control, management, and crisis management measures. *Project Risk Management* refers to the activity of managing the risks associated with a specific project. When evaluating the possibility of carrying out a project, the costs, financing, interest rates, expected return and other parameters are analyzed, but fundamental to its success is the identification, evaluation, and management of the risks to which that project may be exposed, and which could prevent its realization or could alter the estimated results.

In particular, the success of a project is evaluated in three directions - the time required for its completion; - the costs required to carry it out; and - the results and benefits that it generates. However, the presence of risks is detrimental given their potential to influence key factors in project success and this is precisely why the PRM was created. The latter, unlike ERM which uses more of a managerial and statistical/financial approach, is characterized by strong use of technology and engineering systems and procedures. *Traditional Risk Management (TRM)* deals with the identification, analysis, and management of pure corporate risks. As for Enterprise Risk Management, TRM aims to eliminate those factors of interference (risks) to the creation of company value and efficient corporate performance, but

it differs from the ERM since it takes into consideration only pure and not all business risks. Yet, since Enterprise Risk Management is derived from Traditional Risk Management, there is a transition process whereby companies move from the former to the latter. This happens when the company and managers must consider not only pure risks but also the other risks to which the company is exposed in order to make decisions that do not fall into error and also when the management of pure risks is not central to the success or failure of the company. *Financial Risk Management (FRM)* is a process that has become increasingly widespread among companies and financial intermediaries, given the spread of a huge number of financial instruments and derivatives, the growing development of financial markets, and the increased volatility and risks in the face of the various crises that have occurred over the years. FRM includes the same activities as Enterprise Risk Management and Traditional Risk Management, but focuses on financial risks, i.e., risks arising from financial markets that threaten the enterprise. The main approach used is the statistical/financial one with extensive use of historical information that allows more accurate results, especially regarding hedging and monitoring activities (main phases of FRM). The main disadvantage of Financial Risk Management is that, by focusing only on financial risks, it doesn't take into account strategic and operational risks potentially arising from uncertain and unpredictable future events. This entails the risk that the company may implement certain measures to cover and eliminate financial risks, but at the same time be damaged by other business risks. Finally, another approach to risk management is *Risk Control or RC*, in which one person supervises another person (e.g., an asset manager or a credit manager) in order to ensure that the latter does not take risks that are higher than the maximum allowed by the policies adopted by the company or the regulations in force and to assess whether he has the necessary resources to cope with them. Risk control is of great importance in the banking and insurance sector because of the strict rules aimed at preventing these intermediaries from taking too high risks and exposing themselves to the risk of insolvency, which would cause serious repercussions on the economic system. However, in some cases, the Risk Control activity may limit the creation of value for shareholders, since some strategies/activities that could be implemented and that would lead to an increase in the company's performance, must be stopped because they do not reflect the risk profiles of the regulations in force (see Floreani, 2004).

Nowadays having a Risk Management that operates in the best possible way and avoids great economic damage to companies has become of paramount importance and a vital element for their survival. But for Risk Management efforts to be successful, it is essential to have a well-articulated process to follow, which will be described below.

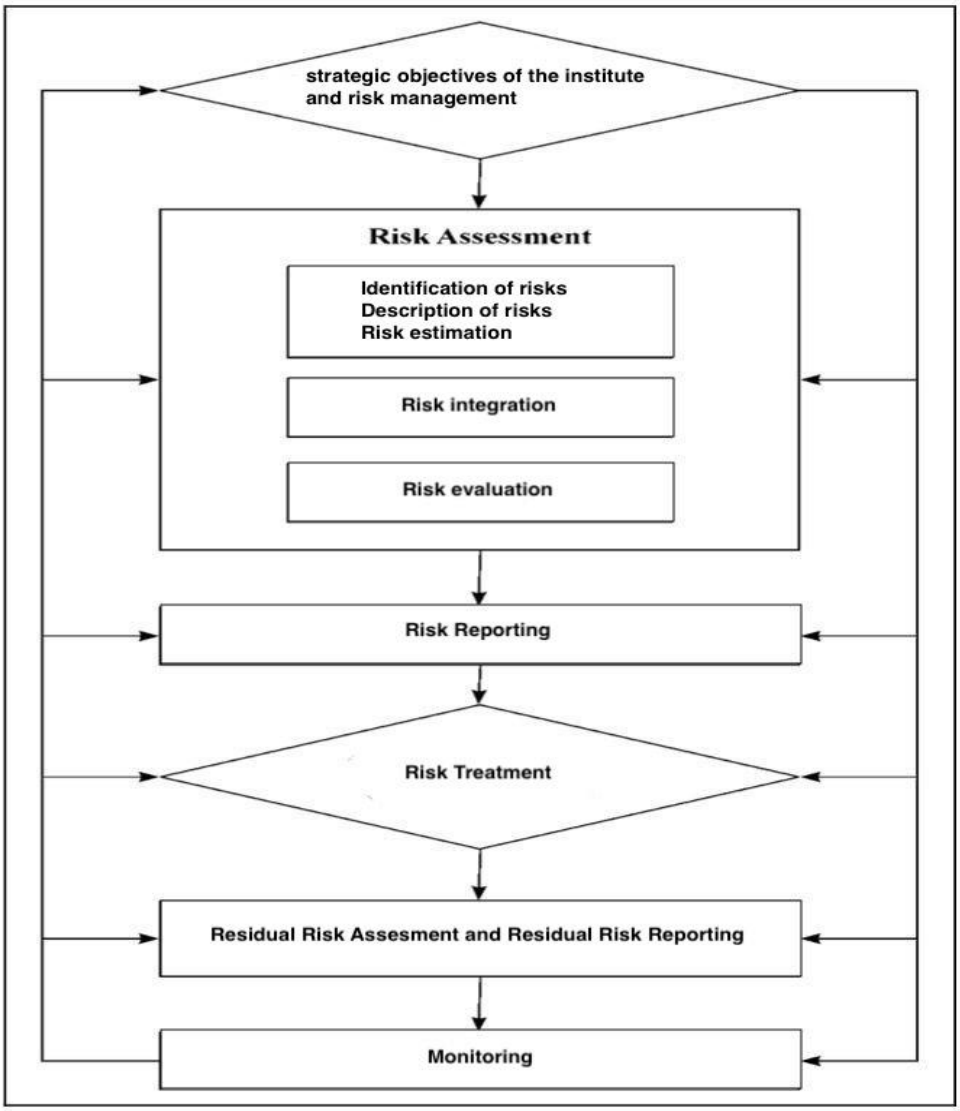


Figure 1. Source: Floreani, 2004

The first step in the Risk Management process is to *define the strategic objectives of the company and the risk management objectives.* This step is fundamental because it will have an influence on the next steps and on the way risks are managed. In fact, the definition of the objectives influences the behaviour of the company in the face of the various types of risks, the criteria, and strategies to be implemented, the resources dedicated to the risk management activity and so on. Subsequently, the second step refers to *Risk Assessment,* which is divided into three other sub-parts:

- risk identification/description/estimation
- risk integration
- risk evaluation.

Risk identification is the part through which are analyzed all those factors/events/phenomena that are of uncertain future manifestation, but which if they were to occur could threaten the financial health of the

company. For these reasons, this part of the process is very delicate as an incorrect or lack of identification of risks may endanger the economic and financial stability of the company. The identification of risks is followed by their description (*Risk description*), which consists of highlighting the characteristics of each individual risk according to standardized methods. The last step of the first subgroup is the *Risk estimation*, which is the most delicate and central step of the whole process, since the probability that a certain risk may occur, the criticality levels based on whether certain parameters are exceeded, and the consequences as well as the losses that these risks may cause, are calculated. The techniques used can be of different types and can be quantitative, qualitative or both.

Following these steps, there is the phase of *Risk integration* in which all previously identified and estimated business risks are aggregated and their level of harm to the company is calculated.

Finally, the last step of Risk assessment, is the *Risk evaluation*, through which the estimates made in the previous phases and the risk levels are analyzed to arrive at a final evaluation. For example, a company may introduce, as a risk assessment criterion, the ratio of costs to a limit value (let's hypothesize 500 thousand euros) and assign the following valuations according to the value assumed by the ratio: - less than 80%, normal situation; - between 80% and 100%, situation close to the limit; - between 100% and 120%, situation above the limit; - greater than 120%, situation well above the limit.

Once this point is reached, the risk management process continues with the *Risk reporting* phase, which is the phase of the process where all the identified risks, their criticality, and their assessment are reported. The risks to which the firm is currently exposed and the risks to which the firm will be exposed if it makes certain decisions, such as initiating a new project, are reported. This first report is critical in the next phase, the phase of *Risk treatment*, because it allows responsible managers to make appropriate decisions based on whether the risk can be defined as adequate or not. In the first case the risk will only be monitored, while in the second case, an intervention strategy will be adopted.

The penultimate step in the Risk Management process is *Risk Treatment*, which consists of implementing the most appropriate measures to eliminate or reduce risks and to avoid the negative consequences that would have occurred had no action been taken. However, this step in the process can be articulated in several ways:

- by taking hedging measures, aimed at assuming a business risk with characteristics mirroring the existing one

- by taking protective or preventive actions with the purpose of reducing the probability and consequences of the downside risk.

Once the appropriate risk management measures have been taken, there follows another phase of assessing and estimating the residual risks to which the company is exposed and a subsequent reporting phase in which all the information at the end of the previous phases of the risk management process are reported. These two phases are the *Residual Risk Assessment* and the *Residual Risk Reporting*.

The last phase of the process is the monitoring phase (*Risk monitoring*), which is an activity already present in the entire risk management process. Monitoring essentially consists of control, which may include the following activities:

- partial or total reiteration of the risk management process if necessary
- monitoring of the trend of risks taken and residual risks
- verification of the efficiency of the risk management process and possible revision of the same. (see Floreani, 2004).

As mentioned in the previous paragraph, one of the activities of the risk management process is the treatment of risk, which may consist either of the implementations of prevention measures or hedging measures. In particular, with reference to the latter, a practice that has developed greatly in recent decades, is the use of derivatives (mainly options, futures, forwards, and swaps) due to the efficiency of financial engineering in creating a wide range of OTC[4] and exchange-traded products and due to the needs in offsetting increasing risks. As shown in a study conducted in 1998 (see Bodnar, Hayt, and Marston, 1998), 80% of the non-financial firms analyzed used financial engineering instruments as well as derivatives to hedge against the risk of movements in interest rates, exchange rates and commodity prices. However, the extensive use of derivatives by companies with widespread ownership is viewed unfavourably by modern financial theory. This is explained by the fact that investors holding shares in these companies operate in a complete and frictionless market and can therefore eliminate or reduce non - systematic risk simply by managing their portfolio choices. Consequently, the use of derivatives as a hedging instrument for the companies would be seen as an unnecessary cost that would destroy shareholder value. Over time, contrary to this theory, other theories and hypotheses have been added

[4] OTC (Over - The - Counter) is the term used to indicate unregulated markets, where transactions take place outside the official channels of stock exchanges. In these markets, transactions take place through bilateral exchanges between the parties and prices are determined by the law of supply and demand.

supporting the use of derivatives as risk hedging instruments that could maximize corporate value thanks to the market imperfections (see Cummins, D.J., Philips, R.D. and Smith, D., 2001). Among these theories, three streams of research have developed:

- a theoretical framework demonstrating the ability of risk management to add value to the firm and shareholders
- an empirical strand describing the cross-sectional determinants of hedging and risk management
- a research questionnaire shedding light on the motivations and rationale behind firms' hedging practices in the United States and other countries.

Thus, although the three research streams have focused on different aspects, they all share the potential of corporate hedging activities and the use of derivatives to increase firm value by reducing agency costs (see Bessembinder, 1991; Mayers and Smith, 1987), expected taxes and financial distress costs (see Mayers and Smith, 1982; and Smith and Stultz, 1985) and the costs of imperfect access to external capital markets (Froot, Scharfstein and Stein, 1993).

1.2 DERIVATIVES

The last few decades have been characterized by various phenomena that have increased volatility in financial markets, the risks involved in conducting economic activities, and the possible dramatic effects that could occur in the event of the default of large financial intermediaries as happened in 2007/08 (cascade effect)[5]. In addition, companies are continually exposed to the risks associated with changes in the prices of the commodities they use in the ordinary course of their business, changes in interest rates affecting investment and sources of financing, and changes in exchange rates since most companies buy and export abroad where other currencies are used. In view of this, many companies and their risk management departments have started to use instruments that can generate a hedge against such risks and avoid huge losses that the company might suffer. Such instruments are better known as financial

[5] The cascade effect occurs when there is a close dependency between a multiplicity of entities, to such an extent that the failure of one of them would also have negative repercussions on all the others, increasing the probability of their failure or generating their default.

derivatives. The history of derivatives is long, so long that it can be skipped and proceeded to explain what is meant by a financial derivative and the various definitions attached to this term.

Source	Definition of Financial Derivative
Title 12 Code of Federal Regulations (CFR) § 163.172 - Financial derivatives.	"A financial derivative is a financial contract whose value depends on the value of one or more underlying assets, indices, or reference rates. The most common types of financial derivatives are futures, forward contracts, options, and swaps. A mortgage derivative security, such as a collateralized mortgage obligation or a real estate mortgage investment conduit, is not a financial derivative under this section".
Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4 July 2012 on OTC derivatives, central counterparties, and trade repositories ("EMIR")	"A derivative is a financial contract linked to the fluctuation in the price of an underlying asset or a basket of assets. Common examples of assets on which a derivative contract can be written are interest rates instruments, equities, or commodities".
IMF Committee on Balance of Payments Statistics, 1998	"Financial derivatives are financial instruments that are linked to a specific financial instrument or indicator or commodity, and through which specific financial risks can be traded in financial markets in their own right. Transactions in financial derivatives should be treated as separate transactions rather than as integral parts of the value of underlying transactions to which they may be linked. The value of a financial derivative derives from the price of an underlying item, such as an asset or index. Unlike debt instruments, no principal amount is advanced to be repaid and no investment income accrues. Financial derivatives are used for a number of purposes including risk management, hedging, arbitrage between markets, and speculation".

CONSOB official website	"Derivatives are so called because their value is derived from the change in the value of an asset or the occurrence of an objectively observable event in the future. The asset or event, which can be of any nature or kind, constitutes the "underlying" of the derivative product".

Apart from the various definitions that can be attached to the notion of financial derivatives, several technical terms are used when talking about such financial instruments:

- *Notional value:* this is the size of the existing position, often with reference to the underlying of the contract (e.g., a derivative contract is on 1,000 barrels of crude oil and the price is $80 per barrel, the notional value of this contract is $80000)

- *Market Value:* is the current value of a contract that can be bought or sold in the market. The main difference with the national value is that the latter refers to the size of a given position while the market value refers to the price at which such a contract could be traded.

- *Credit exposure:* is the exposure of the market participant to the loss he might suffer if the counterparty does not meet its obligations to repay principal and pay interest.

- *Trading volume:* is a term used to refer to the number of contracts traded in a given period of time, usually one day.

- *Open interest:* a term used to refer to derivative contracts that have not yet closed and for which counterparties have a future obligation to perform.

In any case, nowadays, the markets in which financial derivatives are traded are huge and constantly growing in both advanced economies and emerging markets, just think that the notional value of all outstanding contracts is about seven times the world's GDP. This phenomenon of progressive growth is due to the large issuance of new derivative contracts (a phenomenon known as financial engineering)[6] that cover all tradable risks, and not as in the past, when the few derivatives available allowed only market risks to be covered. Related to the latter aspect is the place where financial derivatives can be traded, i.e., either Over-the-Counter (OTC) or Exchange-Traded markets. Exchange-traded markets are

[6] Term used to refer to the process of studying, evaluating, and creating new financial instruments using sophisticated statistical/mathematical/financial models.

markets where individuals can trade standardized contracts, i.e., contracts in which the expiration date, the quantity of the underlying for each contract, the settlement process and so on, are defined. What characterizes these markets is the high level of transparency and the elimination of the risk of counterparty insolvency due to the presence of the Clearing House[7], which is not present in OTC markets. Among the various advantages of exchange-traded derivatives, one is the high liquidity of the market due to price transparency, which makes it possible for market participants to easily buy and sell and close a position when they need to or take a position in the opposite direction to the one they started. In addition, these markets are differentiated due to the strict regulation in force which makes them undoubtedly safer than OTC markets, where less information are released to the public. Leaving aside these positive aspects of exchange-traded markets, one drawback also emerges: these markets are characterized by less flexibility as the characteristics of each contract cannot be decided by the investor, as they are standardized contracts, and this leads to problems especially when it comes to hedging, since one would not be able to find standardized contracts that cover the desired amount (see Corporate Finance Institute). However, as mentioned above, the market for exchange-traded derivatives has grown with time, as shown in the following graph.

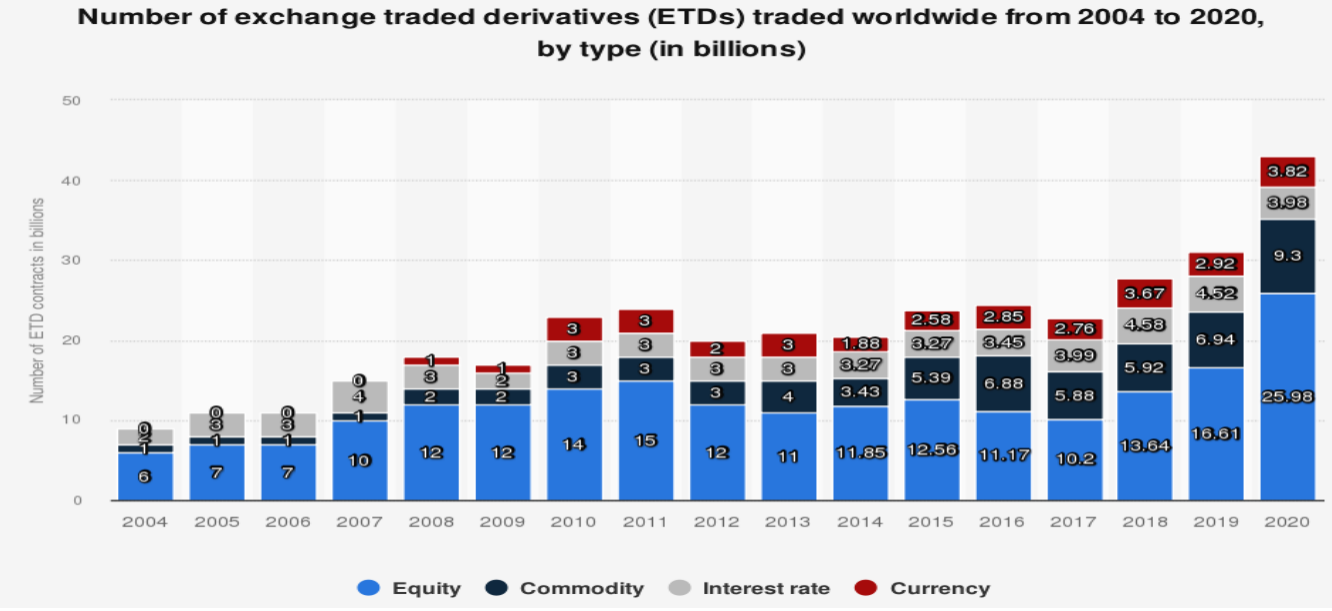


Figure 2. Source: Statista, 2021

[7] The Clearing House is a financial intermediary that manages transactions between two traders, preventing either of them from being unable to meet their obligations. This is made possible because the Clearing House requires each of the traders to make a deposit of funds (known as margin) in order to be certain of their financial readiness to meet any daily losses. In addition, a certain margin (known as maintenance margin) must be respected below which the market participant is forced to replenish this margin, or the position will be closed.

With reference to the graph:

- *Equity derivatives* saw a 56.5% increase between 2019 and 2020, thanks to an increase in all regions (Americas, APAC, EMEA)[8]. In 2020, they reached their highest value over the period (25.98 billion contracts), with stock index options representing the largest component of equity derivatives (19.5%) traded in the market.

- *Interest rate derivatives* reached a value of 3.98 billion contracts in 2020, down 11.9% from 2019 since STIR[9] options (47.4%), STIR futures (63.4%), LTIR[10] options (29.9%) and LTIR futures (12.3%) decreased. However, the majority of interest rate derivatives are traded in the Americas region (68.2%), where there was a sharp decline in volumes of around 14%.

- *Currency derivatives* reached a value of 3.83 billion contracts traded in 2020, an increase of 30.9% compared to 2019. This increase was mainly due to volume growth recorded in the Americas region (27.4%) where 29.7% of total currency derivatives were traded and in the EMEA region where an increase of 59.6% was recorded. The APAC region, where 43.3% of contracts are traded, saw less significant growth (19.7%).

- *Commodity derivatives:* with 9.2 billion contracts, recorded an increase of 34.1% in relation to 2019. This also represents the highest value recorded over the period (see World Federation of Exchanges Derivatives Report, 2021).

As mentioned above, derivative contracts may be traded on officially regulated markets or in Over-the-Counter markets. Over-the-counter markets are markets in which the parties conduct transactions independently through so-called bilateral agreements, in which the parties set out all the terms of the agreement and under which outstanding transactions can be terminated, how settlement amounts are calculated in the event of a termination, and how the collaterals (if any), that must be posted by each side, are calculated. Moreover, the parties involved in a transaction contract with each other directly via telephone and email or through brokers.

OTC markets were largely unregulated prior to the 2007/08 crisis, but then, in view of the negative consequences that emerged, and the economic/financial and social damage generated in subsequent years, OTC markets also underwent a process of regulation and the introduction of various legal provisions. Specifically, the aim of reforming OTC markets was justified by the fact that it would ensure

[8] The Americas region includes North and South America, the APAC region refers to Asia Pacific countries, and EMEA refers to countries in Europe, the Middle East, and Africa.
[9] STIR refers to short term interest rate
[10] LTIR refers to long term interest rate

greater transparency, safety, and reduction of systemic risk[11] in a market where transactions take place directly between parties. Among the most significant changes that have been introduced: - the inclusion of the law that all trades must be reported in a central register; - the regulation that the most standardized derivatives transactions must be managed by central counterparties (CCPs)[12]. Yet, important to remember is the introduction of the Swap Execution Facilities (SEFs), which are platforms where the most standardized derivatives contracts are traded and where participants can publish the bid and ask prices at which they are willing to execute the transaction. However, the OTC markets are huge and growing all the time. As reported by the Bank of International Settlement (see BIS, 2021) in its latest report at the end of June 2021, the notional value of outstanding derivatives reached $610 trillion. However, the gross market value[13] decreased by 20% to $12.6 trillion in the first half of 2021, and also the gross market credit exposure[14] decreased by 21% passing from 3,4 trillion dollars to $ 2,7 trillion. These values are represented in the graph below:

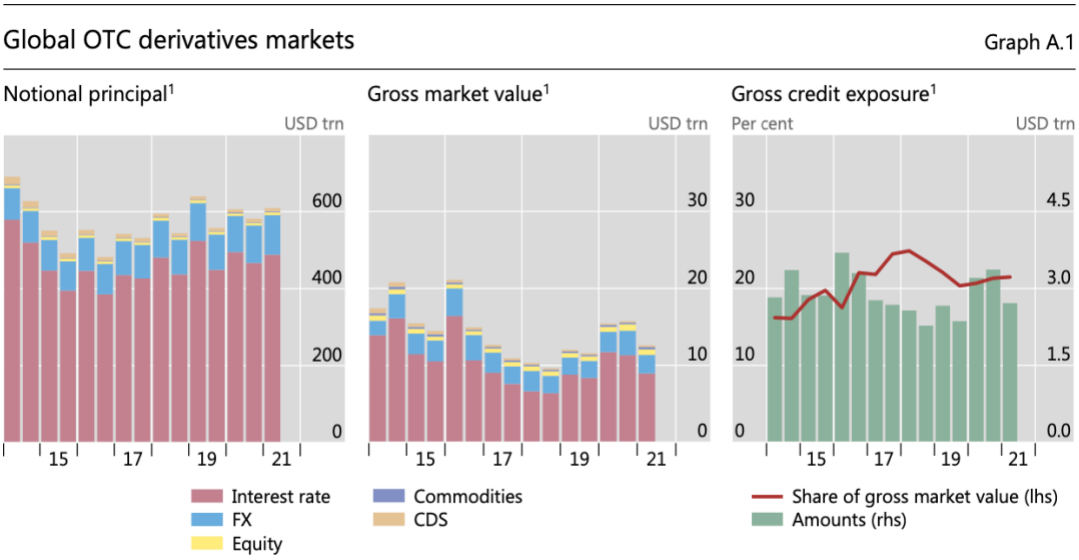


Figure 3. Source: Bank of International Settlement, 2021

However, when considering the various types of derivative contracts, namely interest rate derivatives (IRDs), foreign exchange derivatives (FXDs), equity derivatives (EDs), commodity derivatives and

[11] In this case, systemic risk is understood as the risk that the failure of one institution could lead to a cascade effect on other financial institutions, undermining the financial stability of the financial system.
[12] Central counterparts are intermediaries between the parties involved in the transaction and have the same role as the Clearing House in exchange trades. They ensure the ability of the parties to meet their financial commitments and avoid defaults that would prevent the proper execution of the transaction.
[13] Gross market value is a measure of the amount exposed to risk and is equal to the sum of positive and negative positions.
[14] Gross credit exposure, with respect to any credit transaction, means "the credit exposure of the covered corporation before adjustment for the effect of any eligible collateral, eligible guarantee, eligible credit derivative, eligible equity derivative, other eligible hedge, and any unused portion of certain credit extensions" (see Law Insider).

credit derivatives (CDs), their gross market value is different and follows inconsistent trends. When looking at EDs, CDs, and commodity derivatives, it can be seen that these have a similar trend and have remained slightly stable over the period, with the exception of credit derivatives that have seen a more pronounced decrease from 2012 to 2021 H1. On the other side of the coin, IRDs and FXDs appeared more volatile in terms of gross market value with a trend characterized by rises and peaks. However, beyond the initial growth in the second half of 2020, IRDs fell 21% to $8.9 trillion at the end of June, quite above the value recorded at the end of 2019 ($8.4 trillion). FXDs on the other hand, dropped by 24% to $2.4 trillion, just above the value at the end of the second half of 2019 ($ 2.2 trillion) (see BIS, 2021). Notwithstanding the foregoing, the great breadth of derivatives markets and their continuous development is explained by the fact that such instruments can be used for a variety of activities. Derivative contracts can undoubtedly be used to speculate on future price changes, where the investor tries to predict the market trend in order to make a profit. It is a very risky activity as forecasting is difficult and can't be based on standardized models, but apart from the riskiness, speculation is crucial for the markets as it provides a certain degree of liquidity (see Kilian and Murphy, 2011) and can be used to explain how bubbles develop and how they, in turn, will help the corporate hedgers to adjust their corporate strategies (see Tokic, 2012). Besides speculation, another activity for which derivative contracts are used is arbitrage, made possible by market inefficiencies. The latter consists of simultaneously buying a security on one market at a certain price and selling the same security in another market at a higher price. Although the risks of arbitrage are lower than those of speculation, in some cases these risks may be significant and adversely affect the trader's position. Therefore, arbitrage is most often performed by large investors or hedge funds, as they are able to invest in large amounts by exploiting small price differences and thus expecting a profit with low risks. In addition to speculation and arbitrage, derivatives are also used for hedging strategies, i.e., activities that consist in taking an offsetting or opposite position for a given security in order to reduce the risk to which the individual/company is exposed (see Gitman and Joehnk, 1985). However, it is on hedging that this work focuses and in the following paragraph we will analyze the main derivative instruments existing on the market:

- options
- forwards
- futures
- swaps

1.2.1 OPTIONS

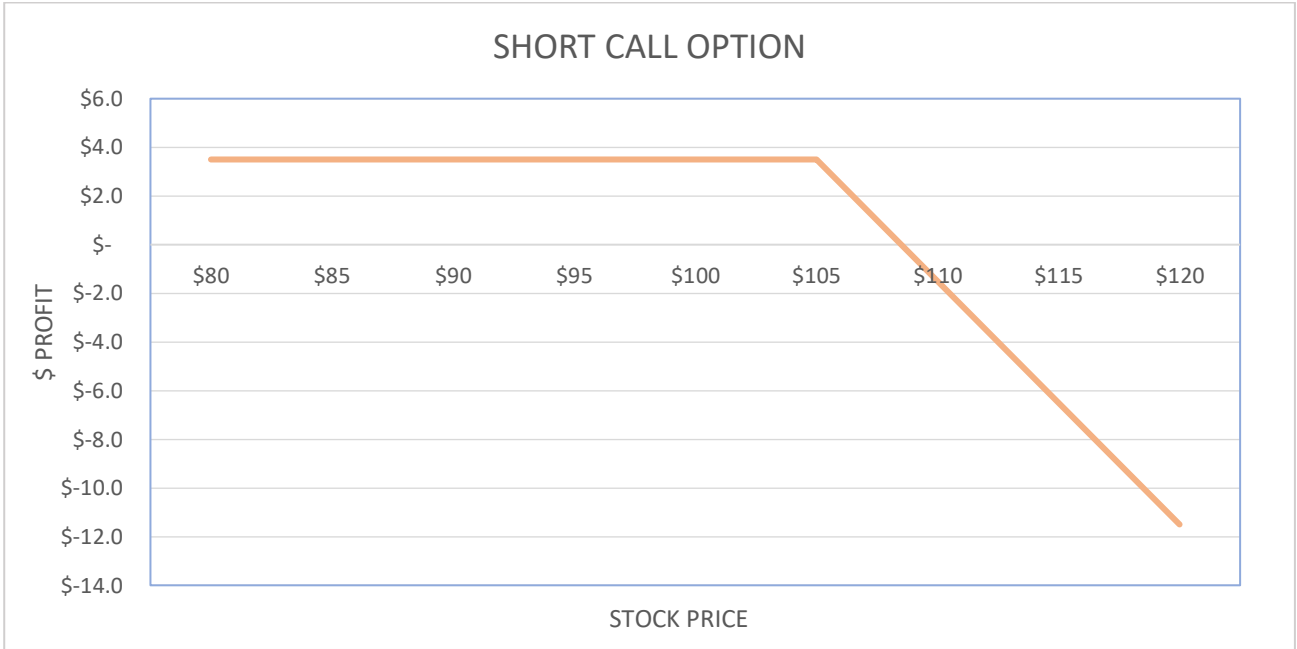
Among the various derivative contracts, options are undoubtedly one of the most widely used and account for a large proportion of the total trades that take place in the markets. Options can be of different types, with different underlyings, different maturities and so on, but the main categorization is the division into calls and puts.

- *Call options:* are derivative contracts that give the buyer the right to buy the underlying at a certain price, called "strike price" or "exercise price" on a certain date (see McMillan, 1986), which is the maturity date if we are talking about European options, or any date before and at maturity if we are talking about American options. In addition, we speak of Bermudan options, when they can only be exercised on specific periods/dates. Since options grant the buyer the right and not the obligation to be able to buy the underlying asset, this benefit is realized by the payment of a price called "option premium", i.e., a cost for the buyer (see Gitman and Joehnk, 1999). Furthermore, call options can be bought and sold. When they are bought, the investor is taking a long position, in which case they are referred to as long call options; when the investor sells the calls, he is taking a short position, in which case they are referred to as short call options. In the case of a long call option, the buyer purchases the call and pays the option premium to the seller, whereas if the investor takes a short position, he receives the option premium from the buyer and sells the call (sells the right). Despite the option premium, what changes between a long and a short position is that in the long position the buyer forecasts that the price of the underlying will rise and he can exercise his right and earn the profit given by the difference between the price of the underlying and the strike price less the costs. If the price of the underlying is lower than the strike price, the buyer will not exercise his right and the payoff is 0. Written in a formula we have: $Max\ (S_t - K, 0)$[15].

If the investor takes a short position on the call, he will hope that the price of the underlying remains below the strike price, so that the buyer will not exercise his right and he will not be obliged to sell the underlying at a price below the market price incurring in a loss. So, in case St < K the seller of the call earns the option premium paid by the buyer at the time the position is entered and nothing happens, otherwise he must sell the underlying to the buyer at the strike price (that is lower than current market value). Written in formula we have $-Max\ (S_t - K, 0) = Min\ (K - S_t, 0)$.

[15] St is the spot price of the underlying; K= is the strike price or exercise price

Next, charts for both long call and short call will be illustrated to highlight the main differences between the two derivative contracts. Let's assume that an investor wants to go long on a call option with as underlying the Brent Crude Oil. The spot price in 0 of the Brent Crude Oil is $95.56 per barrel and the strike price for the European long call option is $105. The option premium is $3.5. In this case the buyer will exercise his right to buy the underlying only if S_t is greater than K, therefore only if St > $105. In the case where the investor takes a short position, so he sells a call option, he immediately earns the option premium of $3.5, but if the price of the underlying asset S_t rises above the strike price K, the seller will have to sell the underlying at a disadvantageous price and suffer a loss as represented graphically (net of the option premium). The profit diagram of both positions is shown below.



Figures 4 and 5. Source: personal elaboration on Excel

- *Put options:* are contracts that give the investor the right to sell the underlying asset at a given price (strike price) at a given time (see Bhalla, 2004). As with call options, European put options allow the option to be exercised only on the maturity date, American put options allow the option to be exercised at any time before and at maturity, and finally Bermudan put options which can only be exercised on specific dates.

Even for put options the buyer must pay a premium (the option premium) to the seller, since such options give the right and not the obligation to be exercised, and this advantage is balanced by the premium payment. However, put options can also be long put options or short put options, depending on whether the investor forecasts a fall in prices and therefore takes a long position on the put option, or whether the investor sells the put option and takes a short position, thereby earning the premium and hoping for a rise or stability in prices.

In the case of long put options, the buyer buys the derivative and pays the option premium to the seller. Subsequently, if the price of the underlying asset S_t is lower than the strike price K, i.e., S_t < K, the buyer exercises the option and sells the underlying asset at a higher price (K) than the current market value (S_t), thereby making a positive payoff. If S_t > K, the buyer of the long-put option will not exercise his right and his payoff will be 0. Written in formula: $Max\ (\ K\ -\ S_t, 0)$.

If, on the other hand, the investor decides to take a short position, he will sell the put option and earn the premium. If S_t > K, the seller will have earned the premium and will not have to buy the underlying asset from the buyer of the put option at a higher price (K) than the market price (S_t). If St < K, then the investor who has taken a short position will have to buy the underlying from the counterparty and record a loss given by the difference between K and S_t. Written into the formula we have: $-Max\ (\ K - S_t\ , 0) = Min\ (S_t - K, 0)$.

For convenience, we assume the same example as for call options. The graphs for both long puts and short puts will be illustrated to show how these instruments differ. Suppose an investor wants to go long on a put option with Brent Crude Oil as the underlying asset. The spot price in 0 of Brent Crude Oil is \$95.56 per barrel and the strike price of the European long put option is \$105. The option premium is \$3.5. In this case the buyer will only exercise his right to sell the underlying asset if S_t is lower than K, i.e., only if St < \$105, earning a profit equal to \$105 - $S_t\ -\ option\ premium$. If, on the other hand, he takes a short position, i.e., sells a put option, he immediately earns the option premium of \$3.5, but if the price of the underlying asset S_t falls below the strike price K, the seller will have to buy the

underlying asset at a disadvantageous price and incur a loss as shown graphically. The profitability diagram for both positions is shown below.

Figures 6 and 7. Source: personal elaboration on Excel

However, the differences between call and put options have been described above, but what this work now wants to highlight, is how different variables can affect the prices of both types of options, both European and American.

- ***Stock Price**:* this is a variable that influences the price of both options, as changing the stock price changes the evaluation of whether to exercise the right or not. For both European and American call options, as the stock price increases, the price of call options increases due to the possibility of obtaining higher gains (given by the difference between S_t and K). For put options, both American and European, the reasoning is inverse. As the stock price increases, the price of options decreases, as the possibility that the investor will exercise his right (i.e., sell the underlying asset when S_t < K) decreases.

- ***Strike price:*** as well as the stock price, the strike price also affects the possibility that the options can be exercised, and consequently influences their price. For both European and American call options, if the strike price is large, there are fewer possibilities to exercise the option by buying the underlying and obtaining a gain (given by S_t - K). For this reason, if the strike price is higher, the call option prices are lower. On the contrary, for European and American put options, the higher the strike price, the more their price increases, since there are more possibilities that K is greater than S_t and therefore the option will be exercised.

- ***Time to Maturity:*** as far as European call and put options are concerned, there is no evidence of any price change when the time to maturity changes since the relationship is uncertain. For American call and put options that can be exercised at any time before maturity, an increase in the time to maturity leads to an increase in their price, as the possibilities that they can be exercised when they are "in the money"[16] are greater.

- ***Sigma:*** refers to the fluctuations in the market price of the underlying asset, and greater volatility leads to an increase in the prices of both American and European call and put options. This is explained by the fact that the greater the volatility, the greater the chances that the options can be exercised.

- ***Interest rate:*** an increase in interest rates in the market leads to an increase in prices for both American and European call options. This is because buying a call option is less expensive than buying stock directly on the market, and this difference can be invested at higher interest rates in the market. Because of this, investors are more likely to pay more for call options when interest rates are higher. Conversely, with put options an increase in interest rates leads to a depreciation of these options. This is because an investor prefers to short a stock than to buy a put option, as the former guarantees the investor cash

[16] "In the money" is a term used to indicate that the option is likely to be exercised, i.e., when St > K for call options and St < K for put options. Moreover, there are also other terms that are used. The term "out-the-money" is used to indicate the opposite situation, i.e., when options are not likely to be exercised (see Keasey et al., 2000). The term "at-the-money" is used to refer to options for which the strike price is exactly equal to the current value of the underlying asset.

which can be invested at higher rates. Hence, put option prices are impacted negatively by increasing interest rates.

- ***Dividends:*** in this case, the present value of the dividends paid during the life of the option is considered. For European and American call options, an increase in dividends leads to a decrease in the call price, as the stock price at the ex-dividend date is lower and this reduces the chances of the option being exercised. Obviously, for European and American put options, an increase in dividends leads to a lower stock price at the ex-dividend date, and consequently a higher chance that the option is in the money (i.e., S_t < K).

The table below summarizes the impact of these variables on option prices.

Notations: c/p = European options; C/P = American options

Variable	c	C	p	P
St	+	+	-	-
K	-	-	+	+
T	?	+	?	+
σ	+	+	+	+
r	+	+	-	-
D	-	-	+	+

Figure 10. Source: personal elaboration on Excel

1.2.2 FUTURES

Among the various derivative contracts, in addition to options, futures contracts also account for a large proportion of trade within markets (in 2021, 29.28 billion futures contracts were traded worldwide, see Statista, 2022). But what is a futures contract? A futures contract is an agreement between two parties - the buyer and the seller - whereby they agree to execute a transaction (sell or buy the underlying asset) at a predetermined price on a future date. However, the history of futures is very long and laid its foundations many decades ago. The earliest forms of futures contracts can be traced back to ancient Mesopotamia around 1750 b.C., when the Babylonian king Hammurabi introduced Hammurabi's code,

which was a set of rules for the community, including the possibility of selling goods and merchandise at a future date and at an agreed price. This code required the written form for such transactions, which can be defined as the first form of derivative contracts, and in particular of futures. (Parker E. & Parker G., 2014)

However, an early form of futures contracts could also be seen in the ancient Greece of Aristotle. This is recounted in the story of Thales, a philosopher skilled in predicting future events, who, convinced of a great olive harvest the following year, entered into contracts with mill owners whereby he deposited money with them in exchange for being able to exploit the mills the following year. The owners accepted this contract as there was no certainty about the next year's harvest, and they wanted to protect themselves from not using their facilities. Later, when harvest time came, the harvest was abundant and Thales sold his contracts to use the mills to the other farmers at a higher price, as demand was too high in relation to supply (see Benjamin J., 1885).

However, the first organized futures exchange began in 1710 in Japan, at the Dojima Rice Exchange[17] in Osaka, and a few years later there was the creation of the London Metal Exchange in 1877, one of the largest exchanges markets for metal futures and forwards. Initially, before the creation of the exchange, metals were traded between traders in London cafes, but there was little choice as in the early days only copper, lead and zinc were traded. Later, other metals were added, the exchange grew and today it has a total annual value of 148,835,279 lots.

Nevertheless, in addition to metals, traders began to enter into contracts to buy or sell grain/corn and cattle at predetermined prices and future dates, to protect themselves from price volatility caused by pollution and low demand. The problem was that many of these contracts were not honoured because one of the parties involved in the transaction backed out when the prices were very different from those agreed, and the transaction was not completed. So, in 1848, the Chicago Board of Trade (CBOT) was founded, where the first contract was written in 1851 and it had corn as underlying. This exchange was merged with the CME (Chicago Mercantile Exchange) in 2007 to form the CME Group. The CME Group is one of the largest futures exchanges in the world today.

However, the CME was founded in 1874 as the Chicago Produce Exchange, which was renamed the Chicago Butter and Egg Board in 1898 and then reorganized into the Chicago Mercantile Exchange in

[17] Founded in 1697 and developed independently and privately in the Edo period, it was the Japan's market in which rice brokers operate for its trade

1919. Moreover, it is also important to mention in history the Minneapolis Grain Exchange (MGEX) which is today the main exchange where hard red spring wheat is traded.

The opium futures market in India between 1870 and 1880 is also noteworthy. The main markets were those of Calcutta and Bombay, and it was in the latter that the Bombay Cotton Trade Association established the first organized cotton futures market after the establishment of the cotton futures trade in the United Kingdom.

In any case, the development of the futures market was characterized by important changes in the 1970s, which introduced some novelties. First of all, futures contracts with interest rates as underlying were born, which allowed to lock the interest rate at which the future transaction would be executed and thus reducing the exposure to changes in those rates. Prominent among these contracts was the 90-day Eurodollar contract introduced in 1981. The year after the introduction of these contracts, following the model of the CBOT and the CME and to take advantage of the abolition of currency controls in the UK in 1979, the London International Financial Futures Exchange (LIFFE) was established. The latter was bought by Euronext[18] in 2002, which in turn was acquired by the NYSE in 2006. The combined NYSE-Euronext, including LIFFE, was acquired by ICE[19] in 2014.

However, over the years the futures market has evolved more and more to include not only agricultural commodities, but also other types of products as underlying, becoming an increasingly diversified and attractive market for different investors. This has been emphasized by the establishment of the New York Mercantile Exchange (NYMEX), an exchange controlled by the CME Group and one of the most important in terms of contracts traded, but also in terms of technological advances made that have allowed for greater speed in operations thanks to the use of the internet and automated systems.

In addition, the futures market has been enriched by contracts based on open-pit energy, which used to be traded on the Petroleum Exchange (IPE), which was later acquired by the Intercontinental Exchange (ICE). Of particular significance is the year 2006, in which the NYSE (New York Stock Exchange) collaborated with "Euronext" Amsterdam-Brussels-Lisbon-Paris Exchanges to form the first transcontinental exchange of futures and options (the NYSE Euronext).

[18] Euronext is the European stock exchange born from the merger of the Amsterdam - Brussels - Paris - Lisbon stock exchanges with a capitalization of 6.900 billion euros in 2021.

[19] The Intercontinental Exchange is a US Fortune 500 company formed in 2000 that conducts global exchanges, clearinghouses and provides mortgage technology, data, and listing services. The company holds exchanges for the financial and commodity markets and administers 12 stock exchanges and regulated markets.

The latter, until its dissolution, represented the largest stock market in the world, but then after the acquisition by the Intercontinental Exchange, the exchange was dissolved and the part of the exchange of Euronext was sold. Nowadays, the futures market is always growing, with trillions of dollars traded every day on the various exchanges and with constant changes and innovations.

Despite the history, as with options, futures contracts can have various underlying assets, including commodities, currencies, indices, cryptocurrencies and so on. Specifically, futures contracts can be categorized into two main groups:

- *financial futures:* contracts based on financial instruments such as interest rates, indices, FX exchange and others.
- *commodity futures:* are contracts based on commodities such as oil, metals, wheat, and others.

The pre-established price of the futures contract is called the exercise price or futures price and being standardized, all its characteristics are pre-determined. In fact, futures are exclusively traded on regulated markets, the exchanges, where the size, quality, grade, and trading months are standardized, and relationships are managed by the Clearing house. The Clearing House's main task is to prevent parties from defaulting on their obligations during transactions in futures contracts and on all other transactions that take place on exchange-trades.

Therefore, to prevent one of the parties to the transaction from reneging on the contract or failing because it does not have the necessary resources, the Clearing House sets an amount of cash or marketable securities that investors must deposit at the beginning of the transaction, the so-called initial margin. However, futures contracts are settled daily in a process called marking-to-market, where the balance in the margin account is adjusted to reflect daily settlement. This means that every day the difference between the price of the futures on that day and the price of the futures on the previous day is calculated. If the difference is positive, this generates a gain in the case of a long position which increases the margin, or a loss in the case of a short position. If the difference is negative, the situation is reversed.

The formula is $(FP_t - FP_{t-1})$ x (quantity of the underlying asset per contract) x (number of contracts).

In addition, another aspect that recurs when discussing futures is leverage. When entering a transaction using futures, the initial margin is usually lower than the contract nominal amount, and this difference is the amount that is funded by the broker. This means that leverage leads to an increase in gains, but at the same time, also to an increase in losses in the event of unfavourable market conditions.

However, the functions for which futures contracts are used are different and among these there are:

- ***price discovery:*** futures markets help market participants to make more precise estimates of the future prices of the underlying.

- ***hedging:*** futures contracts are used to lock-in the value of the underlying at which to execute the transaction at a future date, reducing exposure to price/rate volatility due to market changes. In particular, a long hedge is used when a buyer, being exposed to the price increase of a certain asset, decides to lock-in the price at which to execute the purchase in the future by buying futures contracts (long futures).

Example: Suppose a necklace manufacturer needs to buy large quantities of gold on the market, specifically 25 pounds of gold (400 ounces) on May 25th. Today the price of gold is $1213.8 an ounce and the manufacturer wants to protect himself from a price increase on May 25th. The futures price at the time of purchase is $1180 an ounce and the producer buys 4 futures contracts (each contract is for the delivery of 100 ounces). Let's assume that on May 25 the price of gold is $1200 an ounce. The cost of buying gold on the spot market is $480,000, while the payoff accrued from the futures contract is $8000: ($1200 - $1180) x 100 ounces x 4 contracts. The total net cost is $472,000. Let's now assume that the price of gold on May 25 is $1160, buy the gold on the market the investor spends $464,000 and the payoff accrued on the futures contract is - $8000: ($1160 - $1180) x 100 ounces x 4 contracts. The total net cost is $472,000.

On the other hand, a short futures hedge is when a seller wants to sell a quantity of a product at a future date but, being exposed to a possible price drop that would reduce his profit, he decides to go short by selling futures contracts. Example: Suppose that an oil company decides to sell 500,000 barrels of oil on May 25 and to protect itself from possible price declines, decides to hedge by selling futures. The current price of oil futures is $105, and the company can hedge itself by selling 500 futures contracts (each contract is for the delivery of 1000 oil barrels). Let's assume that on 25 May the price of oil is $90 per barrel, the gain from the spot sale is $45 million, while the futures payoff is $7.5 million: ($105 - $90) x 1000 barrels x 500 contracts. The total net cost is $52.5 million. Let us now assume that the price is $120 on May 25, the gain from selling in the spot market is $60 million, while the futures payoff is - $7.5 million: ($105 - $120) x 1000 barrels x 500 contracts. The total net cost is $52.5 million.

- ***Speculation:*** futures contracts are used to speculate on price movements in the market and this process leads to an increase in the liquidity, where the price risk is absorbed by speculators.

- ***Transaction costs:*** futures contracts are used to circumvent and reduce transaction costs, as trading futures is cheaper than trading the underlying itself. This allows to invest in the same asset but with less exposure to costs (see Shakik, K., 2014).

1.2.3 FORWARDS

Very similar to futures contracts, forwards are contracts that allow an individual to buy or sell the underlying asset at a pre-determined price and at a specified future date.

This makes forward contracts different from spot contracts, which are contracts to buy or sell assets immediately at the current market prices.

However, forward contracts differ from futures because forwards are traded on OTC markets since they are not standardized and the parties can decide on quantity, collateral, settlement and so on, while futures are traded on exchange-trades. The difference between futures and forwards is also characterized by the different modalities in which the settlement takes place:

- in futures contracts the settlement takes place daily and the gain or loss are added to the margin deposited by the investor through the marking-to-market process (see the previous paragraph)
- in forwards the settlement takes place at the maturity of the contract.

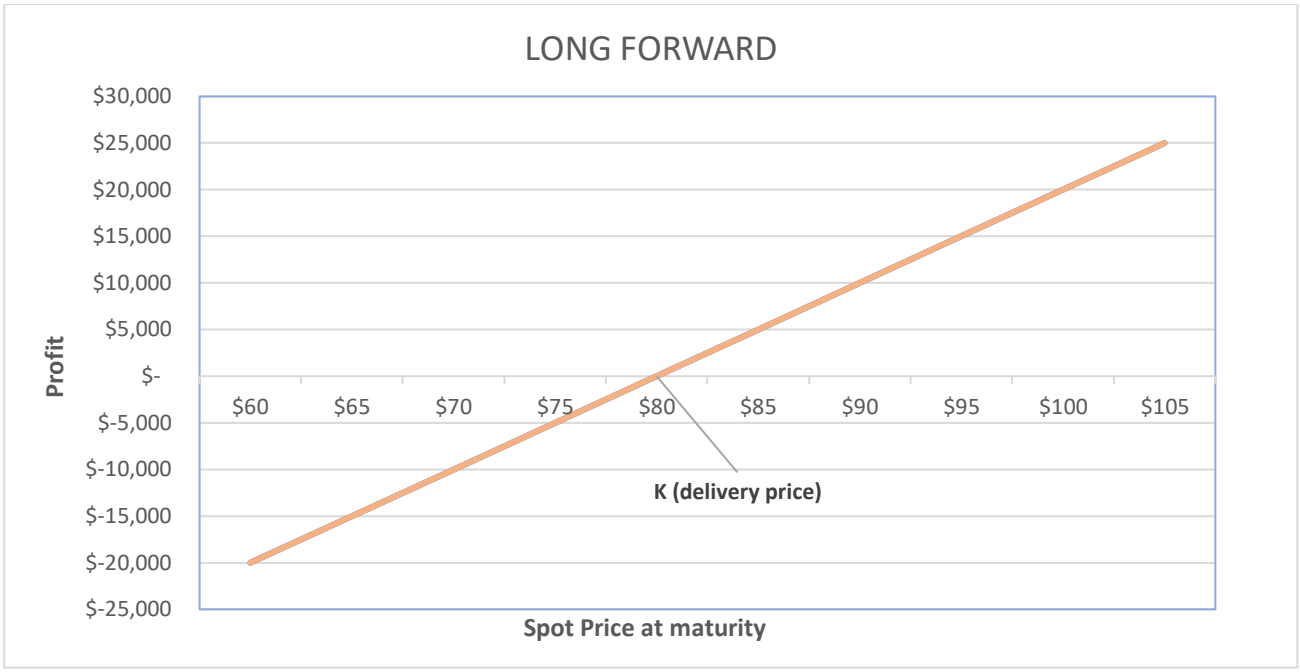
Beyond these differences, forward and futures contracts are very similar, and this similarity is reflected in the positions that can be taken by the investor, i.e., long or short positions.

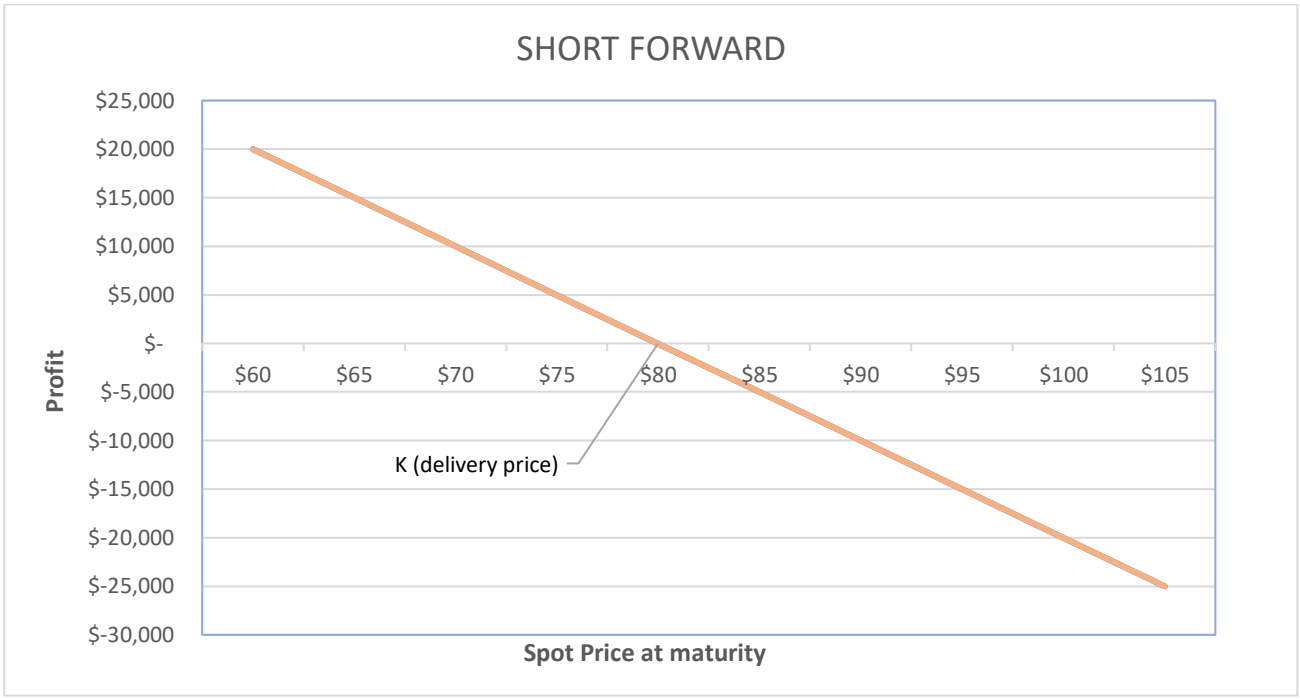
As with futures, in forward contracts, if the investor expects the price of the underlying asset to rise in the future, he decides to go long and buy a forward contract (long forward) which allows him to buy the underlying asset at a future date at the predetermined price. On the contrary, if the investor expects a fall in the price of the underlying, he decides to go short by selling the underlying at the predetermined price at a future date, in this case he has a short forward. To better understand this concept an example is given below:

On February 15, 2018, the manager of the risk management division of an oil company goes long buying forward contracts to buy 1000 barrels of crude oil after 6 months at a price per barrel of $80 (exercise price). Each forward contract is for delivery of 500 barrels, so the manager will buy two forward contracts and pay a total of $80000 on August 15, 2018. Now consider that the price of the underlying asset on August 15, 2018 (St) is:

1) S_t = $85; 2) S_t = $75.

In the first case the manager gets a profit given by ($85 - $80) x (500 barrels) x (2 contracts) = $5000. In the second case the manager incurs a loss given by ($75 - $80) x (500 barrels) x (2 contracts) =-$5000. Payoff graphs in both cases are shown below.





Figures 11 and 12. Source: personal elaboration on Excel

1.2.4 SWAPS

This work, after describing the main derivative instruments (options, forwards, and futures), will focus on the description of swap derivative contracts, which represent an important portion of the trades that

take place in OTC markets, in fact about 60% of all over-the-counter derivatives are interest rate swaps and in 2014 the total notional amount of interest rate and currency swaps outstanding was nearly $250 trillion.

Interest rate swaps are contracts between parties to exchange future cash flows based on interest rates. These agreements set out the dates on which payments will be made and how the cash flows will be calculated for each of the parties involved in the transaction. Among these types of contracts, the most popular are the so-called "plain vanilla" swaps in which one party exchanges cash flows based on LIBOR[20] and the other party exchanges cash flows computed with a fixed interest rate (called a swap rate) at specified future dates. An explanatory example is provided below (see Hull, J. C., 2000).

Assume that Apple enters into a contract with Tesla to exchange cash flows calculated with a fixed interest rate of 5% on a national principal of $500 million for a time period of 5 years. Apple receives in return from Tesla cash flows based on a variable rate, assuming 6-month LIBOR, on the same notional principal for the same period. This example assumes payments are made every 6 months. In this case Apple has entered a payer swap[21] while Tesla has a receiver swap[22]. The cash flows that Apple will pay to Tesla are calculated as N x r x 0.5[23], while the cash flows it will receive are calculated as N x l (t, t+0.5)[24] x 0.5. Let's assume that cash flow exchanges occur in the 5 years between 2015 and 2019, and that the value of the 6-months LIBOR rate is:

Date	Libor rate
January 2015	4,20%
July 2015	3,80%
January 2016	4,50%
July 2016	5%
January 2017	4,90%
July 2017	5%
January 2018	5,20%
July 2018	5,90%
January 2019	4,70%
July 2019	5,40%

Figure 13. Source: personal elaboration on Excel

[20] LIBOR (London Interbank Offer Rate) is the interest rate offered by banks on the deposits of other banks, so it is the benchmark interest rate at which the world's largest banks lend to each other. LIBOR is administered by the Intercontinental Exchange, which asks the major global banks what they would ask from other banks for short-term loans. However, LIBOR can be at 1 month, 3 months, 6 months and so on and is influenced by economic conditions.

[21] Payer swap is the term used to refer to the party that has entered into a swap contract and commits to pay cash flows based on a fixed interest rate and receive cash flows calculated on variable rates, such as LIBOR in this case.

[22] Receiver swap is the term used to refer to the party that has entered into a swap contract and commits to pay cash flows based on a variable interest rate and receive cash flows calculated on fixed rates.

[23] r=is the fixed and predetermined interest rate, N=is the notional principal; 0,5=is the period in which the cash flows are exchanged

[24] Is the 6-months LIBOR RATE

The cash flows generated are:

data are expressed in millions of dollars

Date	*Six-month LIBOR rate (%)*	*Floating cash flow received*	*Fixed cash flow paid*	*Net cash flow*
January 2015	4,20%			
July 2015	3,80%	+10.5	-12.5	-2.0
January 2016	5,50%	+9.5	-12.5	-3.0
July 2016	5%	+13.75	-12.5	+1.25
January 2017	4,90%	+12.5	-12.5	0.0
July 2017	5%	+12.25	-12.5	-0.25
January 2018	5,20%	+12.5	-12.5	0.0
July 2018	5,90%	+13.0	-12.5	+0.5
January 2019	4,70%	+14.75	-12.5	+2.25
July 2019	5,40%	+11.75	-12.5	-0.75
January 2020		+13.5	-12.5	+1.0

Figure 14. Source: personal elaboration on Excel

In January 2015 (starting date of the swap), Apple will pay Tesla after 6 months (July 2015) a cash flow of $12.5 million based on a fixed interest rate of 5% (5% x $500 million x 0.5). Always in July 2015, Apple having entered into a payer swap, will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (4.2%) of $10.5 million (4.2% x $500 million x 0.5). Net cash flow is - $2.0 million. Subsequently, the second swap will occur in January 2016, when Apple will pay Tesla a cash flow of $12.5 million based on a fixed interest rate of 5% (5% x $500 million x 0.5). Always in January 2016, Apple will receive a cash flow payment from Tesla based on a 6-month LIBOR rate (3.8%), of $9.5 million (3.8% x $500 million x 0.5). Net cash flow is - $3.0 million.

Then, the third exchange will occur in July 2016, when Apple will pay Tesla a cash flow of $12.5 million based on the fixed interest rate of 5% (5% x $500 million x 0.5). Also in July 2016, Apple will receive a cash flow payment from Tesla based on a 6-month LIBOR rate (5.5%) of $13.75 million (5.5% x $500 million x 0.5). Net cash flow is + $1.25 million.

The fourth exchange will occur in January 2017, when Apple will pay Tesla a cash flow payment of $12.5 million based on a fixed interest rate of 5% (5% x $500 million x 0.5). On the same date, Apple will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (5%) of $12.5 million (5% x $500 million x 0.5). The net cash flow is $0 million.

The fifth exchange will occur in July 2017, when Apple will pay Tesla a cash flow payment of $12.5 million based on the fixed interest rate of 5% (5% x $500 million x 0.5). Also in July 2017, Apple will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (4.9%) of $12.25 million (4.9% x $500 million x 0.5). The net cash flow is - $0.25 million.

The sixth exchange will occur in January 2018, when Apple will pay Tesla a cash flow of $12.5 million based on the fixed interest rate of 5% (5% x $500 million x 0.5). On the same date, Apple will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (5%) of $12.5 million (5% x $500 million x 0.5). The net cash flow is $0 million.

The seventh exchange will occur in July 2018, when Apple will pay Tesla a cash flow of $12.5 million based on the fixed interest rate of 5% (5% x $500 million x 0.5). On the same date, Apple will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (5.2%) of $13 million (5.2% x $500 million x 0.5). Net cash flow is + $0.5 million.

The eighth exchange will occur in January 2019, when Apple will pay Tesla a cash flow of $12.5 million based on a fixed interest rate of 5% (5% x $500 million x 0.5). On the same date, Apple will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (5.9%) of $14.75 million (5.9% x $500 million x 0.5). Net cash flow is + $2.25 million.

The ninth exchange will occur in July 2019, when Apple will pay Tesla a cash flow of $12.5 million based on the fixed interest rate of 5% (5% x $500 million x 0.5). On the same date, Apple will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (4.7%) of $11.75 million (4.7% x $500 million x 0.5). The net cash flow is - $0.75 million.

The last exchange will occur in January 2020, when Apple will pay Tesla a cash flow of $12.5 million based on a fixed interest rate of 5% (5% x $500 million x 0.5). On the same date, Apple will receive a cash flow payment from Tesla based on the 6-month LIBOR rate (5.4%), of $13.5 million (5.4% x $500 million x 0.5). Net cash flow is + $1 million.

Moreover, swaps can be used for purposes other than to trade cash flows, they can be used also to transform liabilities and assets.

- Use swaps to transform liabilities: Apple could transform a contracted floating-rate loan into a fixed-rate loan using swaps. Let's assume that Apple has borrowed through a received loan of $500 million at LIBOR + 50 basis points[25], what happens by using the swap is that Apple is able to transform the loan at LIBOR + 50 basis points into a fixed rate loan for the following reasons:

- it receives LIBOR according to the terms set forth in the swap
- it pays LIBOR + 0.5% to the outside lenders

[25] One basis point equals one-hundredth of 1 per cent, so that the debit rate equals Libor plus 0.5 per cent

- it pays 5% per year according to what is set forth in the swap.

The net total that Apple pays is 5.5% per year, turning what was a loan at LIBOR + 0.5% into a loan at the fixed rate of 5.5%.

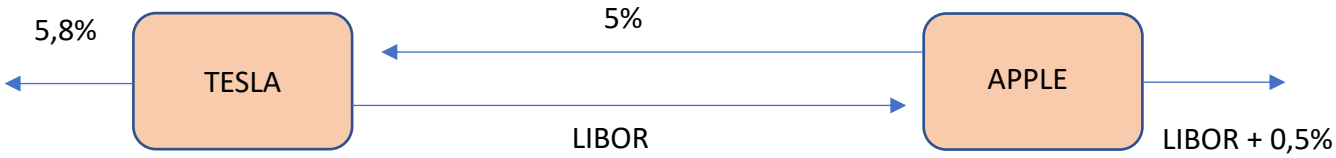
However, the swap could also be used for the opposite situation, i.e., to transform a fixed-rate liability into a variable-rate liability. Let's assume that this time Tesla has funded itself with $500 million of debt at a fixed rate of 5.8%, so each year it must pay an annual amount of $29 million (5.8% x $500 million). To transform this liability, Tesla enters a receiver swap, and the following occurs:

- it pays 5.8% to the external lenders
- pays LIBOR according to the terms of the swap
- receives 5% based on the terms of the swap

The total that Tesla pays is LIBOR + 0.8% per annum, thus transforming a liability at a fixed rate of 5.8% into a liability at LIBOR + 0.8%.

This example is represented graphically below:

1) **first example**



- ***Use swaps to transform assets:*** Apple could transform the fixed-rate cash flows that come from an asset into variable cash flows. Suppose Apple holds a Treasury Bond with a face value of $500 million and a rate of return of 4.3% per year. What happens using the swap is that Apple can transform the bond's yield at the fixed annual rate of 4.8% into a variable rate yield because:

- it receives the 4.3% due to the yield on the Treasury Bond
- it receives LIBOR according to the terms of the swap
- pays 5% per year according to the terms set forth in the swap.

The net total that Apple receives is LIBOR - 0.7% per year, turning what was a fixed rate yield of 4.3% into a floating rate yield (LIBOR - 0.7%).

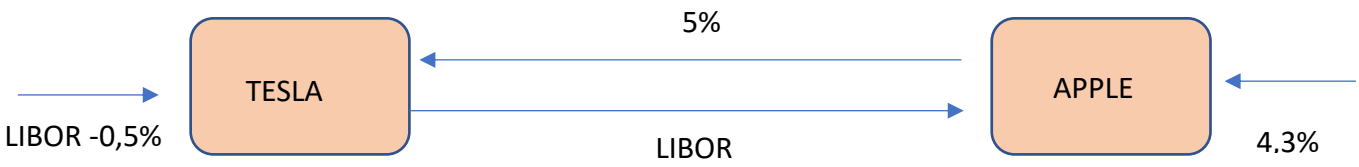
However, the swap could also be used for the opposite situation, i.e., to transform the floating-rate yield on an asset into an asset that generates a fixed-rate yield. Suppose that this time Tesla initiated a long-

term project that yields LIBOR minus 50 basis points. To transform this asset, Tesla enters into a swap, and the following occurs:

- it pays LIBOR according to the terms of the swap
- receives LIBOR -0.5% based on the project
- receives 5% under the terms of the swap.

The total Tesla pays is 4.5% per year, thus transforming a floating rate asset into a 4.5% fixed rate asset. This example is represented graphically below:

2) **second example**



1.3 DERIVATIVES PRICING

When it comes to derivatives, a concept of remarkable relevance is the price of these instruments. Regardless of whether is considered the buy side or the sell side, the price of these instruments is central to making solid investment decisions and knowing how profits and losses might be affected. In addition, there is a range of variables that influence the prices of derivatives, such as interest rates, market volatility, market trends and so on, and an understanding of the relationship between prices and these variables is helpful in making estimates of the benefits that could be gained from certain choices, such as hedging. In the following, this work will describe how the prices of the main derivative instruments described above are derived.

- ***Options:*** as was described earlier with the example of options (see 1.2.1 Options), the long call option takes on value if the stock price increases relative to the strike price, while it becomes worthless if the stock price is less than the strike price. This relationship is represented by the heavy line in the figure

below. Let's consider an option with underlying Apple stock with a strike of $50 and an option premium of $5. Even before expiration, the option price can never remain below the heavy, lower-bound line. In fact, if the stock were priced at $80, it would pay any investor to sell the underlying and then buy back it by purchasing the option and exercising it for an additional $50 (strike price). This generates a gain of $25. Demand for the options from investors looking to take advantage of this opportunity would quickly force the option price up, at least to the heavy line in the figure. For options that still have some time left, the heavy line is, therefore, a lower bound of the option's market price. Written in formula: Lower bound = Max (share price - strike price, 0). However, the upper bound in the figure below is represented by the diagonal line because the option cannot generate a higher payoff than the stock price. If at the option's maturity the stock price ends up above the exercise price, the option is worth the stock price less the exercise price. If the stock price ends up below the exercise price, the option is worthless, but the stock's owner still has a valuable security. In particular, the option price is located somewhere in the shaded region of the figure, because if the stock and the option would have the same price, every investor would sell the option and buy the stock. Specifically, the price that the option can assume is located on the dotted line where three points (A, B, C) represent the value that the option can assume under different scenarios.

- *point A)* is the point where the lower and upper bound meet and the value of the stock price is 0. This means that the option is worthless, as the strike price is greater than the stock price and there would be no motivation to exercise this option. From this, it can be deduced that the value of the option grows as the stock price increase, assuming the strike price is held constant.
- *point B)* at that point, when the stock price becomes large enough, the option price approaches the share price less the strike price. In addition, the value of the option approaches the lower bound because the higher the price of the underlying asset, the greater the possibility that the option will be exercised, and if the stock price is very high, the exercise of the option becomes almost a certainty and the probability that the stock price will fall below the strike price before the maturity of the option is very low.
- *point C)* at this point the stock price is equal to the strike price, and for this reason, the option has no value if exercised immediately. However, if we assume that the option will have a maturity of 6 months, the option could become valuable if the stock price rises above the exercise price, while it could be worthless if the stock price falls below the strike price. There is a 50% probability for both cases, that means the option price at point C exceeds its lower bound, which

at point C is zero. In general, the option prices will exceed their lower-bound values as long as there is time left before expiration (see Allen, F., Brealey, R., and Myers, S., 2017).

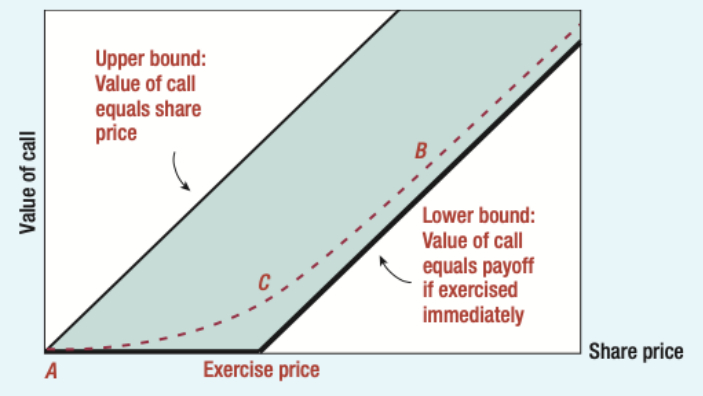


Figure 15. Source: personal elaboration on Excel

In addition, there are various models to proceed to the calculation of the price of options; the main ones are the binomial model and the Black-Scholes model.

The binomial model is based on the concept of setting up a risk-less portfolio, that is, a portfolio that must earn the risk-free rate to prevent arbitrage opportunities, by taking the same value in both future events. Consider the stock price today, S_0 = \$45, and a European call option with strike price K = \$49 and a maturity of 3 months. Let's consider the stock price after the three months (therefore at the maturity of the option) of:

$$1)\ S_T = \$56.25 \qquad 2)\ S_T = \$36.$$

The price of the option at maturity will be equal to its payoff, so in the case where S_t= \$56.25, the option price will be \$7.25, in the case where S_t= \$36, the option price will be 0. As mentioned earlier, the binomial model involves setting up a risk-less portfolio useful for finding the option price at time 0. This portfolio consists in going long on Δ[26] shares of stock and short one call. However, the delta value must be a value that makes the portfolio risk-free, i.e., it must have the same value for both prices that the stock might take. Hence, we have that the value of the portfolio at option maturity in the case of S_t=\$56.25 is Vt=56.25x Δ -7.25, and the value where S_t= \$36 is 36 x Δ . Putting both values equal (risk-less portfolio), i.e., 56.25 x Δ - 7.25 = 36 x Δ , we have that the delta value is 0.358024691.

In summarizing we have that the value of the portfolio after the three months is worth:

$$\text{Vt} = \begin{Bmatrix} 0.358024691\ x\ 56{,}25 - 7{,}25 = \$12{,}888889 \\ 0.358024691\ x\ 36 = \$12{,}888889 \end{Bmatrix} \begin{matrix} if\ up \\ if\ down \end{matrix}$$

[26] The delta (Δ) of a stock option is the ratio of the change in the price of the stock option to the change in the price of the underlying stock. It is the number of units of the stock should be held for each option shorted to create a riskless portfolio.

Since it is a risk-free portfolio, the risk-free rate is assumed to be 5% in continuous compounding[27]. Consequently, the value in 0 of the portfolio is V_0=\$12.888889 x $e^{-12\% \, x \, 0{,}25}$= 12.72878054. The value in 0 is in turn equal to $V_0 = \Delta$ x S_0 - C_0. Thus, 12.72878054 = 45 x 0.35802469 - C_0. Deriving C_0 from this formula, the price is \$3.38.

In addition to calculating the option price using the risk-less portfolio case, it is possible to do the same using the concept of risk-neutral probabilities[28].

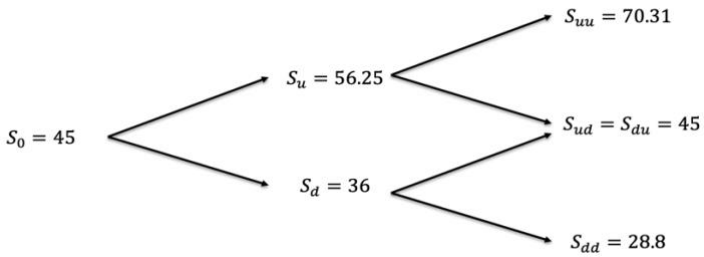
Consider a stock with an initial price in 0 (S_0) and an option with expiration at time T and a price in 0 (X_0). The possible prices at date T can be S_u= S_0 x u and S_d = S_0 x d, where u (d)[29] is the gross return on the stock in the first (second) state of the world. If we set a portfolio where we go long on delta shares and short one derivative, we will have in the up-case S_u x Δ - X_u (price of the option in the up case), while in the down state we will have S_d x Δ - X_d (the price of the option in the down state). The portfolio is risk-free when S_u x Δ - X_u = S_d x Δ - X_d, and solving for delta we get $\Delta = \frac{X_u - X_d}{S_u - S_d}$. The value of the portfolio today is (S_u x Δ - X_u) x $e^{-r \, x \, t}$ or (S_d x Δ - X_d) x $e^{-r \, x \, t}$, and can also be written as $V_0 = S_0$ x Δ- X_0. Where X_0 = S_0 x Δ - (S_u x Δ - X_u) x $e^{-r \, x \, t}$ and substituting for Δ, X_0= ($e^{-r \, x \, t}$ [pX_u +(1-p) X_d], where p = $\frac{e^{r \, x \, t} - d}{u - d}$ (is the risk-neutral probabilities in the up state). To calculate the risk-neutral probabilities in the down state, it is sufficient to do 1 - p. However, p is a fictitious probability and not a true one, that means when investors are risk-neutral they do not increase the expected return they require from an investment to compensate for higher risk. This is equivalent to say that in a risk-neutral world each asset's expected return is the risk-free rate and the discount rate used for the expected payoff of an option (or any other instrument) is the risk-free rate.

These procedures (risk-neutral probabilities and replication portfolio) can be used to calculate the price of an option even when the possible up and down states are more than one. In these cases, one must start from the end of the nodes (i.e., T) and calculate the option price for each mother node. This mechanism is called backward induction. Below there is an example of a binomial tree with two nodes:

[27] Continuous compounding is the mathematical limit that compound interest can reach if it's calculated and reinvested into an account's balance over a theoretically infinite number of periods.

[28] Risk-neutral probabilities are probabilities of possible future outcomes that have been adjusted for risk

[29] u (d) is computed as $\frac{S_u}{S_0}$ ($\frac{S_d}{S_0}$) or as $e^{-\sigma \, x \sqrt{t}}$($\frac{1}{u}$), where σ *is the standard deviation of stock returns*



However, the same procedure performed with the binomial tree can also be processed with put options. In this case, the payoffs with put options are calculated for each node as Max (K- S_t, 0) and these payoffs represent the option price for each node. In the case where the replication portfolio concept is used, the latter is constructed through the long of one derivative and the short of Δ x S_d shares. Obviously, the delta is negative, as the difference between X_u and X_d is negative, and the value in T of the portfolio is calculated as:

$$\text{Vt} = \begin{Bmatrix} \Delta\, x\, S_u = V_t \\ \Delta \text{ x } S_d - option\ price = V_t \end{Bmatrix} \begin{matrix} if\ up \\ if\ down \end{matrix}$$

Since it is a risk-free portfolio, the risk-free rate is assumed to be 5% in continuous compounding. Consequently, the value in 0 of the portfolio is $V_0 = V_t$ x $e^{-r\,x\,t}$. The value in 0 of the put option is in turn equal to $P_0 = S_0\, x\, \Delta - V_0$.

The above examples consider European options, in the case of American ones, for call options nothing would have changed as it is never optimal to exercise a call option before maturity (let's assume that no dividend is paid)[30], while for the put option some aspects have to be taken into account. Specifically, for each node a "check" must be made to verify whether it is optimal to exercise the option immediately or to wait. If the option is exercised immediately the value is Max (K - St, 0), while in the opposite case, the continuation value is equal to the discounted expected value of the option in child nodes. The value of the option at each node is the largest of these two.

One of the limitations of the binomial model concerns the accuracy of the price per option. The greater the number of nodes, the greater the accuracy of the result obtained since a stock can usually assume an almost unlimited number of future values. Calculating the value of options when there is an infinite number of sub-periods may seem a hopeless task. Fortunately, Black and Scholes have derived a formula

[30] Even when there are dividends, you should never exercise early if the dividend you gain is less than the interest you lose by having to pay the exercise price early. However, if the dividend is sufficiently large, you might want to capture it by exercising the option just before the ex-dividend date.

that does this "work" automatically. In fact, as can be seen from the graph below, the option price calculated using the binomial model and that calculated using the Black-Scholes model tend to converge as the number of periods taken into consideration increases, providing more precise results (see Allen, F., Brealey, R., and Myers, S., 2017).

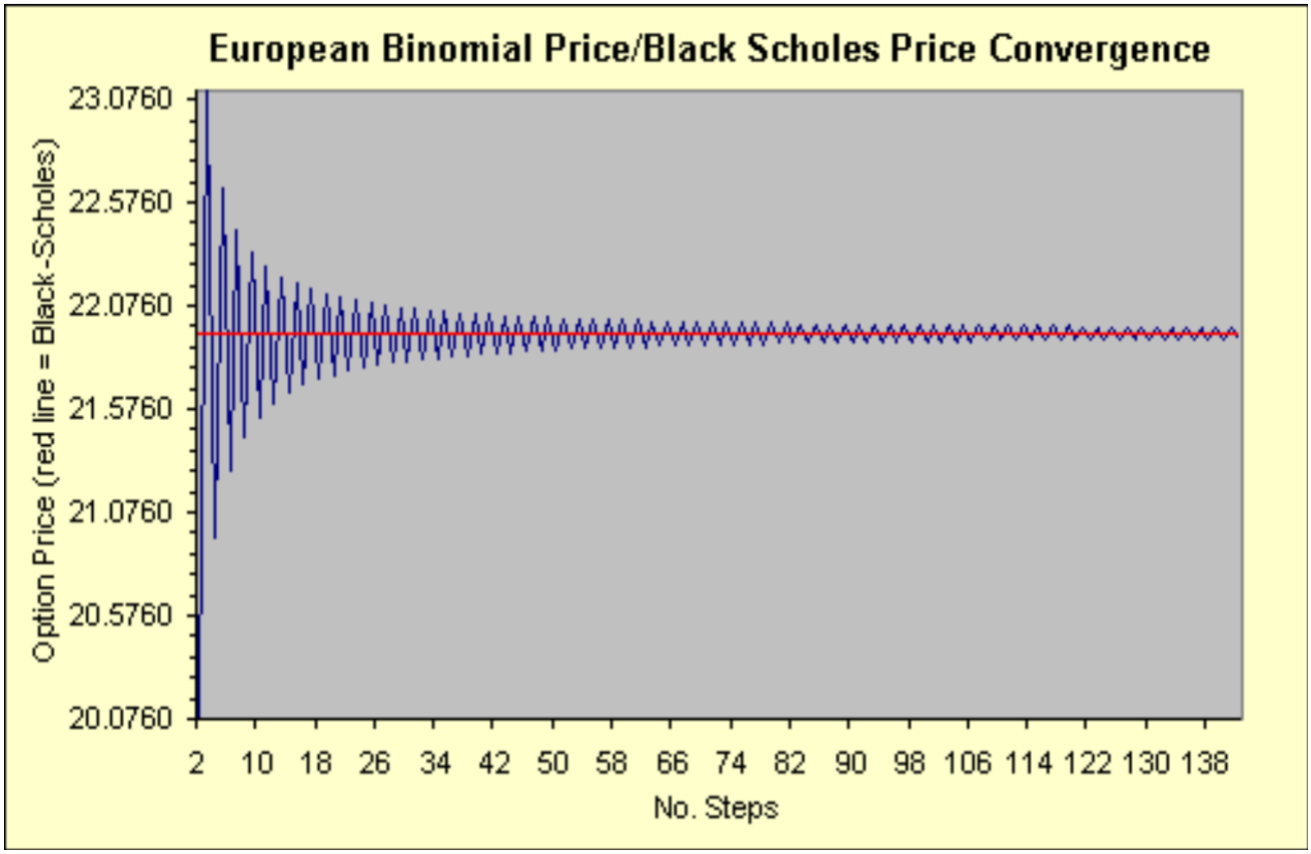


Figure 16. Source: Allen, F., Brealey, R., and Myers, S., (2017).

If we divide the life of the option into an increasing number of smaller and smaller sub-periods, the distribution of price changes becomes more and more smooth.

If we continue to divide the life of the option in this way, we will eventually reach the situation where there is a continuum of possible changes in the share price at expiration and the latter follows a log-normal distribution[31]. The lognormal distribution is often used to summarize the probability of different changes in the share price. In summary, there has been a shift from a world in which the stock price follows a binomial distribution to a world in which the stock price follows a lognormal distribution.

Nevertheless, the Black-Scholes model is based on certain assumptions that underpin its validity. These relate to the economic environment and the asset market.

[31] Log-normal (or lognormal) distribution is a continuous probability distribution of a random variable whose logarithm is normally distributed. Thus, if the random variable X is log-normally distributed, then Y = ln(X) has a normal distribution. Equivalently, if Y has a normal distribution, then the exponential function of Y, X = exp(Y), has a log-normal distribution.

With respect to the *economic environment:*

- there are no transaction costs and taxes, and all securities are divisible
- the risk-free rate is the same for all periods and is constant
- the short-selling[32] of securities with full use of proceeds is permitted.

Regarding the *asset market*, it is assumed that:

- there are no dividends during the life of the derivatives
- security trading is continuous
- the stock prices are log-normally distributed, and log-returns are normally distributed
- there aren't riskless arbitrage opportunities.

Having reached this point, the formula for calculating the option price is:

$C = [N(d_1) \times S_t] - [N(d_2) \times K \times e^{-r \times t}]$,

where,

- $d_1 = \frac{\log(\frac{S_t}{K}) + (r + \frac{\sigma^2}{2})(t)}{\sigma\sqrt{(t)}}$
- $d_2 = d_1 - \sigma\sqrt{(t)}$
- K = strike price
- t = number of periods to exercise date
- St = stock price now
- σ = standard deviation per period of the (continuously compounded) rate of return on the stock
- $N(d_1)$ = is the probability that a normally distributed variable will be less than d_1 standard deviations above the mean.
- $N(d_2)$ = is the probability that the Call option finishes in the money at time T (in which case you pay the strike) in the risk-neutral world.

Be that as it may, the limitation of the Black-Scholes Model is that it doesn't allow for early exercise, and therefore can't be used for American Calls with dividends and for American Puts, where the fairest valuation model is the binomial trees or numerical procedures.

[32] Short selling is the practice to borrows a security, sells it on the spot market, and expects to buy it back later for less money.

- ***forwards and futures:*** the pricing of forward and futures contracts requires consideration of arbitrage opportunities[33] that can only exist when focusing on assets held for investment purposes. The latter are the so-called "investment assets", i.e., assets such as stocks, bonds, gold, which are used for investment purposes, and differ from "consumption assets", which are assets held primarily for consumption purposes such as oil, corn, copper.

In addition, before pricing such contracts, the concept of short selling and some assumptions must be introduced. First of all, short selling is the practice of borrowing a security from another investor via the broker, selling it on the spot market, and expecting to buy it back later for less money to replace the client's account. Example: an investor shorts 1200 shares at a price of $80 and closes the position 6 months later when the price is $55 and with a dividend of $5 per share paid during the 6 months. The net profit is $24k[34], calculated as:

- borrow 1200 shares and sell them for $80 = + $96k
- pay dividend = - $6k
- buy 1200 shares for $55 per share= - $66k.

Secondly, the assumptions are:

- the risk-free rate at which market participants can borrow or lend is the same
- if there are arbitrage situations, investors exploit them to gain an advantage
- there are no transaction costs, and the tax rate is the same for all market participants on all net trading profits.

Now, after highlighting the assumptions and introducing the concept of arbitrage opportunities as well as the short selling concept, we can proceed to pricing forward and futures contracts. The forward price (F_0) is determined in such a way that the arbitrage opportunities are 0, i.e., they are not possible. Let us assume that:

- the price of a stock (no dividend is paid in the period under consideration) is $60
- the interest rate for 6 months is 8% p.a.
- the 6-month forward price is: 1) $65 or 2) $55

In both cases there are arbitrage opportunities that would allow you to make a profit.

In fact, the possible outcomes are shown below:

[33] An arbitrage opportunity is a guaranteed (i.e., no risk involved) profit with zero initial investment

[34] K = thosunands

FORWARD PRICE= $65	FORWARD PRICE= $55
Strategy:	**Strategy:**
borrow $60 at 8% for 6 months	short 1 unit of asset to earn $60
buy one unit of asset	invest $60 at 8% for 6 months
enter into forward contract to sell	enter into forward contract to buy
asset in 6 months for $65	asset in 6 months for $55
After 6 months:	**After 6 months:**
sell asset for $65	buy asset for $55
use $62,4 to repay loan with interest	close short position
	receive $62,4 from investment
Profit realized: $2,6	**Profit realized: $7,4**

Figure 17. Source: personal elaboration on Excel

Consequently, the only forward contract price that limits arbitrage opportunities in this case is:

$F_0 = S_0$ x $e^{r\,x\,t}$. With the data from the previous example, F_0 = $60 x $e^{8\%\,x\,0,5}$ = $62.4.

In addition, the price of a forward contract may change depending on the type of asset. If we consider an asset with known income (a stock that pays dividends or a bond that pays coupons) during the time period to which the forward relates, the price in 0 of the forward is calculated as: $F_0 = (S_0 - I)$ x $e^{r\,x\,t}$, where I is the present value at time 0 of cash income.

On the other hand, if instead of providing a known income, the asset provides a known yield during the life of the forward, the forward price must be:

$F_0 = S_0$ x $e^{(r-q)\,x\,T}$, where q is the average yield in continuous compounding with yields as % of the asset price at the time the income is paid out.

Important to be mentioned is the difference between the value of the forward contract and its price F_0. In fact, while F_0 is the price at which the underlying asset can be sold or bought, the value corresponds to the positive or negative cash flows that are generated by this contract in relation to the spot price of the underlying. If we define K as the delivery price for a contract traded some time ago, which today (time 0) has a residual maturity T and a forward price F_0, By considering the difference between a contract with delivery price K and a contract with delivery price F_0 we can deduce that, today, a long position in the first has value: f = (F_0 - K) x $e^{-r\,x\,t}$, = S_0 - K x $e^{-r\,x\,t}$, while that of a short position is: (K - F_0) x $e^{-r\,x\,t}$ = K x $e^{-r\,x\,t}$ - S_0. The same concept can be applied, as before, to assets with a known income and assets with a known yield:

- in the first case the value of a long position is: f = (F_0 - K) x $e^{-r\,x\,t}$ = S_0 - I - K x $e^{-r\,x\,t}$
- in the second case the value of a long position is: f = (F_0 - K) x $e^{-r\,x\,t}$ = $S_0\,x\,e^{-q\,x\,t}$ – K x $e^{-r\,x\,t}$.

Referring to futures, the futures price represents expectations of the value that the asset might take in the future, i.e., F_0 = E [S_T]. But to calculate the price of a futures with a payoff of S_T - K, one has to consider its discounted expected value, using the expected return on the investment as the discount rate. Given that the value of a futures payoff when the position is entered is 0, this implies that: 0 = $e^{-k\,x\,t}$ E [S_T] - $F_0 e^{-r\,x\,t}$ or F_0 =$e^{(r-k)\,x\,T}$ x E [S_T]. The expected return of the underlying asset (k) can be verified by considering the CAPM: k = r+β(R_M - r), where with a positive correlation with market returns, futures prices are smaller than the expected spot price of the asset, because the investor is willing to bear the risk of buying a future only if he/she expects to make a profit on average.

Underlying asset	*Relationship of expected return k from asset to risk-free rate r*	*Relationship of future price F to expected future spot price E(S_T*
No systematic risk	$k = r$	$F_0 = E(S_T)$
Positive systematic risk	$k > r$	$F_0 < E(S_T)$
Negative systematic risk	$k < r$	$F_0 > E(S_T)$

Figure 18. Source: personal elaboration on Excel

With positive systematic risk, and therefore when F_0 < E [S_T], this case is defined as "normal backwardation", while, with negative systematic risk, and therefore when F_0 > E [S_T], this case is defined as "contango".

However, an important insight that needs to be highlighted is the process of convergence of the futures price to the spot price. The closer the futures expiry date gets, the closer its price is to the spot price, until it equals it when the time to maturity is 0. This is done to avoid arbitrage opportunities that investors could exploit to obtain a positive return by buying at the lowest price and selling at the highest price. Moreover, even if futures contracts are settled with marking-to-market, their price is equal to the forward price only if interest rates are kept constant or undergo insignificant changes. However, if interest rates change randomly as in the real world, forward and futures prices are different, because if the price of the underlying asset is positively correlated with interest rates, future prices are larger than forwards because the gains obtained by the marking-to-market mechanism (considering a price increase and long futures) can be invested at higher market rates and finance losses (when prices go down) at smaller rates. Therefore, the contract is worth more, and you need a larger futures price to make its value zero.

- swaps: the valuation of swaps can be performed primarily in two different ways.

The first valuation method concerns an analysis of the correlation between the value of the swap and the price of the bonds. Considering two entities, A and B, let's assume that A receives interest on a notional principal of $100 million lent to B at a fixed rate of 8% per annum, and B collects interest payments from A on the same notional principal but at a rate indexed to 6-month LIBOR. In other words, it may be said that B has bought from A a floating rate security on a notional principal of $100 million and has sold, to the same counterparty, a security bearing a fixed rate of 8% per annum.

This results in the value of the swap for B being equal to the difference between the two bonds: V_{swap}= B_{fl} - B_{fx}, where B_{fl} is the value of the floating rate security and B_{fx} the fixed rate security. Yet the current value of the fixed-rate instrument is estimated according to the following formula: B_{fx}= $\sum_{i=1}^{n} k\, e^{-r_i t_i}$ + N$e^{-r_n t_n}$, in which t_i is the time until the exchange of the i-th payment, N is the notional amount, r_i is the Libor zero rate, and k represents the fixed-rate interest paid on each of the payment dates. In order to identify the value of the floating rate security, we need to know that its value after the payment of a coupon is exactly equal to the value of a newly issued floating rate security, and therefore we have that B_{fl} = N. Between the two payment dates, the value of such security can be calculated by taking into account that B_{fl} will be equal to N immediately after the coupon payment and just before the next payment it will be equal to N + k*, where k* corresponds to the next variable payment already determined. Consequently, the value of such a security is calculated as: B_{fl}= (N+k*)$e^{-r_i t_i}$. Hence, the value of the swap for those who receive the fixed and pay the variable is V_{swap}= B_{fx} - B_{fl}, while for those who receive the variable and pay the fixed is V_{swap}= B_{fl} - B_{fx}. The swap rate is chosen so that the swap has a value of 0 at the time it is entered into.

The second valuation method is to derive the value of a swap by examining a portfolio of forward rate agreements. Assuming that the risk of default/insolvency is zero, the swap can be valued as a series of long and short positions on different securities or as a portfolio of forward rate agreements (FRAs). The latter are forward contracts traded in the OTC markets with the Libor rate as the underlying. The main purpose of such contracts is to allow the market participants to lock-in the interest rate at which they will be able to borrow or lend in the future, assuming that this rate is the Libor rate. Libor zero rates are used as the discount rate, assuming the credit risk of the derivatives is equal to the risk at which intermediaries lend and borrow in the interbank market. For this reason, Libor zero rates are used as a discount rate because they are an efficient indicator of the supply cost incurred by financial institutions.

Looking at the graph of the example swap (paragraph 1.2.4 Swaps), this swap involves the exchange of 10 payments based on the values assumed by the 6-month Libor and the fixed rate of 5% on a notional amount of $500 million. Nevertheless, each swap can be seen as an FRA, in which the interest to be paid with a rate of 5% and that calculated with the 6-month Libor calculated on the notional value are exchanged. It is important to emphasize that the FRAs are valued assuming that the forward rates are realized, and consequently since the swap is a portfolio of FRAs it can be valued based on the same rates. The procedure is:

- calculation of forward rates for each date on which the cash flows are swapped
- calculation of swap payments assuming that future Libor rates are equal to current forward rates.
- calculation of the current value of the swap by discounting these payments.

However, as reiterated earlier, the value of the swap at the time of purchase is 0, which implies that the value of the FRAs underlying the swap is zero. Anyway, this does not mean that the value of each Forward Rate Agreement is 0, as some may have a positive value and others a negative value, offsetting each other (see Hull, J.C., 2000).

CHAPTER TWO

This chapter will focus on the crude oil sector, analyzing the main characteristics and how hedging measures can be implemented to mitigate the risks arising from price fluctuations in this commodity.

2.1 CRUDE OIL SECTOR

The energy sector is a market in which the economic actors engage in the production and supply of energy. This sector is of central importance as it has and continues to play a leading role in industrial growth and in powering the economy. According to the MSCI Global Industry Classification Standard (2020), the energy sector covers the companies that explore, produce, refine, market, store, and transport oil, gas, coal, and other consumable fuels. Companies offering oil and gas equipment are also considered part of the energy sector. Nevertheless, companies active in this sector handle not only large amounts of energy, but also different types; in fact, the main difference that emerges is the distinction into:

- renewable energy[35] such as solar energy, wind energy, hydropower, and biofuels such as ethanol
- non-renewable energy includes oil and petroleum products, gasoline, natural gas, diesel fuel, and nuclear[36].

The energy industry also includes secondary sources such as electricity (see International Trade Administration, December 27, 2021).

In addition, the energy industry is known as capital intensive[37] because in order to place the final products on the market, various investments, infrastructures, resources and fixed assets are required. These requirements like plants and equipment for crude oil and raw natural gas processing, land for maintaining oil and gas reserves and so on, generate high expenses for the companies because they are forced to invest many funds in capital expenditures.

A large part of the costs is also due to research and development (R&D) expenditure, which is a strategic component for the introduction of new technologies to refine and produce products with the target to increase the company's efficiency and reduce the negative externalities that can arise from the environment and regulations.

[35] Renewable energy is energy from sources that reconstitute themselves naturally but have a limited flow; renewable resources are virtually inexhaustible in their durability but finite in the amount of energy available per unit of time.

[36] Nuclear energy is usually considered another non-renewable energy source. Although nuclear energy itself is a renewable energy source, the material used in nuclear power plants is not.

[37] The term “capital intensive” is used to describe business processes or industries that involve large levels of investment to provide a good or service and therefore have a high proportion of fixed assets.

Yet, according to the Global Industry Classification Standard, the energy sector is categorized into:

- *Energy, Equipment & Services Industry:* includes all oil and gas drilling contractors, as well as all companies and operators providing services, equipment, and assets for the drilling process.

- *Oil, Gas & Consumable Fuels Industry:* includes companies mainly involved in the production, transport or processing of raw materials whose principal end goal is energy generation.

In this sector, according to their role in the supply chain, three subcategories of operators can be distinguished:

- upstream companies are at the top of the supply chain and handle all operational processes from which the production process originates. They are mainly concerned with finding oil and gas wells that can be exploited for extraction, checking whether there are rights to exploit the land, establishing sites and platforms for extraction, and extracting the resources with a view to placing them on the market.
- Midstream companies represent the intermediate stage of the supply chain and manage all the procedures for liquefying resources, transporting them from the extraction site to the refining site via pipelines or tankers and storing the products.
- Downstream companies deal with the processes of refining oil and regasifying natural gas, as well as distribution and sales. Generally speaking, the refining process takes place in four main stages: -physical separation of the components that make up the oil, resulting in several cuts; - chemical processes to improve the quality of the oil; - chemical processes to improve the quality of the cuts obtained; - purification of the final products.

Nevertheless, the energy sector is highly cyclical, i.e., revenue generation and industry performance are linked to the business cycle, which is a series of fluctuations in economic activity (generally measured by the change in the Gross Domestic Product) over a period. This means that the energy sector is very sensitive to macroeconomic variables, such as inflation, employment and disposable income which influence demand and prices. In fact, in periods of economic boom, a general growth of the economy and consequently of the production activities, generates an increase in demand and in the price of products deriving from this sector; on the other hand, periods of recession lead to an inverse trend, with demand and prices falling and a weakening of the industry.

Furthermore, highly influential are the seasons and natural events. During the summer period, oil and gas prices are higher due to increased consumption as a result of increasing tourism (e.g., higher aircraft fuel consumption) and higher summer oil supply costs. In the occurrence of natural disasters such as

hurricanes, earthquakes and severe weather conditions, the price of energy resources rises as production and distribution become more challenging. In addition to natural events, the price of gas and oil is also impacted by the policies adopted by the various governments, especially those that are leaders in oil exports such as Russia, on which many nations depend for their procurement. For these reasons, several organizations have sprung up with the main focus of coordinating energy suppliers and stabilizing markets, one of these is the Organization of Petroleum Exporting Countries (OPEC). OPEC is an intergovernmental organization representing more than 40% of the world's oil production and interacts with 13 member countries to manage the production and supply of oil, influencing its price.

According to the report published by BP Statistical Review of World Energy (2021), the main form of energy consumed is crude oil (33%), followed by coal (27%) and natural gas (24%). Renewable energy sources accounted for a small percentage of total energy consumption (Nuclear 4%, Hydro 7%, Renewables 5%), but in recent years they have been growing more and more as a result of the close proximity to the climate change issue, emissions reduction target, development of electric motors and so on. Furthermore, despite the classification of the various sources of energy consumption, the primary energy consumption has been on a growth path from the 2000s to the 2020s, in which there was a downward slump due to the negative effects brought about by the deployment of Covid-19. This trend is shown graphically below:

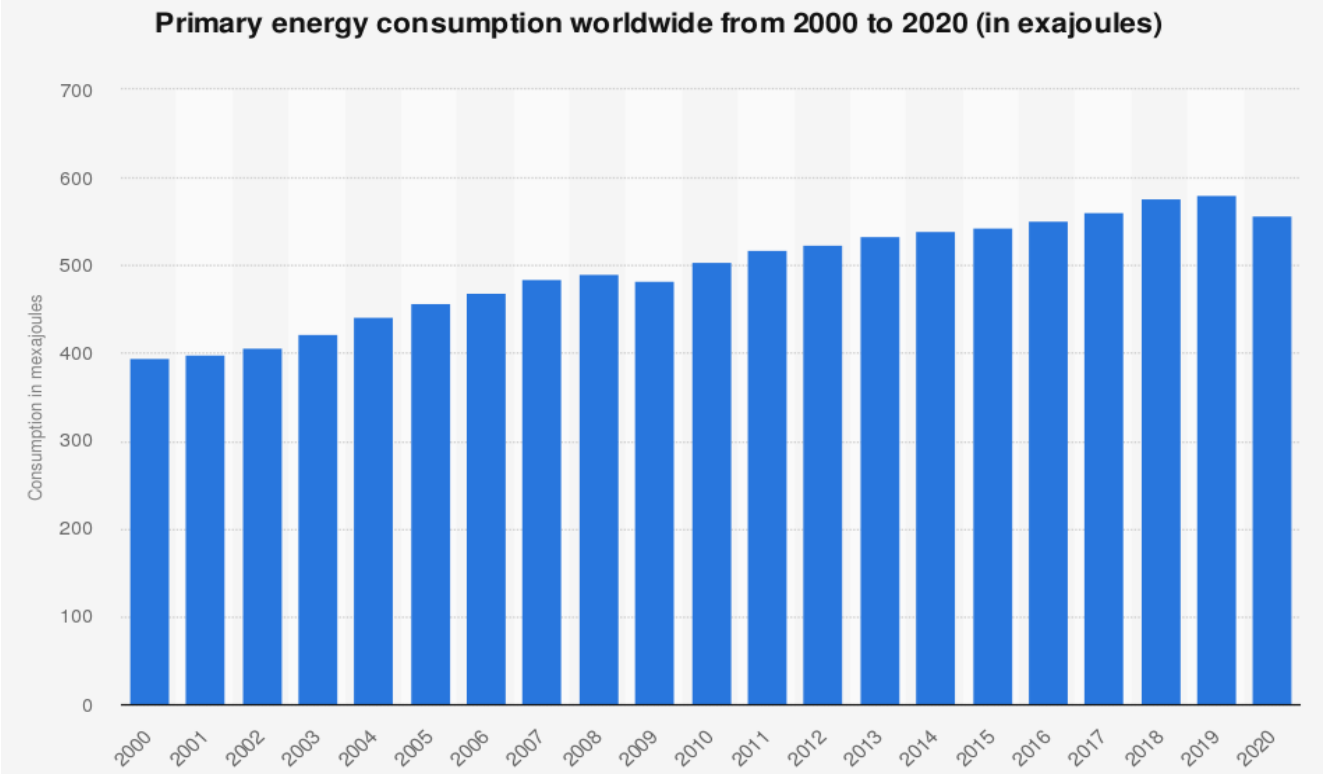


Figure 19. Source: Statista (2021)

In the energy sector, as mentioned before, one of the major consumptions is represented by crude oil, which also represents one of the major commodities traded on the markets together with its derivatives. Crude oil is a mixture of hydrocarbons present underground and is made up of hydrocarbons which are molecules comprised of hydrogen and carbon atoms. It may be present as a very viscous liquid or as a tar-like substance. Nevertheless, after extraction, crude oil goes through a refining process in which other products are derived, in this case is often used to talk about "product yield" or "product slate". These terms are used to indicate the different quantities of refined products that are generated from a barrel of crude oil. On average, a 42 (US) gallon barrel of crude oil will yield about 45 gallons of refined products as the refining process generates a "refinery gain". However, the ability to generate such quantities of products also depends on the flexibility and responsiveness of refineries to macroeconomic changes affecting the demand market. The quality of the crude oil is established through an assay, which is a laboratory-based assessment of the quality of the crude. The assay will also establish the various boiling point fractions and the percentage of each refined product that a particular crude can yield.

In any case, products derived from crude oil include: - gases and liquids such as methane and ethane; - naphtha, whose main use is as petrochemical feedstock; - gasoline used as fuel for motor vehicles; - kerosene used essentially for the production of jet fuel; - gas oils/diesel distillate, these are used to produce diesel engine fuels and for households that use oil as a source of heating; - special products such as coke, asphalt tar, and waxes (see Schofield, N.C., 2021).

However, the history of crude oil can be traced back to the period when the market for crude oil exchange was dominated by seven large multinational companies, called the "seven sisters"[38], who managed the trade and prices of this commodity. These exchanges took place mainly through long-term contracts in which the quantity, price and delivery date were defined and whose object (crude oil) underwent a refining process internalized by these major powers. In those years, the oil sector was a leading sector for economic growth, but at the same time, it was highly risky as there was little regulation and transparency towards the public. This is because the "7 sisters" had created an oligopolistic market in which they tried to impose the prices they wanted in order to obtain undue fiscal advantages, including the reduction of the tax burden. The control of the oil market by these large international companies changed dramatically in 1973 when an oil crisis occurred, increasing the oil price and its derivatives price. The crisis was triggered by Egypt and Syria's attack on Israel in a war known as the Yom Kippur

[38] Seven Sisters is a locution coined by Enrico Mattei, after his appointment as liquidator of AGIP in 1945, to denote the world oil companies that constituted the Consortium for Iran cartel and dominated world oil production in terms of revenues from the 1940s until the 1973 crisis.

War, in which the Arab members of OPEC decided to support Egypt and Syria's war effort by rising oil prices and embargoing mainly pro-Israeli countries, ending a cycle of economic development that had affected the West. Importing countries found themselves faced with an emergency situation, where energy supply was becoming unsustainable, leading them to seek new markets outside the OPEC countries such as Russia, Mexico and the North Sea. This situation tempered the syndicate's ability to negotiate which had hitherto dominated the scene, caused internal dissensions, and eroded the assumptions underlying the oil policies adopted.

Faced with the loss of power of the OPEC's cartel, some member countries decided to adopt less aggressive pricing policies, switching to so-called "netback pricing", so that the price was no longer imposed, but linked to the final sales price of oil to increase demand, severely reduced by the crisis. This system proved harmful as it led to an oversupply that caused the price of oil to plummet to $26 per barrel in 1985.

Following this disastrous scenario, to bring the situation back to stability, a new pricing system was adopted by linking the price of oil to the market. Specifically, the price of oil and its derivatives is established based on petroleum prices taken as benchmarks, including West Texas Intermediate (WTI)[39] and Intercontinental Exchange Brent (ICE Brent)[40]. Since then and for the following years, the oil market has been characterized by a strong expansion, fueled by the emergence of the first derivative contracts around the Brent and WTI spot markets, which were subsequently traded on organized markets such as the International Petroleum Exchange (IPE) and the New York Mercantile Exchange (NYMEX). The first derivative contracts were essentially futures, while options were not listed on the NYMEX until 1986. The NYMEX is the largest commodity futures exchange and is part of the CME Group, was once an open-air market with trading boxes, but like most exchanges today, it has become increasingly electronic.

The ongoing expansion of oil financial derivatives has increased exponentially until the shocking collapse in 2008, when oil touched a price close to 30 dollars a barrel; only a few months prior, its price was around 145 dollars, wreaking havoc on the financial markets. Thus, oil financial derivatives

[39] West Texas Intermediate (WTI) crude oil is a specific grade of crude oil and one of the main three benchmarks in oil pricing, along with Brent and Dubai Crude. WTI is known as a light sweet oil because it contains around 0.34% sulfur, making it "sweet," and has a low density (specific gravity), making it "light."

[40] The ICE Brent Index represents the average price of trading in the prevailing North Sea physical market for the relevant delivery month.

therefore play an important role in this market, especially since this commodity, with its instability, also causes imbalances in financial markets around the world.

2.1.1 MARKET DATA

In recent decades, the crude oil sector has developed considerably as progress has increased energy use in many countries, even if there have been peaks at times due to oil crises and events that impacted on prices. This is demonstrated by an increase in oil refining capacity, which has allowed more oil to be processed after extraction, thereby increasing its production. The increase in refining capacity hasn't been constant for all countries, and while it has remained more or less stable for some countries (e.g., the USA), others such as the Asia Pacific have seen a substantial increase. Below is a representative graph of global refining capacity from 1965 to 2019. Data are expressed in thousands of barrels per day:

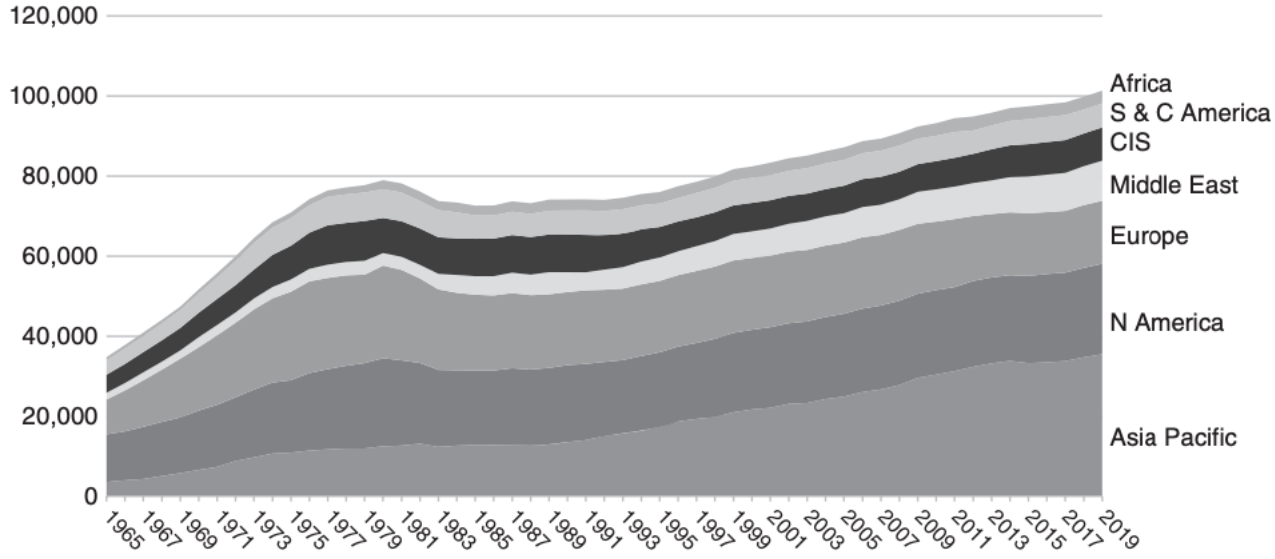


Figure 20. Source: Schofield, N.C. (2021)

When dealing with the concept of refining capacity, an aspect to consider is the refining margin, namely a measure of the refinery's value contribution per unit of input. These margins are calculated, by price reporting institutions, in a generalized way and as benchmark indices since each refinery has different characteristics, meaning it's impossible to apply one single margin value to the whole sector. These benchmark margins published by the agencies represent an amplified view of the well-being of the downstream oil sector and are commonly referred to as "crack spreads". Some of the best known are the

Northwest Europe Light Sweet Cracking, the Us Gulf Coast Sour Cracking and the Singapore Medium Sour Hydrocracking. An example of a crack spread is the "3-2-1 crack spread" which assumes that 3 barrels of crude oil can generate two barrels of gasoline after the refining process and one barrel of fuel oil; mathematically this can be expressed as 1:0.67:0.33. Let's assume that crude oil is traded at $65/bbl., while gasoline is traded at $3.5/gallon and heating oil at $2.8/gallon and that each barrel contains 50 gallons, the crack spread is therefore the sum of the refined products minus the cost of the crude oil:

= Gasoline + heating oil - crude oil=

= ($3.5 x 50 x 0.67) + ($2.8 x 50 x 0.33) - $65=

= $117,25 + $46,2 - $65 = $98,45.

Yet, the growth of the crude oil sector is also justified by an increase in proved oil reserves. According to BP Statistical Review of World Energy (2021), proved oil reserves are "generally considered to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions". In 2020, the majority of these reserves come from the Middle East (48,3%) followed by South and Central America (18,7%), and North America (14%), while the Commonwealth of Independent States (8,4%), Africa (7,2%), Asia Pacific (2,6%) and Europe (0,8%) represent the countries with the fewest proved oil reserves.

However, despite the various crises and concerns about the scarcity of oil fields and the risk of a decrease in supply, the apparent level of proved oil reserves is increasing. In fact, at the end of 2000 the total amount recorded was 1300,9 million barrels, while at the beginning of 2020 it was 1734 million barrels.

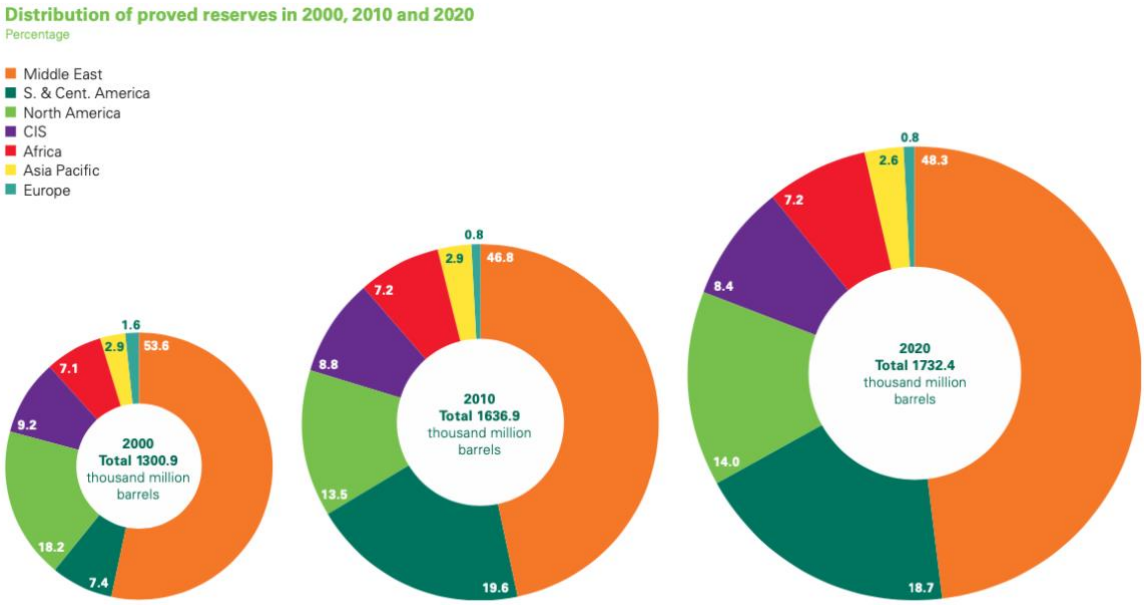


Figure 21. Source: BP Statistical Review of World Energy (2021)

Another meaningful indicator of crude oil sector expansion is the Reserves/Production ratio, also known as R/P, which indicates how long (in years) a country's remaining reserves would last if production continued at current levels.

The calculation of the R/P ratio is:

$$\frac{\text{reserves remaining at the end of the period}}{\text{production in that year}}$$

This index is sensitive to macroeconomic changes during the reference period, as well as the development of renewable energy sources or decreases in oil demand, and for this reason it should be considered with great caution. In fact, when considering this index in 2005, the values suggested that the reserves would be sufficient for 41 years of consumption at the production levels of the time, while the results calculated in 2021 suggested an increase to 50 years. The following graph represents the 2020 R/P ratio by region and evolution trend in the period 1990 – 2020:

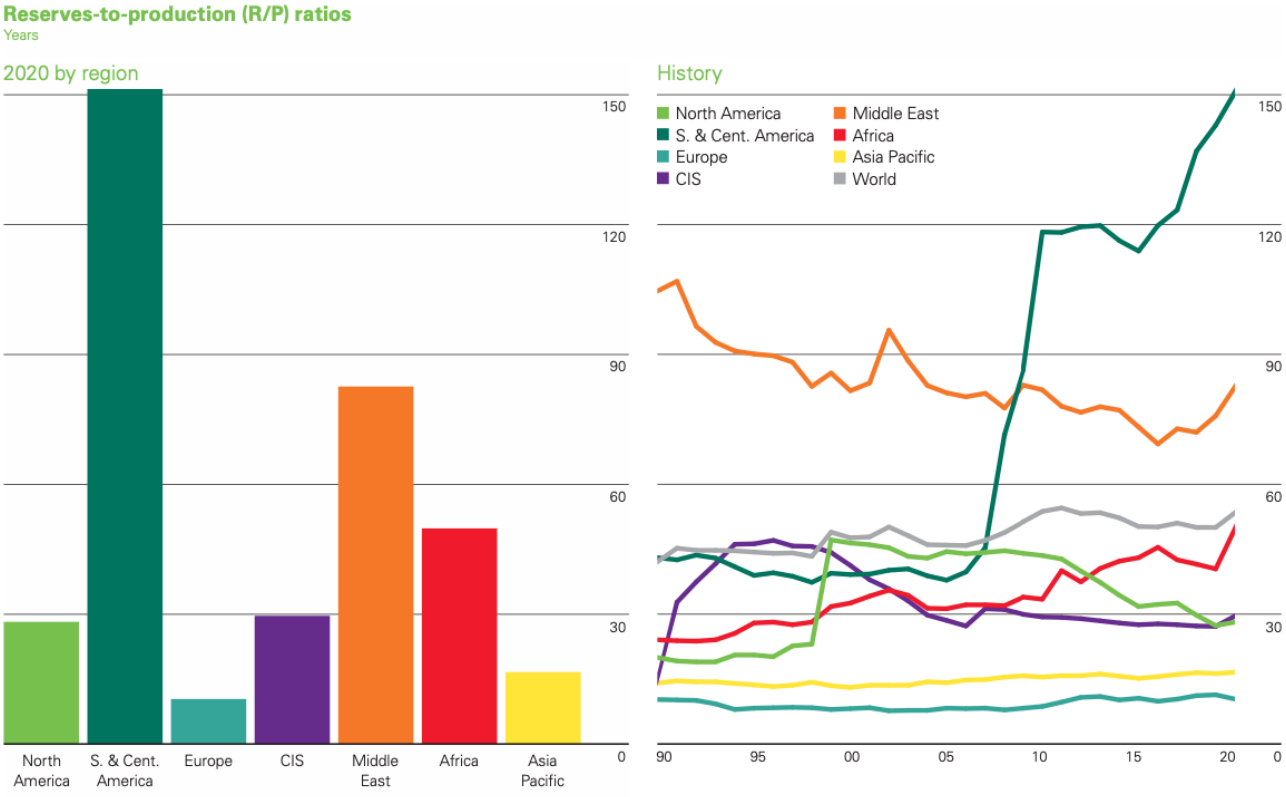


Figure 22. Source: BP Statistical Review of World Energy (2021)

Another core driver for the development of the sector considered here is undoubtedly crude oil production. Its production has been marked by strong growth from 1965 to 2020, although there have been periods of decline such as in 1973/1975 (oil crisis) and the 80s. According to the BP Statistical Review of World Energy (2021), crude oil production grew from an annual output of 31,799 in 1965 to 88,391 thousand barrels per day (tbd) by 2020. In this year the world oil production fell for the first time

since 2009 by 6.6 million b/d in 2020 driven by both OPEC (-4.3 million b/d) and non-OPEC (-2.3 million b/d) countries. Contributed also Russia (-1 million b/d), Libya (-920,000 b/d) and Saudi Arabia (-790,000 b/d). Production only increased in a few countries, mainly Norway (260,000 b/d) and Brazil (150,000 b/d). Among the various producing countries, the largest oil-producing continent in terms of thousands of barrels per day is the Middle East (31,3%), followed by North America with 26,6% of global production, and the CIS (Commonwealth of Independent States, 15,3%), while smaller producers include Africa (7,8%), Asia Pacific (8,4%), South and Central America (6,6%) and Europe (4%). One aspect that deserves to be highlighted, and which is somewhat ambiguous, is how the production of crude oil is independent with respect to the amount of proved oil reserves; in fact, North America, which holds only 14% of global proved oil reserves in 2020, is one of the largest producers of crude oil. The graph of the evolution of crude oil production is shown below:

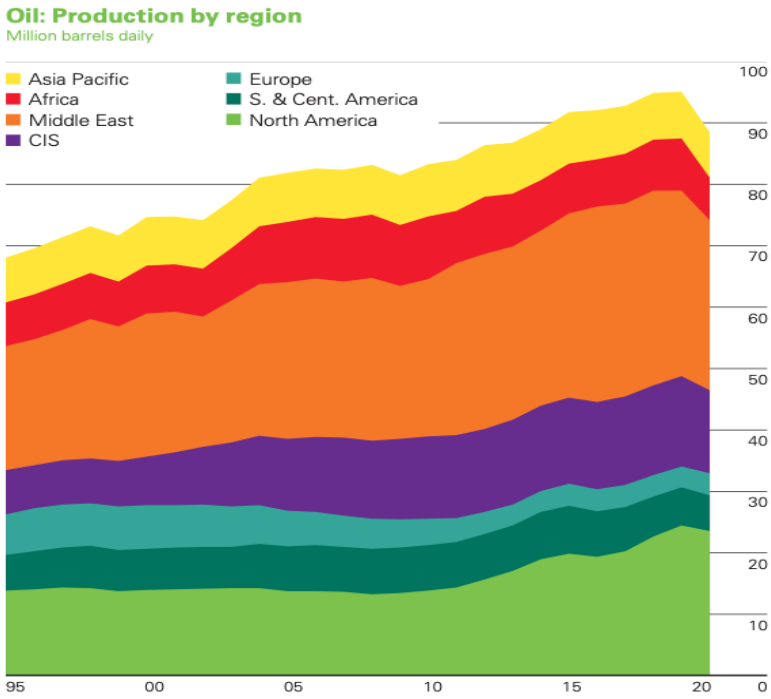


Figure 23. Source: BP Statistical Review of World Energy (2021)

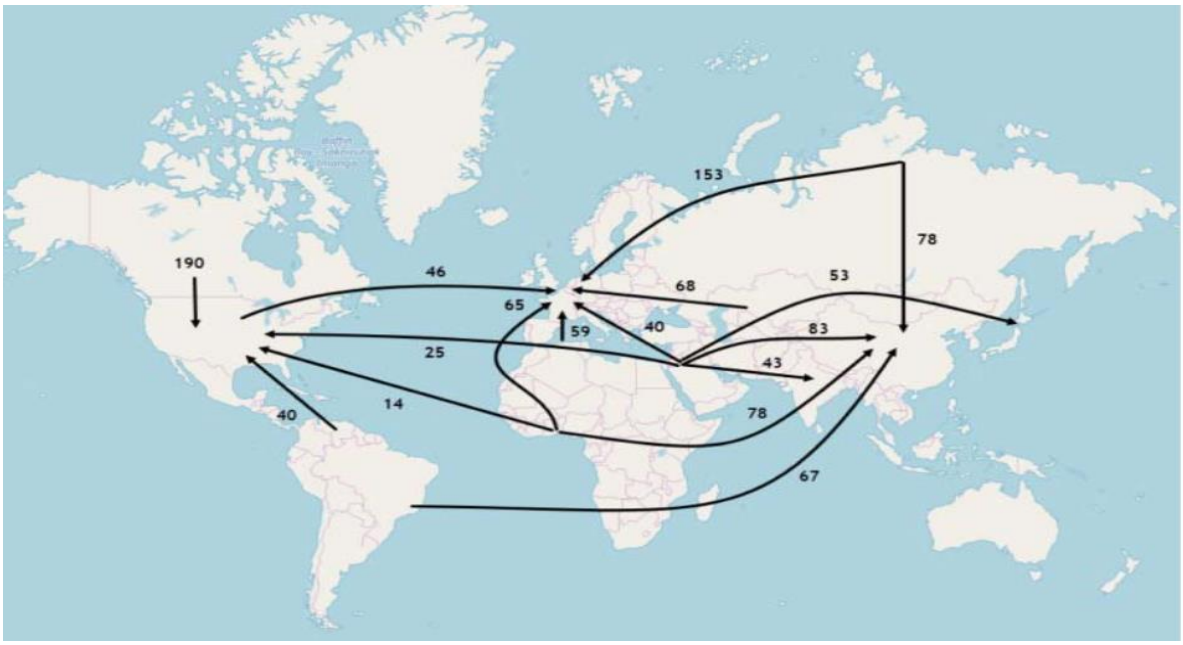
In addition to crude oil production, consumption has also contributed to the growth recorded in the crude oil sector over the decades according to the concept of the law of supply and demand. Still, oil consumption has risen globally from 1965 to 2019 with a decrease in 2020, with China consistently consuming more oil on an absolute and percentage basis; indeed, in 2005 China consumed about 8.5% of the world's oil production, while in 2020 this rate increased to 16,1% of total oil production.

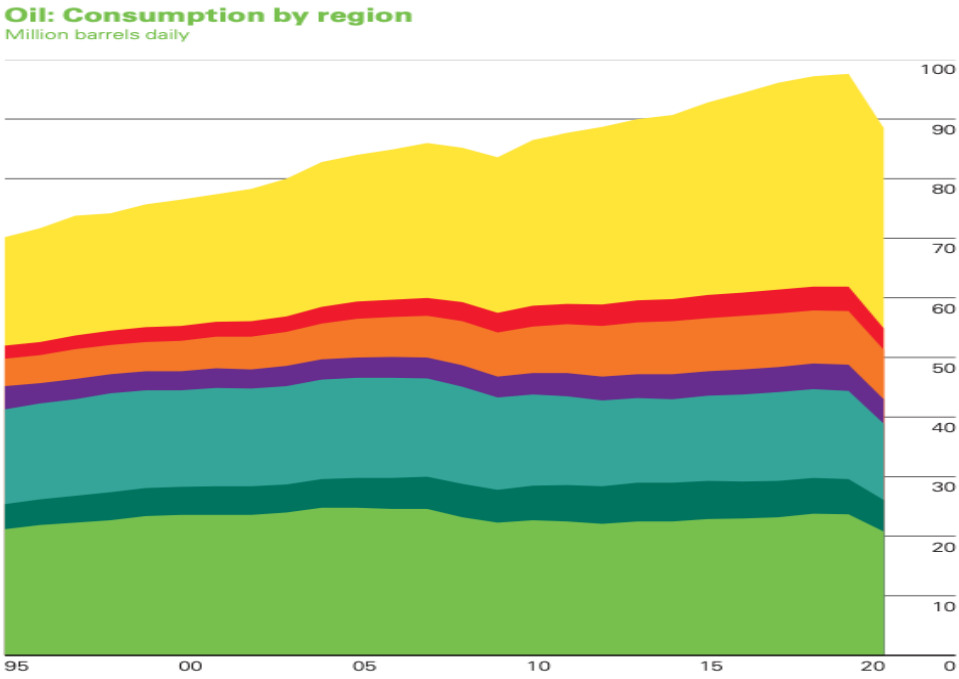
The largest consuming country in the Asia Pacific (38,1%), followed by North America (23,5%), Europe (14,5%), Middle East (9,4%), South and Central America (6%), CIS (4,7%) and Africa (4%). As a result, it can be shown that the location of oil reserves, where it is produced and where it is consumed can differ

significantly, and this also depends on the role played by the various countries, i.e., whether they are net exporters or net importers of oil (see BP Statistical Review of World Energy (2021).

The main inter-regional flows of oil are depicted in the figure below, as well as the oil consumption trend from 1995 to 2020:

data are expressed in million tones





Figures 24 and 25. Source: BP Statistical Review of World Energy (2021)

As already mentioned, the amount of production, consumption and reserves depends also on the type of country and whether it is rich in wells that can be exploited contributing to the production of crude oil

as well as to its export, or whether it is a country that consumes large amounts of oil without having many possibilities for domestic production.

In 2020, the largest oil-importing countries are (in 1,000 barrels per day):

LARGEST OIL IMPORTING COUNTRIES	DATA in 1,000 barrels per day	MAIN SOURCES OF SUPPLY
China	11,158	Russia, West Africa, and Middle East
Europe	9,532	Russia, Other CIS, West Africa
United States	5,387	South and Central America, Canada, and Saudi Arabia

Figure 26. Source: Statista (2021)

2.1.2 KEY DRIVERS ON PRICE DETERMINATION

The aim of this section is to investigate the primary drivers of crude oil prices from different standpoints. The various variables with the potential to drive up or down the price of crude oil, are classed into three main categories:

- variables related to the macroeconomic scenario
- variables related to the geopolitical context
- variables related to the supply chain.

- ***Macroeconomic scenario:*** one of the main drivers related to the macroeconomic environment is the economic cycle, which is represented by the Gross Domestic Product. The latter is representative of the

general economic trend as it reflects the increase or decrease in productive activities. GDP has a positive correlation with oil price movements, in fact, if economic activity increases, and consequently GDP is also higher, the price of crude oil increases allowing higher profits for producers and the need for consumers to hedge through derivative contracts, offsetting the price hikes.

Another crucial factor is oil reserves and oil production. Reserves are a vital source for the oil industry because they can be used in times of crisis or when supply cannot meet demand at specific moments. In addition, reserves also provide an estimate of the health of the crude oil sector, as they allow to define roughly how many years oil could continue to be used assuming production is kept constant (production at the time of the forecast). Consequently, an increase or decrease in reserves affects future expectations of crude oil availability, thus influencing its price. The level of production is also a topic to be monitored for crude oil price movements, as production processes depend on the extraction possibilities and the wells available. The latter are not only limited but are also difficult to exploit due to the technology required and the cost of extraction. In many wells that have already been subjected to the extraction process, there are oil leftovers[41] that require more advanced technologies and a careful evaluation by the producers since such extraction could be economically disadvantageous in terms of profit and return on investment. This means that the effectiveness of technology to retrieve the oil and the price that will result from it, play an important role. Moreover, today there are large areas in many existing oil-producing countries that have not yet been explored in terms of potential oil production. As a result, companies will continue to search for oil in the hope of benefiting from these untapped deposits, referred to in the industry as an "elephant field".

What has a particular influence on oil price are also the so-called substitute goods, i.e., goods that can be used instead of oil with the same degree of utility for the consumer.

In fact, as described in section 2.1, the 1973 crisis led to a price increase as a result of the policies adopted by OPEC countries, pushing importing countries to look for alternative and relatively cheaper sources, such as natural gas. The consequence of this substitution process showed its effects in the '80, when oil prices collapsed in1986. This shows that if the consumer has the possibility of replacing oil with other commodities, its price falls dramatically, and today, given the unstable situation due to the Russia-Ukraine conflict and climate change concerns, the possibilities of switching are gaining momentum. Alternatives include biofuels (ethanol), gas-to-liquids technology (a process that can be

[41] This is because oil recovery rates from wells are around 30%, although in some cases this rate can vary between 30% and 70%.

used to turn gas or coal into products normally produced from crude oil), hydrogen fuel and fuel cells, solar energy, nuclear and wind energy, and wave technology. Especially in the automotive sector, a major change has occurred, where many companies have introduced C02 reduction policies with long-term targets and introduced hydrogen-powered electric engines. The latter is added to a fuel cell and mixed with oxygen, which reacts chemically to produce electricity, propelling cars and generating only water and steam. Nevertheless, even with hydrogen there would be problems as the main source from which it is produced is natural gas, and in the future the intensive use of this commodity could create problems of scarcity of sources that can be processed to produce hydrogen. Although a rise in crude oil prices may encourage the search for substitute sources due to the limited supply, it may also lead oil companies to search for oil in unexplored areas or in the deep sea.

Fundamental to the price of oil and its derivatives is the taxation and fiscal incentives granted by the government. In fact, in the early 2000s, several tax incentives were introduced to boost the purchase of diesel cars, which were considered less harmful than gasoline in terms of CO2 and greenhouse gas emissions. However, the production of diesel cars grew significantly in Europe in the following years, leading to a corresponding increase in diesel consumption. The growing demand for diesel has not been accompanied by a corresponding increase in supply due to the lack of necessary investment in refining technology to convert heavier fuel oils into more attractive middle distillates such as diesel, leading to a higher price for diesel than for gasoline. This is why in recent years, as mentioned above, we are witnessing a process toward electric vehicles with numerous incentive subsidies, which undoubtedly has a major impact on oil prices.

A further driver in changes of the price of crude oil is the increased interest of financial operators and cash flows into the oil patch over the years, which are considered to be responsible for the upward and downward movements in prices. Nonetheless, most financial operators are reluctant to enter into contracts with physical delivery of the underlying asset and prefer to enter into futures positions, the market for which is the main form of gaining exposure to commodities. Many traders operating in commodities markets enter into positions called “total return”, given their difficulty in trading futures. Total return transactions take place by entering into an agreement with an investment bank where they receive a cash flow that mimics the return of a commodity index such as the S&P GSCI[42]. Investment

[42] The S&P GSCI (Standard and Poor's Goldman Sachs Commodity Index) is a benchmark commodities index that tracks the performance of the global commodities market.
It is made up of 24 exchange-traded futures contracts that cover physical commodities spanning five sectors.

in the S&P GSCI is essentially passive in nature as the index is built following a set of predefined rules. It is appealing to "real money" investors such as pension funds and mutual funds because it represents a "long only" forward investment without leverage. Active investors (such as hedge funds or commodity trading advisors) might contemplate a somewhat restrictive index approach and seek to gain a larger return that outweighs the performance of the index. Index investors will earn a return equal to that of the market, which is sometimes called "beta". Active investors try to outperform the index and the improved return is called "alpha". In summary, all these investment and speculative activities move oil prices and are one of the key drivers.

Movements in the foreign exchange rates also affect oil prices as crude oil is priced in USD and therefore a weakening of the currency should result in increased demand for the commodity from non-dollars as the cost is now lower in domestic currency terms.

Seasons also have an important impact on the price of oil, e.g., in summer oil prices are higher due to increased demand from more people traveling (see Schofield, N.C.,2021).

- ***geopolitical context:*** from the point of view of the geopolitical context, wars, terrorism, and sanctions influence the price of oil. Wars lead to the destruction of production facilities or transport channels, making it hard for importing countries to deliver the necessary sources at a sustainable cost. For example, wars in the Middle East, such as the Gulf War in 1991[43], significantly curtailed oil production in Iraq (a country with substantial reserves), which took years to return to pre-conflict levels. Also today, the Russia-Ukraine war has led to substantial increases in the oil price, which reached a price of $128 per barrel in March 2022, as the conflict has slowed down Russian long-term production and transportation of black gold[44], significantly increasing wholesale costs.

Coupled with the various disputes have been acts of terrorism in the Middle East and East African region. One worry about a potential terrorist attack in Saudi Arabia, where two-thirds of production is moved through two processing plants and a single terminal.

Political tensions and the security of supply are crucial for oil price fluctuations. According to Schofield N.C. (2021), the "fear factor" is often reported within commodity markets and typically in connection with worries about the security of supply. As China has further industrialized, it has shown a predisposition to take deliveries from countries with which the US has rejected dealing (e.g., Iran, Sudan,

[43] Is the war between Iraq and a coalition of 35 states formed under the auspices of the ONU and led by the United States, which intended to recover the sovereignty of the small emirate of Kuwait, after it had been invaded and annexed by Iraq.
[44] Term used to refer to oil

Angola). This has led some observers to speculate on future tensions between the superpowers as both struggle for control of strategic oil supplies. For this reason, it is sometimes supposed that the providers of crude oil have greater influence over the price than the buyers. However, this is not necessarily the case, and it is valuable to consider the notion of "security of demand". This means that oil companies have to be certain that they can find a purchaser for their production, implying that while buyers look for diversity/security of supply, producers look for the certainty of demand.

Two further factors connected to oil price determination are resource nationalism and access to new reserves. The first aspect is relevant since some countries have or have threatened to nationalize oil production within their territory, imposing higher prices (this has happened with Ecuador, Bolivia, Venezuela and Russia). This phenomenon is closely linked to access to new deposits by private oil companies. In fact, about 75% of the world's oil production comes from national oil companies, which have the power to give international oil companies access to oil where they themselves don't have the technical capacity. As a result, it has become more complex for private crude companies to replenish their stocks, pushing them into new, more niche sectors, such as the use of Canadian tar sands or gas-to-liquids production.

Despite fluctuations in the value of oil due to the strong resource nationalism, oil cartel countries also have considerable weight in shaping oil prices. An example of this are the OPEC member countries, given their hegemony and the large share of the market they serve (around 40%). Although they do not have total control over global production, their policies have an impact on prices, considering the many countries on which oil imports depend on. In the event of a supply crisis, in parallel to the countries importing from the pool, other countries could also request oil deliveries from OPEC, which would make the production of OPEC countries vital in the crude oil market, affecting consequently the international oil price.

In recent years, however, a reverse trend has been developing, which removes the risk of OPEC countries dominating the market. This trend is represented by the spread of alternative forms of energy and the use of new oil derivatives such as shale[45], which reduce the petroleum dependency of the various countries subject to the cartel's authoritarianism (see Schofield, N.C.,2021).

[45] Shale oil or shale petroleum is an unconventional oil produced from oil shale rock fragments by the processes of pyrolysis, hydrogenation or thermal dissolution.

- ***supply chain landscape:*** From a supply chain perspective, one factor to which the price of oil is exposed, is upstream production. In fact, the price is ruled by the law of supply and demand, and when either of these factors changes, the price adjusts.

In case of a decrease in demand or excess in upstream production, the price of oil begins to follow a downward path due to an excess of material that remains unutilized; in the other case, instead, an increment in demand or a decrease/slowdown in production results in an increase in the price of oil per barrel due to the higher difficulties of availability.

Large oil companies generally have idle production capacity, which is only used whenever there is a substantial increase in demand that pushes up the prices, with the aim of maintaining stability in the market. In fact, as reported by the OPEC's official site, their mission is "to coordinate and unify the petroleum policies of Member Countries and ensure the stabilization of oil prices in order to secure an efficient, economic and regular supply of petroleum to consumers, a steady income to producers and a fair return on capital to those investing in the petroleum industry".

Refining companies also play a very pivotal role, as production possibilities partly depend on the amount a refinery can process, and in an event of excess demand, there is the need to produce much more oil without having the possibilities to refine it. Furthermore, the expansion of an existing refinery could potentially take at least two years, while the construction of a new plant could take up to five years. Global estimates indicate that there are about 700 plants. Nevertheless, refineries are susceptible to environmental laws that are adopted by governments, capable to affect their operational capacity and the possibility of building new ones. Looking at the US, since the mid-1990s, refining companies have spent $47 billion to meet the demands of a range of environmental laws that have been introduced. This issue is very acute in recent times in the face of legislation and the focus on environmental sustainability, the concept of "green", as well as emissions reduction targets. This has an influence on the performance of refineries, in some cases forcing them to review their internal organizational systems, influencing the productiond and consequently the oil price. Yet, as mentioned in the preceding paragraphs of this paper (see 2.1.1 Market data), one of the indicators of profitability of crude oil derivatives is the crack spread, which measures the income generated by refined products compared to the costs supported for crude oil in the production process. In the event of a crack in the market of the supply of oil, refiners specializing in processing "light" crudes will charge a higher price for that category of product, causing the price between light and heavy crudes to go beyond its theoretical value. In this context, a refinery processing heavy crudes will be more likely to achieve higher margins, given the increased possibilities of taking

the heavier, more acidic crudes and refining them into higher value products, which will tend to market at a greater discount than light crudes. This influences the oil prices.

However, the problem of price increases in situations of demand'excess is not only related to refinery capacity, but also to the amount of supply. Nowadays, about 30% is recovered from an oil well, but if new technologies that can drill deeper become available to market players, the extraction rate would increase dramatically, increasing production and reducing oil price volatility in the event of excess demand (see Energy Information Administration, Refinery Capacity report, 2021). This is possible only if the new technologies provide producer with returns commensurate with their investment costs. In fact, oil production is also regulated by production costs. These include the costs of exploration, licensing, production, land drilling, equipment, oil platforms, and so on. It is clear that as these costs rise, the price per barrel of crude increases proportionally. This is more the case when wells or extraction areas become short, forcing oil companies to bear higher costs due to more advanced technologies and equipment required for extraction in new areas, such as the seabed off the coast of Mexico.

According to a report published in 2016 by Rystad Energy UCube, the average cash cost to produce a barrel of oil or gas varies from country to country, ranging from $8.98 in Saudi Arabia to $44.33 in the UK. Below is a graph with the costs in the different countries:

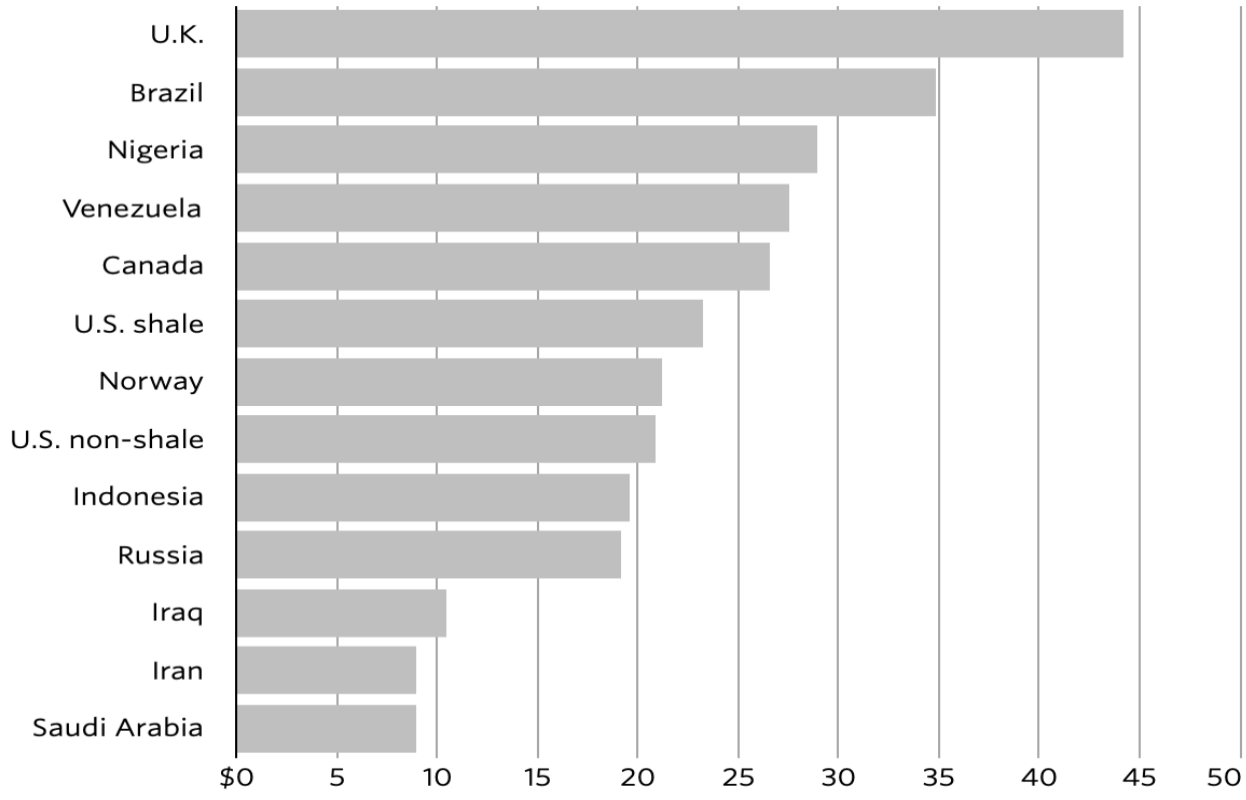


Figure 27. Source: Rystad Energy Ucub (2016)

Linked to the supply chain framework, a further relevant factor in the movement up and down of oil price are the costs of distribution as well as transport costs. In the event of a disaster in a large wellfield, which is a source of supply for many countries, the cost of finding alternative sources, and thus the cost for the transportation related to the availability of very large crude carriers (VLCCs)[46], would be very high since there are around 450 worldwide, impacting rental costs with a knock-on effect on margins and the price per barrel of crude oil.

2.1.3 THE PRICE OF CRUDE OIL

The price of crude oil is expressed in US dollars per barrel (containing 42 US gallons[47] or 159 liters) and commonly depicted as USD/bbl. The latter abbreviation (bbl.) originates from past periods, but its historicity is still unclear. There are two opposing strands that give an explanation for the origin of the term. The first strand argues that the term derives from the practice of storing crude oil in blue-colored barrels, while the second argues that it takes its name because in the past beer barrels were used for its storage.

- the evolution of crude oil prices: since the 1970s the price of crude oil[48] has varied widely, with peaks and troughs at different times, reflecting the impact of the various variables analyzed in the previous section. In December 1973, during the period of the oil crisis, the price per barrel was $26,82/bbl., but in the face of the embargo imposed by OPEC countries on pro-Israeli countries and with policies to

[46] Are large ships for transporting huge quantities of oil
[47] In the United States the U.S. gal or U.S. liquid gallon is used: 1 U.S. liquid gallon = 3,785411784 L
[48] Is taken the WTI oil as reference

increase prices, the price of oil rose drastically until it reached a price of $65.17/bbl. in 1975. The price remained more or less stable until 1979, when there was the second oil crisis known as the “1979 Oil Shock”, when the price of crude oil was around $63,17/bbl. From then on, the price began to rise until the early 1980 due to a decrease in oil production following the Iranian revolution, which caused fluctuations in the price of oil because of fuel shortages and long queues at petrol stations. In addition, the Iran-Iraq war in 1980 also contributed to a sharp rise in the price to over $140/bbl., as oil production in the countries involved in the conflict declined. From then on, the price started to fall until the Gulf War, when the trend was reversed. The first reason for the price decrease was the political election of Ronald Reagan, who signed an executive order abolishing price and allocation controls on domestic oil and gasoline production and distribution, causing prices to fall to $27,54 per barrel. Then, in 1990, there was the Gulf War, in which Iraq invaded Kuwait, causing the price of black gold to rise from $38,72/bbl. to $85,62/bbl., but after a U.S.-led military coalition succeeded in removing Saddam Hussein's Iraq forces from Kuwait in early 1991, the price fell to about $41.81/bbl. Starting in July 1997, the countries of Asia were hit by a heavy financial crisis that triggered fears of a global economic meltdown due to financial contagion and cascading effects. This obviously had an impact on oil prices, which plummeted to just under $20/bbl., only to start a period of recovery until the twin bulls attack in 2001, when the price was around $30/bbl. From 2002 to 2008 oil prices were characterized by a period of recovery, although alternating with decreases in some years, reaching a price of around $183,96/bbl. in June 2008. This increase was justified by the fact that global oil production had fallen sharply in the face of a series of events, such as Venezuela cutting sales to ExxonMobil in a legal battle over the nationalization of that company's assets, or due to exports from Iraq which had not yet recovered from the last war in the region (see Smith, J., 2009). The second half of 2008 was hit by an increasingly dramatic economic recession, accompanied by one of the largest financial crises, which pushed the price of oil to $56.75 in January 2009.

US oil and gas production has increased by about 57% over the past decade to the early 2020s, as improvements in fracking technology have unlocked large reserves in several areas of the country. Fracking has elevated the US to the status of one of the world's largest oil producers, reducing US demand for imported oil and turning the US into a net exporter. At its peak, the Permian Basin region of Texas and New Mexico produced more crude oil than most OPEC nations. Due to oversupply in 2014, the price of crude oil fell from about $127.04/bbl. in early 2014 to $40.67/bbl. in 2016. In the following years, the price of oil alternated between periods of growth and falls, reaching $68.33 in December 2019,

and then suffering a large fall due to the impact of Covid-19, reaching $21.74 in March 2020. However, the world's economies are in a phase of economic recovery, in which the dramatic effects brought about by the virus and the lockdowns implemented to prevent its spread are disappearing over time. In fact, the price of oil began to rise in March 2021, reaching a price of $77.54 in December 2021. Furthermore, in the last months of 2022, Russia launched a "special operation" on Ukrainian territory to conquer the former Soviet Union state, creating economic and social damage and causing the price of oil to jump to $104.69/bbl. in April 2022. The graph below shows the development of WTI crude oil:

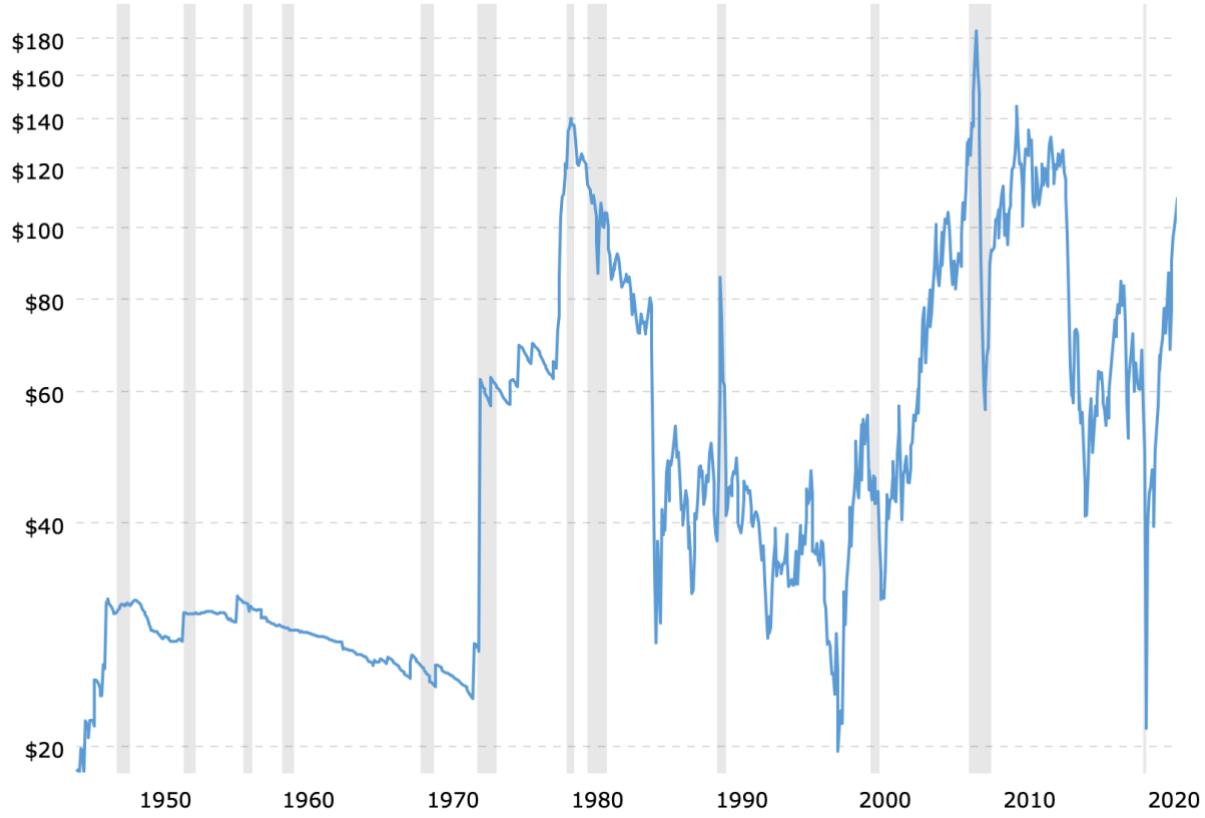


Figure 28. Source: Macrotrends (2022)

- ***delivery price:*** trading on the spot market for the purchase or sale of oil involves entering contracts in which the main items of the transaction are specified. These include:

- the price in the market at the time of the purchase/sale, expressed in USD/bbl.
- whether the contract is to be priced off an index or a “marker crude”
- any commission or difference to be applied to the price
- the type of product, e.g., density or viscosity
- the date of delivery
- the place of delivery
- whether the price is CIF or FOB.

Regarding the last point, CIF stands for Cost, Insurance and Freight and FOB stands for Free-on-Board; both represent two ways in which the price of oil is expressed. The CIF expresses the total cost of proceeding with a transaction, which is the reason why it will be preferred by a buyer, while on the other hand, the Free-on-Board price expresses the price of oil at loading point allowing comparisons between different crude oil prices around the world (see Schofield, N.J., 2021).

However, when entering into a contract involving the delivery of crude oil, the costs are distributed as follows:

- current Free-on-Board price
- dispatch costs
- any ancillary costs related to transporting such as pipeline costs if the refinery is not located on the coast
- losses caused by factors such as evaporation
- insurance costs
- costs of financing the oil bought in transit and prior to its production (there will be an inter-period between when the oil is paid for and when the refined products are sold to generate income).

- ***crude benchmark:*** price reporting institutions proceed with the quotation of different types of crude oil, which price is computed using the price of a benchmark crude oil as a reference. The difference between the quoted oil and the benchmark oil represents the discount/premium that would have to be charged to a certain type of crude oil over another in order to ensure that a refinery would be unconcerned about using one or the other for the production of a certain product portfolio. The major benchmark crudes used are:

- Brent, light crude with a sulfur content of 0.37%.
- West Texas Intermediate, sweet crude with a sulfur content of 0.24%.
- Urals, sulfur content of 1.35%.
- Tapis/Oman, sulfur content of 0.03%.

Nevertheless, the choice of crude benchmarks illustrated above doesn't depend on any predefined formula; for example, Brent represents only 0.3% of world production, but is backed by a highly active derivatives market. It should also be noted that also for a single oil there can be several benchmarks, for example the case of the Dated Brent, i.e., the price for the physical delivery of Brent crude.

It should also be noted that crude benchmarks are subject to several variables that can change their performance in unpredictable ways, such as changes in supply or demand, unforeseen disruptions, natural disasters and so on. For example, the CME crude oil futures is a crude with a delivery location in Oklahoma, where any changes in local supply and demand would affect the price, making it more of an indicator of the circumcised environment there than of the global situation in the sector.

As far as OPEC countries are concerned, oil is priced according to a pool of oils produced by the cartel countries, the ORB - OPEC Reference Basket. Some of the main oils are: Saharan Blend (Algeria), Zafiro (Equatorial Guinea), Iran Heavy (Islamic Republic of Iran), Kuwait Export (Kuwait), Arab Light (Saudi Arabia). The internal pricing policies of OPEC countries depend on the decisions of individual exporting countries according to their own objectives. For example, in 1973 in the Kippur war, OPEC members supported one of the countries involved in the conflict by raising prices and introducing an embargo on certain importing countries.

Also, Saudi Arabia has internal pricing policies based on the destination of the oil produced, in fact, the price for exports to the USA is established as a differential with WTI, and for exports to Europe as a differential with Brent. Although Saudi Arabia plays a predominant role in the Middle East countries (which produce 32% of world production), its crude oils are not considered as benchmarks. The rationale is that in the 1980s oil was quoted on the basis of the derivative products that could be obtained after the refining process. At the time, the refined products were trading at relatively high prices and so the producers set the price of crude based on these higher values, less a margin for refining and transportation. As a result, producers earned a fixed margin independent of how much they generated and therefore had an incentive to work at high capacity. This led to an oversupply of products, the prices of which fell significantly, as did the price of crude oil. Thus, it is more usual for oil from the Saudi Arabian Peninsula to be priced according to the final location or delivery date. Furthermore, under clauses introduced by the country, processing of crude to obtain derivative products is only allowed to the original purchaser, leading to an inactive market in Saudi Arabian oil trade (see Schofield, N.J., 2021).

- ***pricing approach:*** other than the approach of pricing a crude oil contract for the difference with crude oil benchmarks, other pricing approaches can be considered:

- *floating price:* means that the price or a factor of it, agreed in the transaction, is based on a specified index. For crude oil some of these indices are the ones of S&P Platts and the Petroleum Argus. The process of determining the price based on the index is included in the contract and is generally calculated as the average of prices over a specified time period, such as a period around the delivery date or as the average of daily prices over the previous month.
- *official selling prices:* many state-owned oil companies (NOCs) price crude oil sales to long-term customers using an official selling price (OSP) for each of their major crude streams. These OSPs are typically set by each oil company on a monthly basis after an official meeting and then applied to long-term customers.
- *fixed price:* the price is determined bilaterally between the parties and kept constant over a long period. Approximately 90/95% of the crude oil traded is sold on a fixed price basis, and for this reason the spot market constitutes no more than 5-10% of the market.
- *differential to a benchmark crude:* see previous sub-paragraph (crude benchmark).
- *futures price:* the price is relative to a futures price on a particular date or an average of prices over a previously agreed period. It should, however, be noted that a futures market does not exist for every type of crude.
- *exchange for physicals:* in the case of transactions between the parties with physical delivery of the underlying asset, the price is determined based on the futures market.

Besides the price of oil itself, oil cargoes also follow a pricing process by which the parties involved in the transaction enter into a contract that must include:

- the underlying reference prices
- the pricing periods
- any difference with the reference price
- whether the price is FOB or CIF.

For example, the characteristics of a crude cargo contract can be represented as "S&P Platts Dated Brent + USD 1.00/bbl., FOB, pricing 2-1-2". The first term refers to the prices quoted by the S&P Platts company for Dated Brent (price for physical delivery of Brent), plus an amount equal to USD 1.00/bbl. The second term (FOB - Free-on-Board) refers to the type of pricing, i.e., the price that does not include insurance costs, rental costs, etc. The last term "2-1-2 pricing" is another term expressive of the oil cargo price and indicates that the price is calculated as an average of the published Dated Brent price around

a five-day period (2-1-2). The crucial point of this term is the Bill of Lading date, which is a part of the transportation documentation that performs between main functions:

- serves as a receipt for the oil cargo
- is the contract between the parties for the transportation of the goods
- serves as a document of title for the goods transported.

Returning to the example, the term 2-1-2 means that the pricing period covers the 2 days before to, the date of and 2 days after the signing of the Bill of Lading (see Schofield, N.J., 2021).

2.1.4 STRATEGIES TO HEDGE CRUDE OIL EXPOSURE

This paper is concerned with describing how some hedging strategies are implemented in order to reduce exposure to crude oil price changes.

One of the main instruments that are used in order to lock-in the future price at which to execute a transaction is futures contracts. These contracts, although they are traded on regulated markets, are subject to the so-called basis risk[49], which arises in several situations. Basis risk is present when there is a mismatch between the time the company is affected by changes in the price of oil and the period covered by the contract, or when futures contracts with a certain product as underlying are used to protect against the exposure of another. Other situations involve the presence of basis risk: when the contract provides for the physical delivery of the commodity to a different location than the one used to price the hedging instrument, or when there are quality differences between the physical exposure and the exposure to the hedging instrument, and finally also when the position in the futures contract is terminated before maturity. However, let's proceed with an example of a hedging strategy with futures contracts. Consider an oil company that works in upstream production and wants to hedge against exposure to changes in the price of crude oil. It must deliver in the last quarter of the year (October, November and December) 30,000 barrels of WTI crude (10,000 each month) to a refinery. The contract for the sale of the barrels of oil to the refinery will be settled based on the average of the S&P Global

[49] Basis risk is the potential risk that arises from mismatches in a hedged position. Basis risk occurs when a hedge is imperfect, so that losses in an investment are not exactly offset by the hedge.

Platts prices quoted on the first day of the month preceding the delivery (e.g., for the month of October the price paid by the refinery will be equal to the average of the S&P Platts prices in the month of September). If the oil company's expectations would be of lower future prices (lower profit), it could enter into a position of 30 futures contracts with WTI as the underlying (each contract based on 1000 barrels) to have protection. Hence, to hedge its exposure to the pricing windows at the start of each month, the producer decides to initiate a short hedge by selling a strip of futures contracts. So, to hedge its October, November, and December sales, it sells November, December, and January CME WTI futures. However, in a real-world, the maturities of futures contracts do not match the maturities for physical delivery of the asset as they do in a perfect world, thus creating basis risk. In our example, October delivery will be priced at the average September cash price, so the final price will not be known October, when the October futures contract will have expired[50]. Therefore, the oil company may choose to hedge September price movements using a November contract, which will expire towards the end of October. Since the price exposure of the physical sale and futures covers different time periods, the producer runs the risk that the cash and futures prices will not move in tandem; an example of basis risk. The figure below shows the outcome of the hedging program and the effective price realized by the producer:

Date	Physical	Futures	Futures Gain/Loss (USD/bbl.)	Effective Price (USD/bbl.)
Sep 1	Sells 30k bbl. per months on a forward basis for Ott, Nov, and Dec delivery S&P Global Platts cash price=56,35	Sells 30 lots per month of WTI: Nov=58,75 Dec=59,40 Jan=60,2		
Ott 1	S&P Global Platts cash price=55,6	Buy 30 lots Nov=57,35	(58,75-57,35) = 1,4	(55,6+1,4) =57
Nov 1	S&P Global Platts cash price=55,2	Buy 30 lots Dec=57,28	(59,4-57,28) =2,12	(57,28+2,12) =59,4
Dec 1	S&P Global Platts cash price=56,95	Buy 30 lots Jan=63,6	(60,2-63,6) =-3,4	(56,95-3,4) =53,55

Average S&P Global Platts cash price= (55,6+55,2+56,95)/3= 51,917 USD/bbl.
Average effective price= (57+59,4+53,55)/3=56,65 USD/bbl.

Figure 29. Source: Personal elaboration on Excel

[50] The WTI contract expires three business days prior to the 25th calendar day of the month preceding the delivery day

The figure above shows how the oil company hedged by locking in a price of 56.65 USD/bbl. It is important to highlight that this price differs from the price at the time the hedge was initiated (56.35 USD/bbl.), as cash prices and futures did not always move in tandem during the period in question. The basis risk is calculated as the difference between the spot price and the futures prices, and the basis at closeout may also be utilized to establish the actual price paid for crude oil using the subsequent relationship: Original futures price plus basis at closeout = actual crude oil price.

In our example:

	NOVEMBER	DECEMBER	JANUARY
Initial value for basis	(56,35-58,75)=-2,4	(56,35-59,4)=-3,05	(56,35-60,2)=-3,85
Value of basis at close out of future	(55,6-57,35)=-1,75	(55,2-57,28)=-2,08	(56,95-63,6)=-6,65

Figure 30. Source: Personal elaboration on Excel

According to Schofield, N.J., (2021), in certain circumstances, the contract for physical delivery of the underlying is pegged to an average price over a time period that mirrors the loading period. In these cases, the futures position should be closed out according to how the physical contract is priced; so, if the price of the physical delivery contract is determined relative to the 5-day price average, then 1/5 of the futures hedge should be closed out each day. Let's assume it's late February, and an oil company enters into a position for 3-months' time delivery of 500,000 barrels of crude oil (in late May) and enters into a contract with a refinery where the cost of the physical crude oil will depend on the average closing price of the near month's futures during the three days it takes to load the cargo onto the refinery's vessel. In this case, the oil company is exposed to possible decreases in the price of the commodity and therefore decide to sell futures to hedge themselves. At the end of February, 500 July contracts are sold, as this will be the "near month" contract on the expected delivery date. Each contract is for 1000 barrels and the futures price is USD 60. Assume that the closing futures prices for the "prompt" contract for each of the three May delivery dates turn out to be:

- Date 1 = USD 64
- Date 2 = USD 65.5
- Date 3 = USD 62.5

Under the contract for physical delivery with the refiner, the oil company receives the average of these three prices multiplied by the quantity, so USD 64 x 500,000 bbl. = USD 32,000,000.

The oil company decides to close 1/3 of the total futures contracts each date, which means closing 166.67 futures each day. The profit and loss follow below:

DATE 1	DATE 2	DATE 3
USD 64 - USD 60 = USD 4 loss	USD 65,5 - USD 60=5,5 loss	USD 62,5 - USD 60=2,5 loss
Traders buys 166,67 futures	Traders buys 166,67 futures	Traders buys 166,67 futures
The total loss is USD 666.680	The total loss is USD 916.685	The total loss is USD 416.675

Total profit and loss on futures position= USD 666.680 + USD 916.685 + USD 416.675= USD 2.000.040 loss
Income received from sale of physical crude minus futures loss = USD 32.000.000 - USD 2.000.040 = USD 29.999.960

Figure 31. Source: Personal elaboration on Excel

On a per-barrel basis this is equal to selling crude oil at a price of USD 60 – a sum equal to the original futures price.

In this example, the hedging strategy is 100% efficient (even if woul have been better to not hedge) with underlying assumptions:

- since the price of the physical contract refers to a futures contract instead of an index, the hedge moves in line with the price of the underlying asset
- the ending of the futures contracts used as a hedging strategy was performed with the closing prices, which also determinate the price of the physical contract
- it is assumed that the underlying crude oil and the future are for the same type of crude oil

Another hedging strategy that could be implemented to hedge against oil price fluctuations is the use of swaps, in which the underlying asset is exchanged for fixed and variable payments depending on the position taken. Let's assume that a company producing ethylene (a derivative of crude oil) has a contract to buy 50 thousand barrels of crude oil in the next month but expects future price increases that will increase their costs. To hedge against this exposure, the company decides to enter into a swap position with a fixed price of USD 80/bbl. and a floating reference price equal to the average closing price of oil on the reference market in the previous month (e.g., NYMEX). Under such a swap, the company will earn the difference between the fixed price and the average closing price on the market if the price of oil has increased and is greater than USD 80/bbl., while, in the event that the average futures price is less than USD 80/bbl., the company will pay the difference to the counterparty. In the first case the price increase is covered by the gain on the swap, while in the second case the lower cost for the company to buy crude oil is compensated by the difference between the fixed and variable price it has to pay.

Let's assume that the average futures price in the reference period was USD 95/bbl. Therefore, based on the terms of the swap, the company earned: (USD 95/bbl. - USD 80/bbl.) x 50,000= USD 750,000. The

cost it incurs from the price increase is USD 95/bbl. x 50,000= USD 4,750,000. The net total is USD 4,000,000. In this way the company locked-in a price of USD 80/bbl. and hedged against price increases for its crude oil supply. In fact, with a price of USD 80/bbl. the total cost would have been: USD 80/bbl. x 50,000= USD 4,000,000. Let's assume that for the next 5 months' supply, the company decides to follow the same hedging strategy, entering into swap positions with the same characteristics and the same notional amount of 50,000 barrels. The average market closing prices are shown in the table below as well as the cash flows between the parties, assuming they take place at the end of each month:

DATA	AVERAGE CLOSING PRICE ON NYMEX EXCHANGE	FIXED PRICE	NET CASH FLOW
Mar	USD 95/bbl.		
Apr	USD 93/bbl.	USD 80/bbl.	USD 750.000
May	USD 86/bbl.	USD 80/bbl.	USD 650.000
Jun	USD 54/bbl.	USD 80/bbl.	USD 300.000
Jul	USD 67/bbl.	USD 80/bbl.	USD -1.300.000
Aug	USD 85/bbl.	USD 80/bbl.	USD -650.000
		USD 80/bbl.	USD 250.000

Figure 32. Source: Personal elaboration on Excel

However, the cash flows that are exchanged in swap contracts can be calculated in different ways:

- *index price vs index price:* in this type of swap, cash flows are calculated by taking into account two different oil market indices, e.g., Dated Brent and Urals. Like a traditional swap, fixed payments are exchanged for variable payments. The fixed price will take its value from the differential between the two indices. The floating payment will be based on the actual differential that is observed over the agreed payment period for the swap.

- *crude oil vs product:* in this type of swap, the cash flows between the parties are exchanged taking into account different refined products. The payments are based on the price of crude oil against one of the refined products such as jet fuel.

-*fixed price vs. quoted futures price:* this is similar to the case of the above example where, instead of considering the average of the NYMEX market closing prices, the average of the prices of the futures contracts exchanged on the market in the previous month are considered, which constitute the variable part. Payments between the parties are calculated as the differential between the fixed crude oil price (set by the contract) and the value assumed by the variable part.

- *index price vs. futures price:* this is a type of swap in which payments are derived from the differential between an index such as Dated Brent and the price of futures such as ICE Brent futures.

The most common traded crude oil and refined product swaps are shown below:

Underlying Commodity	Settlement price
Brent	Average of daily settlement price of prompt ICE futures contract.
Dated Brent	Average of daily published S&P Global Platts assessment.
WTI	Average of daily settlement price of prompt CME futures contract.
Dubai	Average of daily published S&P Global Platts assessment.
Tapis	Average of daily published Asian Petroleum Pricing Index assessment.
Gasoline 10 ppm 95 Ron Barges FOB Rotterdam	Average of daily published Argus assessment.
CME RBOB Gasoline	Average of daily settlement price of prompt CME futures contract.
ICE gas oil	Average of daily settlement price of prompt ICE futures contract.
CME Ultra Low Sulfur Diesel	Average of daily settlement price of prompt CME futures contract.
Gas oil 0.1% Sulfur Barges FOB Rotterdam	Average of daily published S&P Global Platts assessment.
Gas oil 0.25% Sulfur Cargoes FOB Singapore	Average of daily published S&P Global Platts assessment.
Fuel oil 3.5% Sulfur Barges FOB Rotterdam	Average of daily published S&P Global Platts assessment.
Fuel oil 2% Sulfur Cargoes FOB Singapore	Average of daily published S&P Global Platts assessment.

Note: For the gasoline contract 10 ppm indicates there are 10 parts of lead per million.

Figure 33. Source: Schofield, N.J., 2021

In addition to futures and swaps, options on crude oil also represent a highly liquid market, as they are considered valuable hedging instruments to mitigate exposures to changes in oil prices. As seen in the preceding paragraphs, the price of black gold is influenced by various variables relating to the geopolitical context, the supply chain and the macroeconomic scenario, and today is highly influenced by the policies adopted by OPEC countries, the spread of the Coronavirus and the Russia-Ukraine war. For these reasons, several marketplaces provide the opportunity to trade options on crude oil, giving market participants greater flexibility in setting their hedging strategies. The most popular of these will be discussed below as an example of hedging strategies.

Consider the case of an oil producing company that has drilled a new well and plans to sell the cargo within the next month to a potential buyer. This company is exposed to possible factors that could lead to a decrease in the price of oil, which would be found to be a detrimental factor to the company's revenues. The hedging strategy used by the company is that of the collar, i.e., the purchase of a monthly at-the-money put option and the sale of an out-the-money call option with the same maturity. The rationale of this strategy is to provide the trader with a hedge against price declines, reducing the cost of the strategy by collecting the premium of the shorted call. Let's assume that the firm enters the collar

position on March 1, 2020, when the price of Brent futures May 30 is: $46/bbl. (equal to the spot, it is assumed perfect correlation) and the total position to be hedged is 100,000 barrels. The firm:

- buys 100[51] monthly puts $46/bbl.[52] at a premium of $0.6
- sells 100 monthly calls at $50/bbl. for a premium of $0.4

Both expire on 26 March 2020 (1 March is assumed to be a Monday), when the price of Brent futures May 30 falls to $42/bbl. and the spot price decreases to $42/bbl. due to the outbreak of Covid-19 in Wuhan, China. Against this the trader loses $400,000 [($46/bbl. - $42/bbl.) x 100,000] on the spot market. However, the firm has hedged thanks to the implemented collar strategy:

- gain on the put of $400,000 [($46/bbl. - $42/bbl.) x 100,000] minus the cost of the strategy of $20,000 [- ($0.6 - $0.4) x 100,000].

The following figure is a graphical representation of the collar strategy.

The blue line represents the combined payoff, the celestial dashed line is the company's position if it had not hedged and was exposed to the volatility of oil prices, while the yellow line represents the profit and loss graph of the call and the grey line that of the put.

Important: the values on the y-axis are expressed in thousands of dollars.

Proft&Loss values are expressed in thousands of dollars

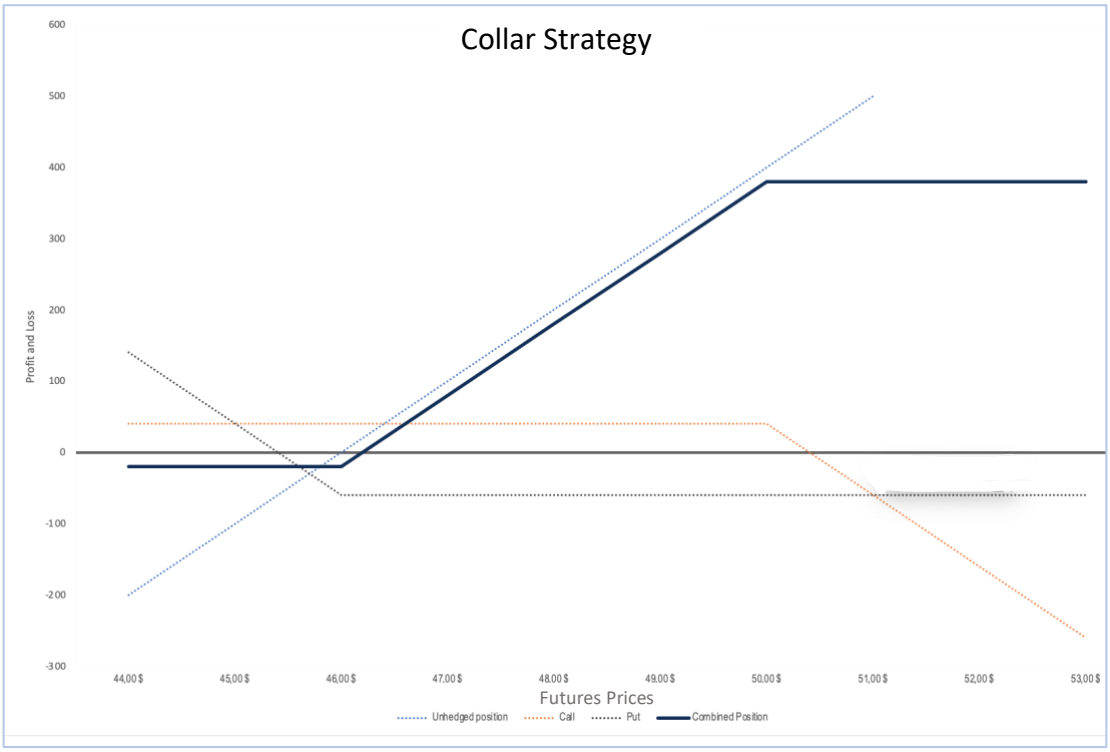


Figure 34. Source: Personal elaboration on Excel

[51] Each option is for 1000 barrels
[52] This is the strike price

A further strategy that can be developed by a trader to protect against the risk of rising crude oil prices is the use of monthly long call options. As seen in the previous paragraph (see 1.2.1 Options), long call options grant the buyer the right to purchase the underlying asset at a specified price (strike price, K) at a future date. The payoff is given by the difference between the spot price of the underlying and the strike, and is positive when S_t > K.

It is clear that the use of such a derivative is an efficient hedging instrument against increases in the price of crude oil, since when it rises, the trader can, if the conditions are met (S_t > K), exercise the option and obtain a gain.

Let's consider a company that needs to purchase 100 thousand barrels of oil in one month in order to do its business. The crude oil will be priced on the day of delivery and the firm fears a possible price increase on that date. To hedge itself, it buys 100 monthly at-the-money long calls with underlying Brent May futures, strike price of $80 and a premium of $0.5. Let's assume that on the day of delivery in March, due to embargo policies imposed by OPEC countries, the price of Brent Futures May goes from a value of $80/bbl. at the time the firm opened the position to a price of $85/bbl and the spot price increases to $85/bbl from an initial value of $80/bbl. (it is assumed perfect correlation). The company buys 100,000 barrels at a price of $85/bbl., with a total cost of $8,500,000 ($500,000 more than when the spot price was $80/bbl.). The profit on the hedging strategy is $450,000 ($500,000 - $50,000 premium), resulting in a reduced net payment of $8,050,000 or $80.5/bbl. The graph of the strategy is provided below:

Proft&Loss values are expressed in thousands of dollars

Figure 35. Source: Personal elaboration on Excel

When a particular trader is exposed to the risk of a price drop, e.g., an oil producer, the use of a bear-put spread hedging strategy would be useful in avoiding losses from falling prices. The bear put spread strategy consists of selling out-the-money put options and buying at-the-money put options, with the objective of hedging against price declines at a lower cost by collecting the premium on shorted puts. Let's consider an oil company in Saudi Arabia, which plans to sell 300,000 barrels of crude oil toward the end of May 2019, 80% hedged by selling 240 July 30 Brent Futures contracts. With a new field found, the producer could increase its production to 380,000 barrels in the first week of May, leaving 80,000 barrels exposed to a price drop that could be influenced by some geopolitical and economic announcements scheduled for the penultimate week of May. To hedge against this risk and to provide some price certainty around the expected increase in volume while finding a buyer, the company uses a bear put spread using July 30 Brent futures expiring on 27 May 2019:

- it purchases 80 monthly puts with a strike of $62 and a premium of $0.6
- sells 80 monthly puts with a strike of $56 and a premium of $0.4.

In the week of geopolitical and economic announcements, Brent July 30 futures fall from $62/bbl. to $56/bbl. and the spot price falls from $62/bbl. to $56/bbl (it is assumed perfect correlation). If it had not been hedged, the value of the unhedged position would be -$480,000, but thanks to the bear spread put strategy, the offsetting gain is $480,000 - $16,000 (total premium paid) = $464,000, meaning the producer manages to maintain a price per barrel of $61.2. Below is the graph of the strategy:

Proft&Loss values are expressed in thousands of dollars

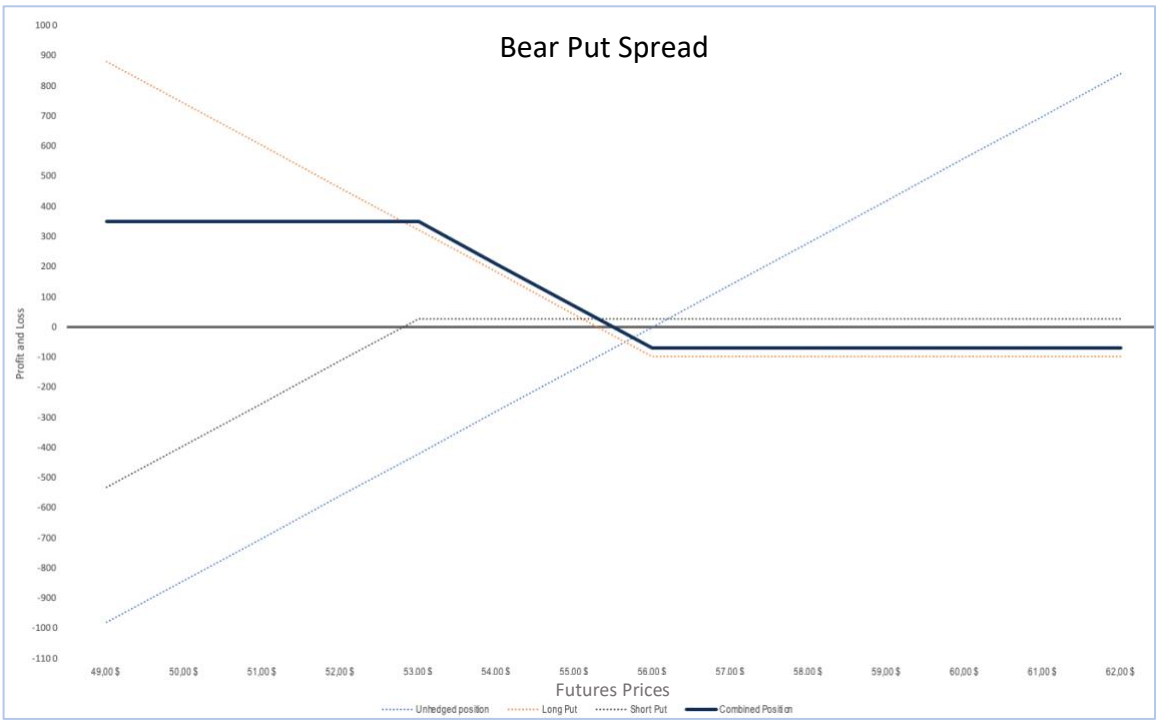


Figure 36. Source: Personal elaboration on Excel

A final strategy that will be investigated, and which will be concretely applied to CNOOC Ltd. in the last chapter, is the use of long put options as protection against price decreases. This strategy makes it possible, in the case of in-the-money options, to generate a profit (net of the cost of the strategy) that can offset losses due to falls in the price of the underlying asset. In the case of a perfect hedge, the profit from the options exactly counterbalances the entire position exposed to risk, but achieving a perfect hedge is difficult in practice due to the mispricing between spot prices and the prices of the underlying asset, due to the time mismatch between the time the options are exercised and the time the position is closed at the spot price, and due to the standardization of the contracts or the lack of required underlying assets.

Let's consider an oil producer company that plans to sell 100,000 barrels of oil 3 working days before the end of February. The spot price at the beginning of February is $75/bbl. However, the company has a bearish future oil price forecast and decides to hedge itself by buying 100 at-the-money long put options, with a strike price of $75 and a premium of $0.75, with Brent futures April 30 as the underlying asset. On 25 February (the day of the sale), the spot price has fallen to $68/bbl. and the company reports a loss of $68/bbl. - $75/bbl. x 100,000 = - $700,000. The price of the underlying futures also drops from $75 to $68 (assuming perfect correlation) and the gain from hedging is $75/bbl. - $68/bbl x 100 x 1000 - $0.75 x 100 x 1000 = $625,000. The firm has hedged itself by reducing the loss from $700,000 it would have recorded without any hedge to -$75,000 with the hedge. Below is the graph:

Proft&Loss values are expressed in thousands of dollars

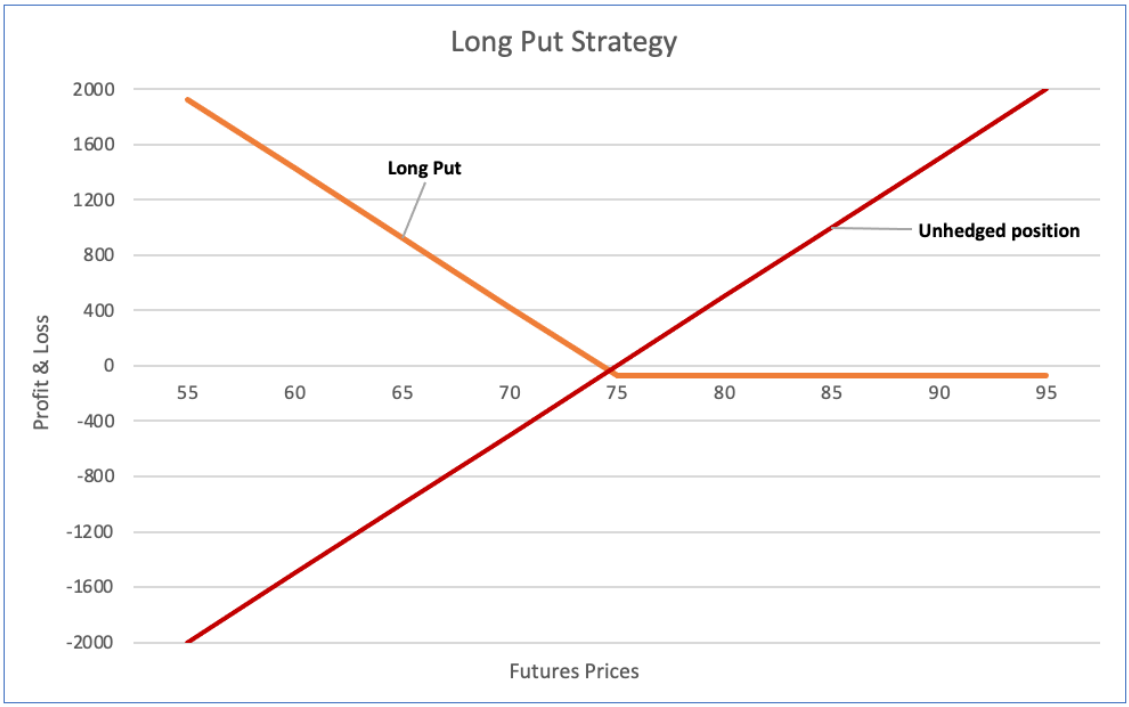


Figure 37. Source: Personal elaboration on Excel

2.2 ACCOUNTING FOR DERIVATIVE CONTRACTS

In this section, the aim of this work is to analyze how derivative contracts are accounted for in company financial statements since this has different implications on the way these instruments impact on company's profit. The new rules to follow regarding this topic, under the changes introduced by IFRS 9 and ASC 815, are considered. Financial statements are a crucial accounting report through which investors, financial analysts, stakeholders, and debtholders obtain information about the company of their interest. Also for managers these documents are of crucial importance because allow them to catch the correct business decisions. For this reason, strict rules of transparency and clarity have been introduced regarding the disclosure of company information through financial statements and reports, with the intention of ensuring transparency and the proper functioning of the financial markets. This was particularly decisive after the financial crisis of 2007/2008. However, these rules on the release of relevant information to the public are essentially stricter for listed companies with widespread ownership, since the interests at stake are greater than those of private companies. US companies, for example, are required to file their financial statements with the U.S. Securities and Exchange Commission (SEC) on a quarterly basis on form 10-Q and annually on form 10-K and furthermore must send an annual report with their financial statements to their shareholders each year. On the other hand, private US companies, prepare financial statements as well, but they usually don't have to disclose these reports to the public.

Anyway, corporate financial statements and reports also include information on financial instruments such as derivatives, which due to their use and technical characteristics have been the subject of changes in their accounting for years.

The two main regulatory sources for accounting for derivative instruments are currently IFRS 9 and ASC 815.

IFRS 9 (International Financial Reporting Standard) published by the IASB (International Accounting Standards Board)[53] deals with financial instruments and is divided into three main topics - classification

[53] International Accounting Standards (acronym: IAS) issued by a group of accounting professionals (International Accounting Standards Committee (IASC)) since 1973, was the first effort to standardize accounting rules globally. Until 2001, the IASC operated as an internal committee of the International Federation of Accountants (IFAC) and then transformed into a private foundation under US law (IASC foundation). Within this foundation, the board responsible for issuing accounting standards is called the IASB (International Accounting Standards Board) and the standards issued in 2004 by this board are called IFRS (International Financial Reporting Standards). Since these standards coexist, at least for the time being, with the previous IAS, the international standards are often referred to as IAS/IFRS (see Wikipedia, 2021)

and measurement of financial instruments: - impairment of financial assets and - hedge accounting. This accounting standard came into force on 1 January 2018 with early adoption allowed, replacing IAS 39 "Financial Instruments - Recognition and Measurement" considered too complex, inconsistent with the way entities manage their business, and inefficient as it postpones the recognition of loan losses too late in the credit cycle. The IASB released updated versions of IFRS 9 as each phase was finalized or amended, the entities had the option to adopt the updated version. The final standard was issued in July 2014 (see PWC, 2017).

In the United States, the accounting standards issued are the US GAAP (General Accounting Accepted Principles) issued by the FASB (Financial Accounting Standards Board). One of the first standards for accounting for derivative instruments was FASB No. 133 (Accounting for Derivative Instruments and Hedging Activities,1998), which requires companies to measure all assets and liabilities on their balance sheet at fair value. This standard was amended several times in the following years, with the issuance of more than 170 interpretative documents with the aim of addressing the various issues related to this standard. For these reasons of uncertainty, these standards have been replaced by the Accounting Standards Codification (ASC 815, Derivatives and Hedging).

Both IFRS 9 and ACS 815 on derivatives represent what falls under hedge accounting. Hedge accounting aims to closely align accounting with the economics of risk mitigation endeavors by identifying the effect of the derivative instrument in the same period that the underlying hedged asset or liability affects an entity's financial performance. By aligning economics with financial accounting, hedge accounting reduces earnings volatility without altering the economics of the underlying transaction. So, the purpose of hedge accounting is to represent, in the financial statements, the effect of risk management activities that use financial instruments to manage exposures arising from particular risks that could affect profit or loss (P&L) or other comprehensive income (OCI) (see Gaapdynamics website).

2.2.1 IFRS 9: THE NEW RULES FOR HEDGING ACCOUNTING

As mentioned before, IFRS 9 has significantly improved the alignment of hedge accounting with the assets and instruments held for the purpose of managing an entity's risks. The change introduced, compared to IAS 39, has introduced more flexibility by extending the scope of hedge accounting. The downside of these advantages is that IFRS 9 is a very complex standard, which requires managers to carefully consider the impact of the changes on their activities.

Hedge accounting measures apply to all hedging relationships, apart from those relating to the fair value of the interest rate exposure of a portfolio of financial assets or liabilities, where IAS 39 continues to apply.

- The three-accounting model: IFRS 9 provides for different forms of accounting in line with IAS 39: - fair value hedges; - cash flow hedges; - net investment hedges.

- *fair value hedge:* the fair value hedge consists of absorbing the risk of a change in the fair value of an asset or liability or an unrecognized firm commitment relating to a specific risk and capable of affecting the profit and loss of the company. What entails a change in fair value is the risk of changes in commodity prices, interest rates, and changes in exchange rates. The carrying amount of the hedged item is periodically adjusted for changes in fair value due to the hedged risk, and these changes in fair value are recognized in the P&L, while the instrument used to mitigate the risk is accounted at fair value and changes in the latter are recognized in the P&L. The amendment to IAS 39 concerns fair value hedges of equity instruments accounted at fair value through Other Comprehensive Income (OCI), the variations of which are recorded in Other Comprehensive Income without recognition in Profit&Loss (see PWC, 2017).

- *cash flow hedge:* refers to strategies for hedging risks that could impact the company's financial position, which arise from an unrecognized firm commitment or a highly probable forecast transaction. Also for cash flows, the risk of changes is related to changes in commodity prices (due to cash flows generated by their use in the company's normal operations), changes in interest rates (when cash flows are linked to variable rates) and changes in exchange rates (when, for example, the company buys or sells goods on foreign markets in a currency different from that of the country in which the company operates). According to section 1 of IFRS 9 (2014), for cash flow hedges whose hedge is effective (see

“qualifying criteria” for more information), changes in the fair value of the hedging instruments are initially recognized in Other Comprehensive Income, while the ineffective portion of the change in the fair value of the instrument is recognized in P&L. The amount that appears in Other Comprehensive Income must be the lower of:

- the accumulated gain or loss on the hedging instrument since its inception
- the accumulated change in the present value of the expected cash flows of the hedging instrument since inception.

However, ineffectiveness is recognized when "over hedge" situations occur, i.e., when the accumulated change in the instrument used to mitigate risk exceeds the change in the hedged item. In the opposite case, the situation is defined as "under hedge", but in this case the hedge is not recognized as ineffective, differently from the fair value hedge where both over hedge and under hedge are recognized as ineffective. Yet, according to Section 1- IFRS 9 “for cash flow hedges of a forecast transaction that results in the recognition of a financial asset or financial liability, accumulated gains and losses recognized in equity shall be reclassified to P&L in the same period or periods in which the hedged forecast future cash flows affect P&L. If there is an accumulated loss on the hedging instrument and the loss is no longer expected to be recovered, it shall be recognized in P&L immediately” (see section 1 of IFRS 9, 2014). What IFRS 9 introduced with respect to IAS 39 according to cash flow hedges, concerns:

- for cash flow hedges related to transactions arising from non-financial assets, or to transitions related to non-financial assets/liabilities that constitute a fixed commitment for which the fair value hedge is applied, the carrying amount of that asset must be adjusted for the cumulative gain or loss recognized directly in equity. Moreover, IFRS 9 no longer allows the option under IAS 39 to choose between the accounting described above or the accounting by which gains and losses are recognized in equity and reclassified to P&L if they affect it.
- the cash flow hedge accounting model can only be applied to hedge foreign currency risk if the net position of multiple items containing offsetting risk exposures is designated as the hedged item. The designation of this net position is required to specify both the reporting period in which the projected transactions are forecast to affect the P&L and the nature and volume expected to affect the P&L in each period. Hedging gains or losses must be presented as a separate line item in the income statement.
- In the case of multiple items that don’t contain offsetting risk positions, the presentation of the hedging profits or losses is allocated to the line items affected by the hedged items.

- *net investment hedge:* is the pattern of accounting for hedging transactions entered into by an entity with the purpose of hedging against changes in foreign exchange rates, which affect the value of net investments between the entity itself and one of its foreign subsidiaries (operating in a currency different from that of the parent entity). As long as the parent entity maintains control over the foreign subsidiary, differences in the value of net investments due to changes in foreign exchange rates are recognized in equity. On disposal or liquidation of the foreign operation, they are recognized in P&L as a gain or loss on disposal. For hedging instruments, foreign exchange gains or losses are recognized in Other Comprehensive Income if the hedge is considered effective and the foreign asset is not liquidated or terminated.

Compared to IAS 39, IFRS 9 in this section didn't make any particular changes, but it did establish requirements for considering the time value of money, which could potentially influence hedging strategies. It also introduces a guideline on the time value of options, forward points and currency basis (see IFRS 9, 2014).

- **Qualifying criteria for hedge accounting:** companies using risk hedging instruments and activities must follow precise accounting rules and only if certain requirements are met, there is the possibility to follow the rules of hedge accounting under IFRS 9. In fact, hedge accounting remains an option and is not mandatory. Below is a table containing the criteria necessary for the application of hedge accounting under IFRS 39, in comparison with those of IAS 39:

IAS 39	IFRS 9
3.1 Formal designation and documentation of: • Risk management objective and strategy • Hedging instrument • Hedged item • Nature of risk being hedged • Hedge effectiveness (including how it will be calculated)	Formal designation and documentation of: • Risk management objective and strategy • Hedging instrument • Hedged item • Nature of risk being hedged • Hedge effectiveness (including sources of ineffectiveness and how the hedge ratio is determined)
3.2 Hedging relationship consists only of eligible hedging instruments and eligible hedged items.	The general requirement remains unchanged. However, some items that were not eligible as hedged items or hedging instruments under IAS 39 are now eligible under IFRS 9 (refer to sections 4 and 5 below).
3.3 Hedge effectiveness requirements: • Effectiveness can be reliably measured • Hedge is expected to be highly effective (prospective testing) • Hedge is assessed on an on-going basis and determined actually to have been highly effective (retrospective testing 80%-125%).	Hedge effectiveness requirements (prospective): • Economic relationship exists • Credit risk does not dominate value changes • Designated hedge ratio is consistent with risk management strategy.
3.4 Voluntary discontinuation of hedge accounting is allowed.	Discontinuation of hedge accounting only under specified circumstances.

Figure 38. Source: PWC, 2017

- **Hedging effectiveness:** Hedge effectiveness is described as the degree to which variations in the fair value or cash flows of the hedging instrument offset changes in the fair value or cash flows of the hedged item.

IFRS 9 introduces three hedge effectiveness requirements:

- *economic relationship:* one of the requirements for verifying the effectiveness of hedging measures is the presence of an economic relationship between the hedging instrument and the hedged item. This is reflected in the inverse trend between the value recorded by the hedging instrument and the hedged item as a result of the common underlying or hedged risk. For example, in the case of the sale of oil and the short of futures contracts with underlying oil.
- *credit risk:* for a hedging strategy to be classified as effective, the economic relationship between the hedging instrument and the hedged item must not be affected by credit risk, in particular, the latter must not influence changes in value associated with the hedged risk, otherwise the level of compensation could become erratic. For example, if an oil company wants to hedge against possible increases in the price of a barrel of oil that would affect its costs, it could purchase through a Y bank a futures to buy the barrels of oil at a fixed price at a future date. But if such a contract is not guaranteed and Bank Y suffers a sharp decline in its credit rating, the futures on the balance sheet would suffer a change in fair value, while changes in the value of the hedged item would mostly be affected by changes in the price of oil barrels and would not be impacted by Bank Y's credit risk.
- *hedge ratio:* the hedge ratio expresses the association between the value of a position protected using a hedge and the magnitude of the entire position. IFRS 9 stipulates that the hedge ratio used for hedge accounting purposes should be the same as the one used for risk management purposes, in order to ensure consistency between the two and to avoid misalignment. The latter could arise when there is incoherency between the hedged position and the hedging instrument to obtain an accounting outcome that is not in line with the hedge accounting objectives.

Furthermore, this accounting standard under review does not require backward analysis of hedge effectiveness, but only the ongoing verification that the hedge meets the hedge effectiveness criteria and that the hedge ratio remains appropriate, without creating an inconsistency between the purposes of hedge accounting and risk management hedges. However, in some cases, mismatches between the hedged position and the hedging instruments used are allowed if this is due to the characteristics of the instrument used, e.g. if a company wants to hedge a position of 1500 barrels of oil through the use of futures, it will have to buy either 1 contract or 2 contracts (each contract is for the delivery of 1000

barrels), generating a hedge ratio of 0.67:1 or 1.33:1 respectively. In this case, it is possible for the company to account for the hedge ratio actually used, as the hedge ineffectiveness due to the standardization of futures contracts does not create a mismatch with the objectives of the hedge accounting (see PWC, 2017).

- Rebalancing: rebalancing is a new concept introduced by IFRS 9, consisting of changes to the values of the hedging instruments or the hedged item in order to meet hedge effectiveness requirements. This allows entities to cope with changes that impact the hedging relationship by recording the ineffectiveness of the hedge in the P&L before rebalancing.
The advantage of rebalancing is that it isn't recorded in the accounts but appears as a continuum of the hedging relationship. On the other hand, it should be noted that rebalancing isn't always applicable; this occurs when the risks impacting the hedging relationship are not covered by the hedging instrument, making compensation through adjustment of the coverage ratio inapplicable.
Additionally, if the risk management target has changed, rebalancing is not permitted, and hedge accounting must be discontinued (see PWC, 2017).

- Hedging effectiveness assessment: a recurring concept in IFRS 9 is hedge effectiveness, but nothing is said about specific assessment methods to be followed. An entity shall review periodically whether the hedging relationship is effective and whether the effectiveness requirements described above are met. It is a form of forward-looking assessment, i.e., based on expectations about effectiveness, ensuring that only economically sound hedging strategies (i.e., those that reflect the underlying economic relationship and are aligned with the risk management strategy) qualify for hedge accounting purposes. Any form of hedge ineffectiveness must be taken into account, as well as the sources from which such ineffectiveness arises, capable of undermining the hedging relationship during its life. The assessment could be both qualitative and quantitative, depending on the characteristics and complexity of the hedging relationship (see PWC, 2017).

- Hedging instruments: compared to IAS 39, IFRS 9 didn't implement many changes to the instruments that can be qualified as hedging instruments. In fact, most derivatives can be accounted for as hedging instruments as long as they are contracts with external parties. Regarding intragroup derivatives of companies that prepare consolidated financial statements, such instruments can't qualify as hedging

instruments in the consolidated financial statements but can instead be accounted for in the individual financial statements of the entities belonging to the group.

Among the impairments introduced by IFRS 9, there are the accounting for the time value of options; the interest element of forward contracts and the currency basis of cross-currency swaps[54] for hedging purposes (see PWC, 2017). The table below illustrates the differences between IAS 39 and IFRS 9 regarding the qualification of hedging instruments:

IAS 39	IFRS 9
4.1 Derivatives	Unchanged
4.2 Non-derivative financial instruments are only allowed for hedging FX risk.	Non-derivative financial instruments continue to be allowed for hedging FX risk. In addition, if non-derivative financial instruments are measured at fair value through P&L they are also allowed for hedging risks other than FX risk.
4.3 Embedded derivatives that are separated are allowed as hedging instruments.	Derivatives embedded in financial assets are no longer accounted for separately under IFRS 9. Therefore, only derivatives embedded in financial liabilities or non-financial contracts (and that are accounted for separately) are allowed to be designated as hedging instruments.
4.4 Changes in the time value of an option are recognised in P&L.	Where the time value of an option is excluded from the designation, changes in the aligned time value are deferred in OCI w. The timing of the reclassification to P&L depends on the nature of the hedged item (whether it is transaction related or time-period related).
4.5 Two alternatives are provided for recognising fair value changes of forward points.	An additional alternative for recognising fair value changes of forward points is introduced.
4.6 No specific accounting treatment is prescribed for currency basis spreads.	Currency basis spreads may be considered as costs of the hedge relationship, in which case changes in them can be recognised through OCI.

Figure 39. Source: PWC, 2017

- **Hedged items**: according to IAS 39 and IFRS 9, a hedged item can be "a recognized asset or liability, an unrecognized firm commitment, a forecast transaction, or a net investment in a foreign operation". The hedged item can be:

- a single item, or

- a group of items.

If the hedged item is a forecast transaction, it must be highly probable.

However, the changes introduced by IFRS 9 regarding the qualification of the hedged item relate to the elimination of limits on the accounting for economically reasonable hedging strategies as hedge accounting.

[54] Cross currency swap denotes a swap between two parties to exchange currencies.

The table below illustrates the differences between the two accounting standards:

IAS 39	IFRS 9
5.1 Definition of hedged item.	Unchanged.
5.2 Possible to hedge risk components of financial items only.	Also possible to hedge risk components of non- financial items.
5.3 Net positions not allowed as hedged items.	Net positions (including net nil positions) allowed as hedged items in some circumstances.
5.4 Use of layers as hedged item relatively restricted. Layers allowed only for cash flow hedges.	Layers allowed for both cash flow hedges and fair value hedges in some circumstances. Some restrictions apply for prepayable items.
5.5 Derivatives not allowed to be designated as (or be part of) hedged items.	Aggregated exposures allowed as hedged items.

Figure 40. Source: PWC, 2017

2.1.2 ASC 815: HEDGING ACCOUNTING STANDARD

The changes introduced by IFRS 9 on accounting for derivatives represent a major step forward internationally, but not the only one. The accounting for derivatives under US GAAP[55] has also been revised with the issuance of Accounting Standards Codification 815: Derivatives and Hedging, by the FASB. However, this accounting guidance is extremely complex and inflexible, both of the complexity of the subject matter being audited (derivatives) and the accounting rules involved. Therefore, the FASB issued Accounting Standard Update 2017-12 - topic 815 (ASU 2017-12 - 815): Improvements Targeted to Hedge Accounting, with the goal of facilitating understanding of the accounting rules and providing more clarity on the subject. Below is considered the ASC 815 after the adoption of ASU 2017.

[55] These are the generally accepted accounting principles of the United States, i.e., a set of commonly followed accounting rules and standards for financial reporting. They are adopted by public companies in the United States when preparing financial statements.

ASC 815 provides the definition of a derivative agreement, as well as the requirements for its classification:

- "a derivative instrument represents a right or obligation that meets the definition of an asset[56] or of a liability[57] and should be reported in the financial statements" (see ASC 815, 2014)
- "entities should apply hedge accounting for items designated as being hedged only to qualifying transactions, and the accounting varies based on the type of hedging relationship: fair value, cash flow or net investment in a foreign operation" (see ASC 815, 2014)
- "derivatives should be reported at fair value, and changes in fair value are reported in earnings, unless designated in a hedge accounting relationship" (see ASC 815, 2014)
- the contract has to include an underlying variable on which its value depends (such as indices, interest rates, commodities, foreign exchange rates, and so forth); it should contain a notional amount that relates to the total value of the position, and an order to pay, both expressed as units of currency, shares, barrels or other units specified in the contract. Based on the underlying reference and the notional value, the amount of the settlement is established (e.g., in an interest rate swap, the notional value represents the principal amount on which interest is paid).
- the contract requires no initial net settlement or a lower initial settlement than would be payable for contracts whose value depends to the same extent on changes in the value of the underlying, i.e., the parties must not invest or own the notional value at the time they enter the position.
- the contract must guarantee net settlement (including by a means external to the contract) or delivery of the underlying to the recipient who benefits from it to an extent not different from the net settlement.

Nevertheless, a contract may be considered a derivative contract under ASC 815 if it meets all the above requirements. This dictates that the entity's accountant must verify whether all the requirements of the accounting guidance in question are met, otherwise further verification is required to verify whether the contract contains any embedded derivatives that must be recorded separately. The latter must be accounted for independently in accordance with ASC 815 if there is a disconnection of economic properties and exposures to risks between the host instrument and the embedded derivative.

Furthermore, certain hedge accounting rules are not required to be applied by all entities that don't record profits as a separate line item in the statement of financial performance, like non-profit companies or certain pension plans.

[56] Expected future cash inflows due from another party
[57] Expected future cash outflows due to another party

- **Hedgeable risks and types of hedges**: under ASC 815, derivative instruments are recognized in the financial statements at fair value, but if the instrument isn't utilized for hedge accounting purposes, the gain or loss from changes in its value are reported in earnings. What is relevant is that the hedgeable risks allowed for financial instrument-related exposures differ somewhat from non-financial exposures, with some cases prohibiting the hedging of specific risks.

The hedgeable risks under ASC 815 for financial instrument-related exposures are:

- interest rate risk
- market price risk
- foreign exchange risk
- credit risk.

Of all these risks, only market price risk is permissible for a fair value hedge relationship, while for a cash flow hedge relating to an estimated purchase or sale transaction, the foreign exchange risk[58] or change in components specified in the contract may also be hedged (see EY, 2021).

As with IFRS 9, ASC 815 identifies three types of hedges to mitigate hedgeable risks:

- *fair value hedges:* refers to hedges of changes in the fair value of recognized assets or liabilities or of a firm unrecognized commitment that are potentially detrimental to the entity's financial performance. Fair value hedges are used also to mitigate the risks arising from fixed or known prices or rates, or to hedge firm commitments[59]. An example is an interest rate swap "pay-floating/receive-fixed", where one entity exchanges cash flow payments based on a fixed rate into a floating one, benefiting from its decreases,
- *cash flow hedges:* covers hedges of the exposure of expected future cash flows of recognized assets or liabilities or unrecognized forecast transactions. Cash flow hedges are used to hedge against risks arising from market movements in prices or rates that are variable, either by contract or because they will be entered into at market prices that are in effect at a future date (e.g., fluctuating commodity sales prices, variable-rate debt, foreign-currency-denominated sales prices).

Moreover, this accounting approach is implemented to mitigate the risk related to transactions that are yet to materialize, where the terms of the prognosticated transaction are not fixed or locked. A

[58] The foreign exchange risk associated with the receivables and payables that might result from such expected transactions is similarly hedged.

[59] Are transactions that will take place in the future where all the terms are contractually fixed

representative example is the opposite of fair value hedges, so an interest rate swap is "pay-fixed/receive-floating", where the entity pays a fixed rate and benefits from no exposure to interest rate changes in the market.

- *net investment hedges:* covers hedges of net investments from exposures to changes in foreign exchange rates between one entity and others operating in a currency different from the former (see EY, 2021).

Notwithstanding the three accounting methods, ASC 815 also provides special implementations of the application of fair value hedges or cash flow hedges in connection with foreign currency hedging strategies. They relate to:

- Cash flow hedges of forecasted foreign currency transactions or forecasted intercompany foreign currency transactions
- Cash flow hedges of forecasted cash flows equivalent to the functional currency associated with a recognized asset or liability.

recognized asset or liability

- Cash flow hedges of unrecognized firm commitments denominated in a foreign currency
- Fair value hedges of certain available-for-sale debt securities denominated in a foreign currency
- Fair value hedges of unrecognized firm commitments denominated in a foreign currency
- Fair value hedges of recognized assets or liabilities for which a foreign currency transaction gain or loss is recorded in profits (see EY, 2021).

- **Hedge accounting criteria:** the criteria for which a hedging relationship may be classified as a fair value or cash flow hedge are specified in ASC 815. They are:

- there must be formal documentation of the hedging relationship at the time it is entered, the primary scopes for which the hedge is taken, the risks that could affect the entity, the hedged item and the hedging instruments used. Last but not least, the method of assessing the effectiveness of the hedge in offsetting changes in the fair value or cash flows of the hedged item, must be reported.
- the effectiveness of the hedge must be highly effective and adequate to eliminate the risks inherent in the hedged position by offsetting changes in cash flows and fair value. This effectiveness must be assessed continuously, at least every three months and whenever financial statements/earnings are published.

- changes in cash flows or in the fair value of a given item that are covered by hedging instruments are likely to affect reported earnings.

- there is no relationship between the hedged component and: - values recorded in the financial statements remeasured with changes in fair value related to the risk offset and currently reported in earnings; - an investment that is or will be accounted for using the equity method[60];- a present or future non-controlling interest in one or more consolidated subsidiaries; - an investment in shares in a consolidated subsidiary; - a future M&A transaction; - an equity instrument issued or to be issued by the entity and classified in stockholders' equity.

An important issue highlighted by ASC 815 is the ability to use cash flow hedges and fair value hedges simultaneously, but only if the hedging instruments are used to offset different risks. This might be the case for an entity that hedges exposure to interest rate changes in a debt contract with a cash flow hedge, and at the same time uses a fair value hedge to mitigate credit risk on the same liability (see EY, 2021).

- **Rules for accounting for derivatives:** during the bookkeeping process, the derivative instrument is invariably stated at fair value in the statement of financial position, but the accounting for the counter-item depends on the purpose for which the instrument is used. If it is used for a reason other than hedging, the counter-item is income. If, on the other hand, the instrument is utilized for hedging purposes by demonstrating its effectiveness in offsetting risks, the counter-item is related to its use as a fair value hedge, cash flow hedge or net investment hedge. In the former case gain or loss on a derivative instrument comprised in the assessment of hedge effectiveness is recognized currently in earnings in the same accounting period. For derivatives that qualify as cash flow hedges, gain or loss in its fair value included in the assessment of hedge effectiveness is directly accounted as a component of Accumulated Other Comprehensive Income (AOCI) and reclassified to earnings in the same period or periods in which the hedged expected transaction influences earnings. Finally, for derivatives that qualify as net investment hedges, the change in their fair value included in the assessment of hedge effectiveness is reported in AOCI (see ASU 2017-12).

All three hedges feature the recognition in earnings of amounts excluded from the assessment of hedge effectiveness through amortization processes. The exception is for entities that choose accounting methods to directly record the change in fair value of any excluded components in earnings.

[60] The equity method is an accounting procedure in which an investment is first accounted for at cost and then subsequently reclassified for the post-acquisition change in the investor's share of the investee's equity.

- **Disclosure:** ASC 815 envisages widespread disclosure in the company's financial statements about hedge accounting, using footnotes and disclosure documents. These disclosures play an absolutely important role, as they provide further clarifications about the hedging relationships, how they have been accounted for, whether the hedging instruments qualify as fair value hedges, cash flow hedges or net investment hedges. Information on the hedged item, the underlying, and the financial results obtained are also reported.

The strong focus on disclosure in ASC 815 is demonstrated by the required extensive tabular disclosure regarding the location and fair values of derivatives and their associated gains and losses. In addition, if these instruments have been designated as qualifying hedges, the balance sheet disclosure table is requested to separately disclose assets and liabilities by contract type and on a gross basis. On the other hand, the income statement disclosure table must, in addition to the separation by type of contract already present in the tabular disclosure of the balance sheet, also separately disseminate gains and losses by type of hedge and specify the geography of the income statement.

As a rule of thumb, credit risks associated with the use of derivatives should be disclosed as they may affect the expected cash flows associated with derivatives.

Under ASC 815, additional information about hedge accounting methods is required. For example, for hedges that qualify as cash flow hedges, ASC 815 disclosure provisions require:

- a forecast of any gain or loss that will be recognized in earnings within the next twelve months
- the events that will result in the recognition in earnings of gains and losses deferred in AOCI
- the time limit on the entity's cash flow hedging strategies associated with expected transactions (see EY, 2021).

In summary, ASC 815 has significantly improved the rules for hedge accounting, providing more clarity and resolving previously unresolved accounting issues. However, it is a complex accounting standard in its entirety, requiring great efforts to be understood and to avoid accounting errors.

CHAPTER THREE

After dealing with derivatives and focusing on the crude oil sector, in this chapter, the task of the paper is to test the efficiency of a hedging strategy using long ATM put options each month to hedge exposures to changes in crude oil prices. A large Chinese oil producer (CNOOC Ltd.) that didn't adopt any hedging strategy will be considered and a counterfactual analysis will be performed to see how much it would have saved if it had engaged in the use of long puts in the period 2017 -2021.

3.1 CNOOC LTD.: COMPANY OVERVIEW

On February 28, 2001, CNOOC Limited (China National Offshore Oil Corporation) which was founded in the Hong Kong Special Administrative Region ("Hong Kong") in August 1999, was listed on The Stock Exchange of Hong Kong Limited (stock code: 00883). In July 2001, the company was accepted as a Hang Seng Index component stock.

The company is China's largest offshore crude oil and natural gas producer, as well as one of the world's largest independent oil and gas exploration and production businesses. The company's primary business is crude oil and natural gas exploration, development, production, and sale.

Bohai, the Western South China Sea, the Eastern South China Sea, and the East China Sea in offshore China are the company's main operational locations. Oil and gas assets are owned by the company across Asia, Africa, North America, South America, Oceania, and Europe.

CNOOC, the controlling shareholder of CNOOC Ltd., was established as a state-owned offshore petroleum company by the PRC government in 1982 under the PRC[61] Regulation on the Exploitation of Offshore Petroleum Resources in Cooperation with Foreign Enterprises. CNOOC took on some administration and development responsibilities for PRC offshore petroleum operations with foreign oil and gas companies. Prior to its reorganization in 1999, CNOOC and its various subsidiaries performed both commercial and administrative functions in offshore China relating to oil and natural gas exploration and development. In 1999, CNOOC transferred all of its existing operational and business interests in offshore oil and gas activities, including all associated assets and liabilities, to CNOOC Ltd.

[61] People's Republic of China

Consequently, the company and its subsidiaries are the only channels through which CNOOC engages in oil and gas exploration, development, production, and sales activities both inside and outside the PRC. CNOOC Ltd. is the premier oil and natural gas producer in China's offshore and one of the world's biggest independent oil and natural gas exploration and production companies in terms of reserves and production. In fact, in the past years, the company recorded net proved reserves of about BOE 5.3 billion.

Competitive Advantages

Its past success and future prospects are directly linked to a mix of strengths, which encompass the following:

- a diverse and extensive asset base with significant exploitation potential
- large operational areas off the coast of China with proven exploration potential
- a track record of autonomous exploration and development success
- PSCs[62] in offshore China provide access to money and technology as well as lower risk
- a skilled management team and a high standard of corporate governance. The asset base is large and diverse, with great exploitation potential.

CNOOC Ltd. has a broad worldwide portfolio that allows it to expand its exploration and exploitation capabilities beyond China, indeed the company has a long history of effectively purchasing and operating high-quality offshore upstream properties around the world. Its assets are currently located in Indonesia, Australia, Nigeria, Iraq, Uganda, Argentina, the United States, Canada, the United Kingdom, Brazil, Guyana, Russia, the United Arab Emirates, and other countries.

Another competitive advantage of the company under analysis relates to the potential exploitation of operational areas in offshore China, with a very high percentage of exploration. Furthermore, this area is considered underexplored compared to other prolific offshore exploration areas such as the shallow waters of the U.S. Gulf of Mexico. For these reasons, the company is active in exploration programs with boreholes, which can raise its lead over competitors. However, CNOOC Ltd. has a track record of success in the exploration, independent development, and expansion of its petroleum and natural gas supply base, both independently and through PSCs. In recent years, the company has increased its revenue and production mainly due to these achievements. On the development front, the company's

[62] Production sharing contracts are contract signed between a government and a resource extraction company (or group of companies) concerning how much of the resource (usually oil) extracted from the country each will receive.

main new development projects have gone ahead without a hitch, with no less than eleven new projects planned for the Chinese offshore.

The company's remarkable success is also due to a top team of senior managers with extensive knowledge in that sector, thanks in part to their close work with international partners, both from a domestic perspective and outside China.

From the standpoint of business ethics and sustainability, CNOOC Ltd. has also achieved important milestones through its adopted high standards and transparency. In 2020, the Company was honored as "Most Honored Company," "Best ESG (Oil & Gas)," "Best IR Programs," and "Best CFO" in Institutional Investor's 2020 All-Asia Executive Team Awards. Moreover, it achieved the "Gold Award" in The Asset's 2020 ESG Corporate Awards, the "2020 China Securities Golden Bauhinia Awards - Best Listed Company," the "Best CEO for Listed Companies" award, the "Best CFO for Listed Companies" award, the "Best Investor Relations Company" award and the "Asia's Best CEO (Investor Relations)," and "Asia's Best CFO (Investor Relations)" in the Asian Excellence Awards (see CNOOC Ltd. Annual Report, 2021).

Business Strategy

The following are the main components of CNOOC Ltd.'s strategy:

- concentrate on reserve and production expansion
- maintain a sound financial strategy
- expand the natural gas industry.

It aims to enhance reserves and production through exploration and development as well as value-driven acquisitions as an upstream firm focusing on the exploration, development, production, and sales of oil and natural gas. In China, the company will continue to focus on autonomous exploration efforts in key operational areas while collaborating with partners through production sharing contracts to reduce capital expenditures and exploration risks. Overseas, the corporation is working to acquire more high-quality exploration blocks while increasing their efficiency.

The company has set up targets as an essential part of its corporate culture to decrease carbon emissions in order to be more sustainable and in line with international guidance, proceeding at the same time with the expansion of the natural gas business. On the latter point, CNOOC Ltd. continues to find solutions for the development of the natural gas market, strengthen exploration and field development activities, and enhance supply capacity.

However, a key factor in the company's strategy is to maintain a prudent financial policy, reducing costs through increased cost awareness by all employees and taking advantage of technological innovation and management innovation (see CNOOC Ltd. Annual Report, 2021).

3.2 COMPANY RISKS

CNOOC Ltd. is exposed to various types of risk that can impinge on its performance by cutting earnings and creating damages from an asset, financial and economic point of view. For each of the risks, the company should implement containment/coverage measures in order to manage the risks in the best possible way. Although this last chapter will focus on the company's risk to crude oil price exposure, the major risks to which the company is exposed will be described below in order to provide a more delineated picture (see CNOOC Ltd. Annual Report, 2021):

The Company and its main shareholder, CNOOC, have been added to the US Government's list of Chinese firms having claimed ties to the Chinese military. Trading in the Company's securities may be impacted. The US President signed Executive Order 13959 on November 12, 2020, titled "Addressing the Threat from Securities Investments that Finance Communist Chinese Military Companies" (as amended on January 13, 2021, “E.O. 13959”). Transactions, including purchases and sales of publicly traded securities, or securities that are designed to provide investment exposure to such

securities ("Covered Securities"), of the company by any United States citizen, permanent resident alien, entity organized under the laws of the United States or any jurisdiction within the United States (including foreign branches), or any person in the United States ("U.S. pecuniary interests"), are prohibited under E.O. 13959. The prohibition took effect for the Company on March 9, 2021, subject to specified divestiture and other exemptions. Considering E.O. 13959 and updated guidance provided by OFAC[63]in General License 1A and frequently asked questions 879 issued on 27 January 2021, the New York Stock Exchange Regulation determined to initiate proceedings to delist the company's ADSs[64] on the basis that the company is no longer suitable for listing pursuant to NYSE Listed Company Manual Section 802.01D. On March 9, 2021, the NYSE ceased trading in the company's ADSs. The company submitted a formal request for a review of the delisting finding with the NYSE, but there is no guarantee that the company's request for a review will be granted. Because the company has been added to such lists and trading in the Covered Securities is prohibited under E.O. 13959, U.S. persons may sell the Covered Securities, causing market price fluctuations in its ADSs listed on the New York Stock Exchange and the Toronto Stock Exchange, its ordinary shares and debt securities listed on the Hong Kong Stock Exchange, and any other publicly traded securities and derivatives. Its business partners may reconsider doing business with CNOOC Ltd. in this situation.

The company's business, cash flows, and profits fluctuate with the volatility of oil and gas prices. Crude oil, natural gas, and petroleum product prices widely fluctuate in reaction to relative shifts in crude oil and natural gas supply and demand, market unpredictability, and various other factors beyond its control. These include political instability, armed conflicts and acts of terrorism, economic conditions and actions of major oil-producing countries, prices and accessibility of other energy sources, domestic and foreign government regulations, natural disasters, weather conditions, and major health emergencies (e.g., the outbreak of new coronavirus COVID-19 in 2020). Oil and gas prices are volatile and a long-term downward trend in oil and gas prices could damage the company's revenues and profits, as well as result in the diminishment of reserves and higher costs for some activities, a reduction in the amount of oil and natural gas the company is able to produce profitably, and the termination of existing contracts

[63] The Office of Foreign Assets Control is a financial intelligence and enforcement agency of the U.S. Treasury Department. It administers and enforces economic and trade sanctions in support of U.S. national security and foreign policy objectives
[64] An American depositary share (ADS) is an equity share of a non-U.S. company that is held by a U.S. depositary bank and is available for purchase by U.S. investors. The entire issuance of shares by a foreign company is called an American Depositary Receipt (ADR), while the individual shares are referred to as ADSs.

that have become unprofitable. The continued decline in oil and gas prices could have also an impact on the company's long-term investment strategy and the operational capacity of its projects.

Complex macroeconomic conditions, political instability, war and terrorism, as well as changes in regulations, legislation, and fiscal and tax regimes, may have a significant impact on CNOOC Ltd.'s operations and strategy.

The political and economic situation in the world is complicated and precarious, with some of the nations in which the company operates in a politically and economically unstable landscape. As a result, linked international activities, domestic civil unrest and general strikes, political instability, war and acts of terrorism might have a negative impact on the firm's financial status and operating results. Changes in regime or societal instability, political, economic, and diplomatic developments, as well as changes in policies, regulations, budgets, and tax regimes, are outside the solid control of the firm under analysis. These developments, as well as trade and economic penalties resulting from worsening relations among different nations, may substantially and adversely damage CNOOC Ltd. activities, current assets, and future investments.

The company's operations in China may be impacted by China's ongoing oil and gas system reform.

The Opinions on Several Matters Concerning Promoting Reform of Mineral Resources Administration issued by China's Ministry of Natural Resources Management at the end of 2019, posed challenges for the company in obtaining and maintaining business in the oil and gas fields in the future. The foregoing laws and regulations, as well as China's ongoing oil and gas reform, may have an influence on the company's current business model.

The tax and fiscal systems of the host countries in which it operates have an impact on its financial performance, and any changes to these regimes might result in higher costs for the company, including an increase in relevant tax rates in some cases. In addition, the Organization for Economic Cooperation and Development (OECD) launched the "Base Erosion and Profit Shifting Project" (BEPS Project) to improve international cooperation and tighten oversight of worldwide corporate taxes and transfer pricing operations. Several nations have quickly implemented tax legislation modifications and amended tax treaties in response to the BEPS Project.

Oil and gas sector is very competitive.

CNOOC Ltd. competes with national major integrated oil and gas companies and various other independent oil and gas companies for access to oil and gas resources, products, alternative energy, customers, capital financing, technology and equipment, talent, and business opportunities in the People's Republic of China and other countries where CNOOC Ltd. operates. Competition might result in a scarcity of these resources which would raise firm costs and lower revenues, significantly damaging the company's business, financial health, and operating performance.

Besides competition, CNOOC Ltd. may face unfavourable outcomes, such as project delays and cost overruns, because of the need to obtain various approvals from governmental and other regulatory authorities to maintain its operations. This could further hinder the implementation of the strategy and have a negative impact on the company's financial condition.

Simultaneously, environmental protection oversight in the energy industry is getting stricter. The setting of emission reduction requirements, strict adherence to the renewable energy allocation plan, the imposition of high carbon taxes and the passing of stringent regulations have promoted a worldwide shift towards clean and low-carbon energy. Green and low-carbon transformations could lead to increased competition in the energy supply sector, significantly raising CNOOC Ltd.'s costs.

Growing worries about climate change may result in new regulatory measures that raise expenses.

As corporate output rises, CO2 emissions are likely to rise, because without a developed and dependable gas collecting infrastructure, CO2 emissions from combustion will continue to grow. Carbon emission laws from many nations have been established one after another as the Paris Agreement[65] takes effect and public awareness of climate change concerns soars. In the future, CNOOC Ltd. intends to be supervised by relevant agencies and organizations and may incur increased expenses and see its reputation damaged if it is unable to identify economically feasible and publicly accepted methods to minimize carbon emissions from new and ongoing projects.

[65] The Paris Agreement, often referred to as the Paris Accords or the Paris Climate Accords, is an international treaty on climate change, adopted in 2015. It covers climate change mitigation, adaptation, and finance. The Agreement was negotiated by 196 parties at the 2015 United Nations Climate Change Conference near Paris, France.

Mergers, acquisitions and divestitures may expose the company to new risks and uncertainties and may not allow it to obtain the expected benefits from these transactions.

Mergers and acquisitions can fail for a variety of reasons, including problems in integrating activities and generating synergies, the achievement of results different from those assumed, reactions or responses of the host government different from expectations, or miscalculations of liabilities and costs. Any of these factors would limit the company's ability to reap the expected benefits, and the inability to sell non-core assets at acceptable prices would further strain cash reserves. In the event of asset sales, CNOOC Ltd. could be held liable for prior actions, omissions of actions or failures to perform, as well as be subject to liabilities if the buyer fails to meet its obligations. These dangers could result in increased expenses and the failure to meet business objectives.

Given the geographic expanse, operational diversity, and technological complexity of the company's activities, CNOOC Ltd. and the communities in which it works are exposed to a wide range of health, safety, and environmental threats.

Some of its oil and gas activities take place in ecologically sensitive or politically risky locations, such as Iraq or Nigeria, or operate offshore, particularly in new deep-water areas such as Mexico. This exposes the company to a number of risks, including serious process safety incidents, natural disasters, social unrest, health and safety failures, as well as the potential consequences of unpredictable external disruptions, such as typhoons, sea ice and other external forces that can damage the platform structure and cause oil spills and gas leaks. If a serious HSSE[66] risk materializes, such as an explosion or a hydrocarbon leak, it might result in fatalities, environmental damage, economic interruption, and a material impact on the company's reputation, as well as exclusion from bids and eventual loss of license to operate. The HSSE regulatory regimes in the host countries where CNOOC Ltd. operates are continually evolving and may grow more restrictive in the future. Indeed, considerable additional expenditures might arise in order to comply with such standards or to avoid liabilities such as fines, penalties, remediation costs, and third-party claims if HSSE rules and regulations are broken.

[66] Health, Safety, Security and Environment (HSSE)

Anti-corruption, anti-fraud, anti-money laundering, and corporate governance rules violations might put CNOOC Ltd. in danger.

Anti-corruption, anti-fraud, anti-money laundering, and corporate governance laws in the host countries or regions in which it operates are constantly evolving and becoming more stricter, particularly in the United States, in the United Kingdom, in the European Union, in Canada, in Australia, in Guyana, and in China. Costs may rise as a result of complying with certain rules and regulations. If the company, its directors, officers, or employees violate these laws and regulations, they risk being prosecuted or punished, damage to the company's reputation and image, as well as CNOOC Ltd.'s ability to obtain new resources and/or access capital markets, potentially exposing the company to civil or criminal liability.

Any failure to replace reserves and develop proven undeveloped reserves might have a negative impact on the company's operations and finances.

Exploration and development activities come with inherent risks, such as the possibility that commercially productive oil or gas fields will not be discovered, or that wells drilled will not be able to start producing or will not be productive enough to generate a return on the company's partial or total investment. The company's future performance is dependent on its ability to exploit these reserves in a timely and cost-effective manner, while also considering the risks involved in doing so, which include construction, operational, geophysical, geological, and regulatory hazards. The dependability of reserve estimations depends on several factors, including the quality and quantity of technical and economic data, market prices of oil and gas products, production dynamics of oil basins, in-depth engineering assessments, general judgment of engineers, and the tax and fiscal regimes of countries where CNOOC Ltd. has operations or assets.

The development of or access to relevant technologies, as well as their effective use, can have a detrimental impact on strategy implementation, competitiveness, and the ability to do business.

In a competitive climate and in exploration and development issues, technology and innovation are essential to the company's competitiveness. For example, in the development of unconventional oil and gas resources such as heavy oil, oil sands, shale oil and coalbed methane, CNOOC Ltd. seeks to rely on technology and innovations to implement the strategy and improve competitiveness and operational

capability. Inadequate core technology could adversely affect the company's reserves, production plans, and cost control objectives.

CNOOC, the Company's controlling shareholder, has the potential to have an influence on the company since CNOOC Ltd. often does business with CNOOC and its affiliates.

CNOOC owns roughly 65.01 percent of CNOOC Ltd.'s shares, both directly and indirectly. As a result, CNOOC may have an influence on board member elections, dividend payments, and other actions. CNOOC has the unique authority to enter into PSCs with foreign businesses for the exploitation of petroleum resources offshore China under existing PRC regulations. Despite CNOOC's commitment to transfer all of its rights and obligations (except those related to administrative functions as a state-owned company) under any new PSCs entered into to CNOOC Ltd. (with certain exceptions), CNOOC Ltd.'s strategies, results of operations, and financial position could be harmed if CNOOC takes actions that favor its interests over those of CNOOC Ltd. Furthermore, the corporation participates in related transactions with CNOOC and its affiliates on a regular basis. Some related transactions are required to approval by independent shareholders and must be reviewed by the Hong Kong Stock Exchange. If these transactions are not allowed, the firm may be unable to complete them as planned, which might have a negative impact on its business and financial situation.

Oil and natural gas transportation may expose CNOOC Ltd. to financial loss and reputational harm.

Capsizing, collision, acts of piracy, damage or loss from extreme weather conditions, explosions, and oil and gas spills and leaks are all risks associated with oil and gas transportation. These risks might lead to large property and equipment damage, environmental contamination, financial loss, and reputational impact. Uninsured losses and liabilities originating from these hazards may restrict the funds available to CNOOC Ltd. for financing, exploration, and investment, which could have a substantial detrimental effect on its business, financial condition, and results of operations.

CNOOC Ltd. faces several hazards in its operations and business in Canada.

Canada's transport and export infrastructure is limited and reaching full oil and gas production capacity could be jeopardized unless additional infrastructure is built. In addition, the company could be forced to sell its products at lower prices in North American markets than in other (international) markets,

which would seriously affect its financial results. In addition, in a large area of western Canada, First Nations have rights to Aboriginal territory, including claims to mineral resources; consequently, the company must engage with First Nations (including surface activities necessary for extraction) before taking future steps. If negotiations with the relevant First Nations are unsuccessful, subsequent development operations may be delayed or postponed.

CNOOC Ltd. has limited control over its joint venture investments and operations with partners. Some activities are carried out as joint ventures or partnerships, with the corporation having little influence and control over the operation or its future development. This limited capacity to influence and control the operation of such joint ventures might have a considerable and negative impact on the achievement of target returns on capital investments and result in unforeseen future expenditures.

Heavy reliance on key customers or suppliers might harm the company's operations, profits, and financial health.

Main customers for sales: if one of the company's key clients drastically reduces crude oil or natural gas purchases, the company's performance may suffer. To maintain consistent collaboration with clients and avoid dependency on a single customer, measures in crude oil sales include verifying the yearly sales plan and participating in market competition. In terms of natural gas sales, precautions have been made, such as negotiating long-term gas supply contracts with a take-or-pay provision[67] to reduce the risk of financial effect. Key suppliers: to preserve a solid working relationship, the company has improved contact with important suppliers, including developing strategic alliances through communication and mutually beneficial collaboration. CNOOC Ltd. also aggressively seeks for new suppliers to assure adequate supply and foster competition.

CNOOC Ltd. is exposed to currency and liquidity issues.

Currency concerns: the company's oil and gas revenues are largely in Renminbi and US dollars. The Renminbi's appreciation versus the US dollar might have two consequences. The company's income from oil and gas sales may be reduced if the dollar depreciates against the Renminbi, but the expenses of importing equipment and raw materials may be reduced.

[67] An agreement to buy something, especially gas and oil, in which the buyer must pay a charge even if they later decide they do not want it.

Liquidity Risks: some dividend distribution limits imposed by the legislation of the host nations in which the firm operates can have a major negative impact on the company's cash flows. Dividends from fully owned subsidiaries in the PRC, for example, must be given in accordance with PRC rules and bylaws, and there is a danger of not receiving sufficient cash flows from such companies.

3.3 HOW MUCH COULD CNOOC LTD. HAVE SAVED WITH OPTIONS?

Following a general description of the company under analysis and the risks to which it is exposed that are potentially threatening to its financial health, the following paragraphs will consider one of the major risks among the totality: the risk of changes in crude oil prices.

CNOOC Ltd. is a large international producer of crude oil and natural gas, but the production and sale of crude oil is its largest business activity, both in terms of quantities produced and in terms of revenues and reserves. For this reason, this paper will focus on the crude oil activity of CNOOC Ltd. and will

implement a counterfactual analysis[68] to see how a potential hedging strategy could have been efficient in covering losses from monthly price declines over the five-year period 2017 - 2021.

An important feature to emphasize is that CNOOC Ltd., in the reporting period (2017 - 2021), as disclosed in the various annual reports, never implemented hedging strategies to offset the commodity price risk, and in particular the risk of crude oil price fluctuations. In contexts where oil prices were low, the company in question concentrated on reducing costs and improving efficiency, without ever considering that a hedge would have allowed saving much more liquidity than the savings obtained by reducing the expenses or by changing some operational characteristics.

In order to demonstrate how efficient hedging would have been and how much money the company would have saved, a hedging strategy of entering in each month into long put options with an expiration close to the end of each month for the entire reporting period is considered.

Review. A long[69] put option is a contract that grants the company the right to sell the underlying asset at a specified price (strike price) at a certain future moment. The buyer of this derivative has to pay a premium to the seller, since such options provide the right and not the obligation to be executed and this benefit is counterbalanced by the payment of the premium. If the price of the underlying asset S_t is lower than the strike price K, i.e., S_t < K, the buyer exercises the option and sells the underlying asset at a price (K) higher than the current market value of the underlying asset (S_t), thus making a positive profit (net of costs). If S_t > K, the buyer of the long-put option will not exercise his right and his payoff will be 0. Written into the formula: Max (K - S_t,0).

The following section will provide all the essential and more specific information about the hedging strategy under analysis, the various steps performed, the estimates made, the data considered and the mathematical procedure for the various calculations performed.

[68] Is a backward analysis in the past that considers one or more aspects that didn't happen, with the aim of understanding how one or more variables would have changed if those events had occurred. In this context, the analysis is to check how much CNOOC Ltd. would have saved if it had adopted a certain hedging strategy (which didn't effectively happen) against falling prices.

[69] Long put options are targeted because they are the ones that allow the buyer to hedge against a price drop. In the case of short put options, the market participant will only gain the premium from the sale of the options, but is at the same time exposed to the risk of loss if the spot price of the underlying asset is below the strike price. (See Chapter 1, Section "1.2.1 options" for additional information).

3.3.1 METHODOLOGY AND DATA

As hinted in the previous paragraph, the hedging approach consists of purchasing put options in each month, which expire towards the end of the same month in which they were purchased (on the same date as the crude oil is sold), renewing this strategy for the following month of the year. The long put options are purchased on the first business day of each month and expire three business days before the last trading day of the underlying futures, which occurs on the last business day of the second month preceding the contract month. For example: to hedge the production month of January, the company will purchase the put options at the beginning of January with expiration towards the end of the month, on the same date on which production is sold. The options will have as its underlying the March futures, since these futures will expire on the last business day of January and the option will expire three business days before the futures last trading day.

Thus, the scope of the hedging strategy is to benefit from the payoffs generated by the options when prices fall below the strike price, thereby reducing company losses and realizing a higher price per barrel than they would have achieved in the absence of hedging. The methodology performed is based on several considerations that will be highlighted below.

Brent Crude Oil Spot Price: CNOOC Ltd. refers to the Brent Crude Oil[70] spot price to determine the selling price of each individual barrel of its crude oil production. As a result, the company is exposed to the risk that falls in the price of Brent crude oil could undermine earnings, causing the "efficiency ratio"[71], i.e., the ratio of costs to earnings from sales, to fall. A very unpleasant development for a company. However, given the presence of various benchmarks for Brent Crude Oil spot price and considering that the company under analysis doesn't disclose any official information about the one considered for its production price, for the purposes of this analysis, the Brent Forties Oseberg Crude Oil (BFO) is assumed to be the benchmark for the production prices. Its data were downloaded from Bloomberg (security name: EUCRBRDT Index). The BFO represents spot market prices for crude oil originating in the NorthSea and Northwest Europe locations of: Brent, Forties and Oseberg. Hence, it is clear that a hedging strategy based on the use of long puts should allow the oil producer to hedge the risk of price fluctuations of the Brent Forties Oseberg Crude Oil spot price.

[70] Is one of the major crude oil benchmarks. See Chapter 2, paragraph "2.1.3 The price of Crude Oil".

[71] The efficiency ratio represents the ratio between the total expenses and revenues, and it tells how much costs the company is supporting to obtain one dollar of revenues.

CNOOC Ltd. Crude Oil Production: for the purpose of the analysis elaborated in this chapter, only the production of crude oil in China by CNOOC Ltd. was considered, bypassing Overseas production. The choice is justified by the fact that the price of oil produced in China is based on Brent crude oil as a benchmark, while for Overseas production the company refers to Brent, Dubai, Oman and WTI crude oil prices, making the analysis on hedging cumbersome and complex. In addition, oil production in China represents the prevailing amount of total oil produced by CNOOC Ltd. The author of this work analyses the quarterly reports of the company and considers the total barrels produced for each quarter. Then, to obtain the number of barrels for each month, the total production of each quarter is divided into the three months according to specific percentages. The quantity produced for each month is an approximation since the actual data are not available. In addition, the day on which crude oil is sold by the company is settled three working days before the last business day of the month and coincides with the expiration date of the options used (see Options section below).

Data are expressed in Bbl.

MONTH	DAY OF SALE	QUANTITY	QUARTERLY PRODUCTION
Jan 2021	26/01/21	11.355.015,00	
Feb 2021	23/02/21	15.140.020,00	75.700.100,00
Mar 2021	26/03/21	49.205.065,00	
Apr 2021	27/04/21	22.295.119,00	
May 2021	25/05/21	25.480.136,00	63.700.340,00
Jun 2021	25/06/21	15.925.085,00	
Jul 2021	27/07/21	27.930.035,00	
Aug 2021	25/08/21	39.900.050,00	79.800.100,00
Sept 2021	27/09/21	19.950.025,00	
Oct 2021	26/10/21	27.466.933,50	
Nov 2021	25/11/21	41.200.400,25	91.556.445,00
Dec 2021	23/12/21	22.889.111,25	
Jan 2020	28/01/20	17.575.027,50	
Feb 2020	27/02/20	21.090.033,00	70.300.110,00
Mar 2020	26/03/20	31.635.049,50	
Apr 2020	27/07/20	27.640.080,00	
May 2020	26/05/20	13.820.040,00	69.100.200,00
Jun 2020	25/06/20	27.640.080,00	
Jul 2020	28/07/20	14.080.020,00	
Aug 2020	25/08/20	24.640.035,00	70.400.100,00
Sept 2020	25/09/20	31.680.045,00	
Oct 2020	27/10/20	25.867.980,60	
Nov 2020	25/11/20	18.477.129,00	73.908.516,00
Dec 2020	23/12/20	29.563.406,40	
Jan 2019	28/01/19	36.025.000,00	
Feb 2019	25/02/19	13.100.000,00	65.500.000,00
Mar 2019	26/03/19	16.375.000,00	
Apr 2019	25/04/19	19.050.000,00	
May 2019	28/05/19	15.875.000,00	63.500.000,00
Jun 2019	25/06/19	28.575.000,00	
Jul 2019	26/07/19	19.650.909,00	
Aug 2019	27/08/19	16.375.757,50	65.503.030,00
Sept 2019	25/09/19	29.476.363,50	
Oct 2019	28/10/19	24.781.071,00	
Nov 2019	26/11/19	17.700.765,00	70.803.060,00
Dec 2019	23/12/19	28.321.224,00	
Jan 2018	26/01/18	16.375.027,50	
Feb 2018	23/02/18	26.200.044,00	65.500.110,00
Mar 2018	26/03/18	22.925.038,50	
Apr 2018	25/04/18	22.050.010,50	
May 2018	28/05/18	25.200.012,00	63.000.030,00
Jun 2018	26/06/18	15.750.007,50	
Jul 2018	26/07/18	12.260.026,00	
Aug 2018	28/08/18	27.585.058,50	61.300.130,00
Sept 2018	25/09/18	21.455.045,50	
Oct 2018	26/10/18	27.063.328,00	
Nov 2018	27/11/18	23.680.412,00	67.658.320,00
Dec 2018	21/12/18	16.914.580,00	
Jan 2017	26/01/17	25.050.075,00	
Feb 2017	23/02/17	20.040.060,00	67.700.115,00
Mar 2017	28/03/17	55.110.165,00	
Apr 2017	25/04/17	26.520.040,00	
May 2017	26/05/17	23.868.036,00	66.300.100,00
Jun 2017	27/06/17	15.912.024,00	
Jul 2017	26/07/17	15.675.030,00	
Aug 2017	28/08/17	18.810.036,00	62.700.120,00
Sept 2017	26/09/17	28.215.054,00	
Oct 2017	26/10/17	24.535.296,00	
Nov 2017	27/11/17	21.468.384,00	61.338.240,00
Dec 2017	21/12/17	15.334.560,00	

Figure 41. Source: personal elaboration on Excel

Underlying of the options, ICE Brent Futures: the options available on the market to hedge the fluctuations of crude oil prices have as underlying futures contracts. Options with ICE Brent Futures as underlying were chosen for the hedging strategy pursued in this work. The ICE Brent Crude futures contract is a deliverable contract based on EFP (exchange of futures for physicals) delivery with an option to cash settle. The contract size is 1,000 barrels. Trading shall cease at the end of the designated settlement period on the last business day of the second month preceding the relevant contract month (e.g., the March contract month will expire on the last business day of January). If the day on which trading is due to cease would be either: (i) the business day preceding Christmas day, or (ii) the business day preceding New Year's Day, then trading shall cease on the next preceding business day. All prices of each underlying ICE Brent Futures for the period 2017 - 2021 are downloaded from Bloomberg and processed on Excel.

It is essential to note that futures prices on the expiration day converge to spot prices to avoid arbitrage situations, and since the options used expire three business days before the expiration of the underlying futures, option payoffs are calculated with a futures price very close to the spot price. However, the futures contracts underlying the options used (ICE Brent Futures) converge to a spot price different from the BFO used as a benchmark for the price of the crude oil sold, but whose difference can be defined as negligible given a high level of correlation (0.9988). Below is the scatter plot between the Crude Oil Brent Forties Oseberg spot prices and ICE Brent Futures prices at expiration:

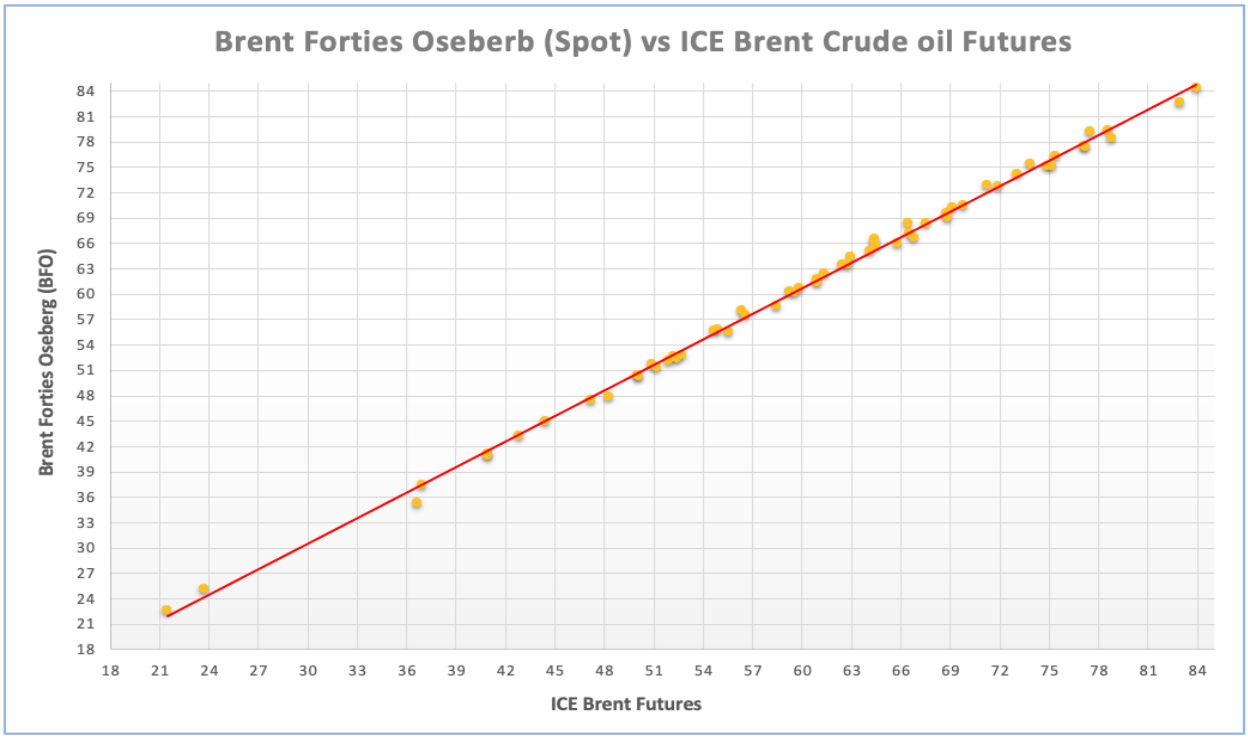


Figure 42. Source: personal elaboration on Excel

Each point represents the relationship between the two variables placed on the y-axis and x-axis respectively. As shown in the graph, the swarm of points has a positive upward trend, demonstrating that as one variable increases, the other also increases. This is explained by the high correlation linking BFO prices with ICE Brent Futures prices.

Options: the put options used are American style, i.e., they can be exercised at any time prior to and on the expiration date, and their other main characteristics are outlined below:

- contract size: 1.000 barrels
- trading shall cease at the end of the designated settlement period of the ICE Brent Crude Futures contract three business days before the scheduled cessation of trading for the relevant contract month of the ICE Brent Crude Futures contract
- unit of trading: any multiple of 1.000 barrels
- minimum price fluctuation[72]: one cent ($0,01) per barrel
- ICE Clear Europe acts as the central counterparty for trades conducted on ICE Futures Europe and ICE OTC. This enables it to guarantee the financial performance of every contract registered with it by its members (the clearing members of the Exchange) up to and including delivery, exercise and/or settlement (see ICE official website).

All the needed option prices for the period 2017 - 2021 have been downloaded from Bloomberg. Nevertheless, all put options at the time the company enters the position are at-the-money. The ATM strike price is the closest value to the previous business day's settlement price of the underlying contract. Since each position in long puts is opened on the first day of each month, for the ATM strike price is considered the settlement price of the ICE Brent Future on the last business day of the month preceding the month in which the long puts are entered.

Furthermore, the hedging strategy established by the author of this paper, wants to consider the exercisability of options only on the day they expire and not at any time before expiry. This would mean considering European options instead of American ones, but since the options with underlying ICE Brent Futures are exclusively American, an adjustment was made to the American options price to obtain the equivalent European options. This adjustment was made by subtracting from the American options price

[72] Minimum price fluctuation is the smallest increment of price movement possible in trading a given contract, this can also be referred to as a tick

the early exercise premium, which is the additional price of the American options to compensate for the fact that they can be exercised at any time before expiry. The early exercise premium for each option was calculated using a Bloomberg analysis tool and the data have been downloaded and processed in Excel. Consequently, to determine the number of options CNOOC Ltd. would have to purchase in any given month to hedge against possible price decreases for that month, the monthly production of barrels of crude oil was taken and divided by 1000 (representing the option's contract size). The result was approximated down to the nearest whole number, thus preventing 100% efficient hedging. Below are the option data for each of the years considered:

2021 OPTIONS DATA

Hedging	Underlying Futures	Futures Pr.**	Previous last month business day	Option expirations	Strike Price	Option Pr.	EEP*	Equivalent European Option Pr.
January 2021	March 2021	$51,3400	30/12/20	26/01/21	$51,2500	$1,8500	$0,0036	$1,8464
February 2021	April 2021	$55,8800	29/01/21	23/02/21	$56,0000	$1,6800	$0,0015	$1,6785
March 2021	May 2021	$66,1300	26/02/21	26/03/21	$66,0000	$1,7000	$0,0017	$1,6983
April 2021	June 2021	$63,5400	31/03/21	27/04/21	$63,5000	$1,8300	$0,0055	$1,8245
May 2021	July 2021	$67,2500	30/04/21	25/05/21	$67,2500	$2,1100	$0,0076	$2,1024
June 2021	August 2021	$69,6300	28/05/21	25/06/21	$69,5000	$1,8300	$0,0125	$1,8175
July 2021	September 2021	$75,1300	30/06/21	27/07/21	$75,0000	$1,9700	$0,0030	$1,9670
August 2021	October 2021	$76,3300	30/07/21	25/08/21	$76,2500	$2,0100	$0,0220	$1,9880
September 2021	November 2021	$72,9900	31/08/21	27/09/21	$73,0000	$2,9100	$0,0171	$2,8929
October 2021	December 2021	$78,5200	30/09/21	26/10/21	$78,5000	$2,3400	$0,0146	$2,3254
November 2021	Jannuary 2022	$84,3800	29/10/21	25/11/21	$84,2500	$1,9800	$0,0015	$1,9785
December 2021	February 2022	$70,5700	30/11/21	23/12/21	$70,5000	$5,0600	$0,0330	$5,0270

*. EEP = Early Exercise premium

**. Future Prices refer to the price of the Futures expiring on the previous last month business day. It is the price used for determine the At-the-Money strike price of the option

Figure 43. Source: personal elaboration on Excel

2020 OPTIONS DATA

Hedging	Underlying Futures	Futures Pr.**	Previous last month business day	Option expirations	Strike Price	Option Pr.	EEP*	Equivalent European option prices
January 2020	March 2020	$68,4400	30/12/19	28/01/20	$68,5000	$3,0200	$0,0127	$3,0073
February 2020	April 2020	$58,1600	31/01/20	27/02/20	$58,0000	$3,0700	$0,0043	$3,0657
March 2020	May 2020	$50,5200	28/02/20	26/03/20	$50,5000	$1,8900	$0,0087	$1,8813
April 2020	June 2020	$22,7400	31/03/20	27/04/20	$22,7500	$2,0800	$0,0056	$2,0744
May 2020	July 2020	$25,2700	30/04/20	26/05/20	$25,2500	$2,3800	$0,0044	$2,3756
June 2020	August 2020	$35,3300	29/05/20	25/06/20	$35,2500	$1,1800	$0,0013	$1,1787
July 2020	September 2020	$41,1500	30/06/20	28/07/20	$41,2500	$1,8000	$0,0062	$1,7938
August 2020	October 2020	$43,3000	31/07/20	25/08/20	$43,2500	$1,1900	$0,0025	$1,1875
September 2020	November 2020	$45,0500	02/08/20	25/09/20	$45,0000	$0,9900	$0,0108	$0,9792
October 2020	December 2020	$40,9500	30/09/20	27/10/20	$41,0000	$1,2400	$0,0026	$1,2374
November 2020	Jannuary 2021	$37,4600	30/10/20	25/11/20	$37,5000	$1,7900	$0,0060	$1,7840
December 2020	February 2021	$47,5900	30/11/20	23/12/20	$47,5000	$1,9900	$0,0073	$1,9827

*. EEP = Early Exercise premium

**. Future Prices refer to the price of the Futures expiring on the previous last month business day. It is the price used for determine the At-the-Money strike price of the option

2019 OPTIONS DATA

Hedging	Underlying Futures	Futures Pr.**	Previous last month business day	Option expirations	Strike Price	Option Pr.	EEP*	Equivalent European option prices
January 2019	March 2019	$52,2000	28/12/18	28/01/19	$52,2500	$1,1200	$0,0104	$1,1096
February 2019	April 2019	$61,8900	31/01/19	25/02/19	$62,0000	$1,5300	$0,0049	$1,5251
March 2019	May 2019	$66,0300	28/02/19	26/03/19	$66,0000	$1,1300	$0,0023	$1,1277
April 2019	June 2019	$68,3900	29/03/19	25/04/19	$69,0000	$1,6700	$0,0028	$1,6672
May 2019	July 2019	$72,8000	30/04/19	28/05/19	$72,7500	$1,0200	$0,0105	$1,0095
June 2019	August 2019	$64,4900	31/05/19	25/06/19	$64,5000	$1,9900	$0,0036	$1,9864
July 2019	September 2019	$66,5500	28/06/19	26/07/19	$66,5000	$3,0000	$0,0059	$2,9941
August 2019	October 2019	$65,1700	31/07/19	27/08/19	$65,2500	$1,4500	$0,0113	$1,4387
September 2019	November 2019	$60,4300	30/08/19	25/09/19	$60,5000	$1,7800	$0,0032	$1,7768
October 2019	December 2019	$60,7800	28/09/19	28/10/19	$60,7500	$1,0100	$0,0060	$1,0040
November 2019	Jannuary 2020	$60,2300	31/10/19	26/11/19	$60,0000	$1,2200	$0,0065	$1,2135
December 2019	February 2020	$62,4300	29/11/19	23/12/19	$62,5000	$2,1800	$0,0024	$2,1776

*. EEP = Early Exercise premium

**. Future Prices refer to the price of the Futures expiring on the previous last month business day. It is the price used for determine the At-the-Money strike price of the option

Figures 44 and 45. Source: personal elaboration on Excel

2018 OPTIONS DATA

Hedging	Underlying Futures	Futures Pr.**	Previous last month business day	Option expirations	Strike Price	Option Pr.	EEP*	Equivalent European option prices
January 2018	March 2018	$66,7200	29/12/17	26/01/18	$66,7500	$1,3600	$0,0088	$1,3512
February 2018	April 2018	$69,0500	31/01/18	23/02/18	$69,0000	$0,9600	$0,0028	$0,9572
March 2018	May 2018	$65,7800	28/02/01	26/03/18	$65,7500	$2,1800	$0,0204	$2,1596
April 2018	June 2018	$70,2700	30/03/18	25/04/18	$70,2500	$2,5600	$0,0168	$2,5432
May 2018	July 2018	$75,1700	30/04/18	28/05/18	$75,2500	$3,0100	$0,0238	$2,9862
June 2018	August 2018	$77,5900	31/05/18	26/06/18	$77,5000	$2,4800	$0,0142	$2,4658
July 2018	September 2018	$79,4400	29/06/18	26/07/18	$79,5000	$3,4700	$0,0135	$3,4565
August 2018	October 2018	$74,2500	31/07/18	28/08/18	$74,2500	$3,0600	$0,0065	$3,0535
September 2018	November 2018	$77,4200	31/08/18	25/09/18	$77,5000	$1,5400	$0,0059	$1,5341
October 2018	December 2018	$82,7200	28/09/18	26/10/18	$82,7500	$1,4300	$0,0048	$1,4252
November 2018	Jannuary 2019	$75,4700	31/10/18	27/11/18	$75,5000	$3,7300	$0,0136	$3,7164
December 2018	February 2019	$58,7100	30/11/18	21/12/18	$58,7500	$1,6100	$0,0077	$1,6023

*. EEP = Early Exercise premium

**. Future Prices refer to the price of the Futures expiring on the previous last month business day. It is the price used for determine the At-the-Money strike price of the option

2017 OPTIONS DATA

Hedging	Underlying Futures	Futures Pr.**	Previous last month business day	Option expirations	Strike Price	Option Pr.	EEP*	Equivalent European option prices
January 2017	March 2017	$60,1000	29/12/16	26/01/17	$60,0000	$1,5400	$0,0059	$1,5341
February 2017	April 2017	$55,7000	31/01/17	23/02/17	$55,7500	$1,2100	$0,0056	$1,2044
March 2017	May 2017	$55,5900	28/02/17	28/03/17	$55,5000	$1,5700	$0,0062	$1,5638
April 2017	June 2017	$52,8300	31/03/17	25/04/17	$52,7500	$0,8100	$0,0036	$0,8064
May 2017	July 2017	$51,7300	28/04/17	26/05/17	$51,7500	$0,8800	$0,0041	$0,8759
June 2017	August 2017	$50,3100	31/05/17	27/06/17	$50,2500	$1,2100	$0,0020	$1,2080
July 2017	September 2017	$47,9200	30/06/17	26/07/17	$48,0000	$0,5700	$0,0018	$0,5682
August 2017	October 2017	$52,6500	31/07/17	28/08/17	$52,5000	$1,1100	$0,0024	$1,1076
September 2017	November 2017	$52,3800	31/08/17	26/09/17	$52,2500	$1,2600	$0,0066	$1,2534
October 2017	December 2017	$57,5400	30/09/17	26/10/17	$57,5000	$2,0100	$0,0111	$1,9989
November 2017	Jannuary 2018	$61,3700	31/10/17	27/11/17	$61,2500	$1,7700	$0,0069	$1,7631
December 2017	February 2018	$63,5700	30/11/17	21/12/17	$63,5000	$1,1400	$0,0058	$1,1342

*. EEP = Early Exercise premium

**. Future Prices refer to the price of the Futures expiring on the previous last month business day. It is the price used for determine the At-the-Money strike price of the option

Figures 46 and 47. Source: personal elaboration on Excel

3.3.2 CALCULATIONS

This section shows the calculations performed for the hedging strategy. The utility of the hedging strategy was calculated by developing the calculations in various steps:

- the revenues that the company would realize each month by selling its products at the spot price (BFO) were calculated.

- the numbers of put option contracts required to hedge CNOOC Ltd.'s exposure to price fluctuations were calculated. This number was calculated by dividing the number of barrels of crude oil sold by the company in the month by the contract size of a single derivative contract. The resulting values were rounded down to the nearest whole number.

- the profit for each option was calculated by considering the prices of the underlying ICE Brent Futures on the expiration date of the option. When the futures prices are lower than the strike price, the profit is calculated as [(K - S_t) x contract size (1,000 bbl.) x n° contracts – the cost of the strategy (option price x contract size x n° contracts)]. If the prices of the underlying futures are higher than the strike price, the options are not exercised, and the profit is equal to: - option price x contract size x n°contracts.

- the hedge ratio for each individual option was calculated as the hedged position divided by the total monthly production. The values are close to 1, which represents a 100% hedge, but they differ slightly due to the standardization of the options used, which creates a mismatch between the production that CNOOC Ltd. would need to hedge and the amount that can be hedged through options.

- total revenues were calculated by incorporating the revenues from the monthly crude oil production sold at the BFO spot price plus the profits of the options used.

- the price per barrel realized considering the impact of the hedging strategy was calculated as the total revenues (previous point) divided by the number of barrels of crude oil sold each month.

The calculations processed in Excel are reported in the tables below:

2021 HEDGING

Hedging Months	Spot Pr. (BFO)	Crude oil Bbl.	Revenues	Option expirations	N° Contracts*	Strike Price	Option Pr.	S_t^{**}	Option Profits	Hedge Ratio	Tot. Revenues	Bbl. Price Realized
January 2021	$54,85	11.355.015,00	$622.822.572,75	26/01/21	11355	$51,25	$1,8464	$55,91	-$20.965.872,00	0,9999987	$601.856.700,75	$53,00
February 2021	$64,43	15.140.020,00	$975.471.488,60	23/02/21	15140	$56,00	$1,6785	$65,37	-$25.412.490,00	0,9999987	$950.058.998,60	$62,75
March 2021	$62,41	49.205.065,00	$3.070.888.106,65	26/03/21	49205	$66,00	$1,6983	$64,57	-$13.201.701,50	0,9999987	$3.057.686.405,15	$62,14
April 2021	$66,53	22.295.119,00	$1.483.294.267,07	27/04/21	22295	$63,50	$1,8245	$66,42	-$40.677.227,50	0,9999947	$1.442.617.039,57	$64,71
May 2021	$68,73	25.480.136,00	$1.751.249.747,28	25/05/21	25480	$67,25	$2,1024	$68,65	-$53.569.152,00	0,9999947	$1.697.680.595,28	$66,63
June 2021	$75,12	15.925.085,00	$1.196.292.385,20	25/06/21	15925	$69,50	$1,8175	$76,18	-$28.943.687,50	0,9999947	$1.167.348.697,70	$73,30
July 2021	$75,38	27.930.035,00	$2.105.366.038,30	27/07/21	27930	$75,00	$1,9670	$74,48	-$40.414.710,00	0,9999987	$2.064.951.328,30	$73,93
August 2021	$71,24	39.900.050,00	$2.842.479.562,00	25/08/21	39900	$76,25	$1,9880	$72,25	$80.278.800,00	0,9999987	$2.922.758.362,00	$73,25
September 2021	$78,77	19.950.025,00	$1.571.463.469,25	27/09/21	19950	$73,00	$2,8929	$79,53	-$57.713.355,00	0,9999987	$1.513.750.114,25	$75,88
October 2021	$83,92	27.466.933,50	$2.305.025.059,32	26/10/21	27467	$78,50	$2,3254	$86,40	-$63.871.761,80	1,0000024	$2.241.153.297,52	$81,59
November 2021	$69,75	41.200.400,25	$2.873.727.917,44	25/11/21	41200	$84,25	$1,9785	$74,35	$326.365.388,00	0,9999903	$3.200.093.305,44	$77,67
December 2021	$78,62	22.889.111,25	$1.799.541.926,48	23/12/21	22889	$70,50	$5,0270	$76,85	-$115.063.003,00	0,9999951	$1.684.478.923,48	$73,59

**. It refers to to the number of long put contracts needed to hedge the postion. It is computed as "Crude oil Bbl. / 1000" and each number is rounded down to the nearest whole

**. It is price of the underlying ICE Brent Futures when the options expipire

2020 HEDGING

Hedging Months	Spot Pr. (BFO)	Crude oil Bbl.	Revenues	Option expirations	N° Contracts*	Strike Price	Option Pr.	S_t^{**}	Option Profits	Hedge Ratio	Tot. Revenues	Bbl. Price Realized
January 2020	$56,33	17.575.027,50	$990.001.299,08	28/01/20	17575	$68,50	$3,0073	$59,51	$105.145.952,50	0,9999984	$1.095.147.251,58	$62,31
February 2020	$50,02	21.090.033,00	$1.054.923.450,66	27/02/20	21090	$58,00	$3,0657	$52,18	$58.088.187,00	0,9999984	$1.113.011.637,66	$52,77
March 2020	$21,47	31.635.049,50	$679.204.512,77	26/03/20	31635	$50,50	$1,8813	$26,34	$704.786.674,50	0,9999984	$1.383.991.187,27	$43,75
April 2020	$23,70	27.640.080,00	$655.069.896,00	27/04/20	27640	$22,75	$2,0744	$19,99	$18.949.984,00	0,9999971	$674.019.880,00	$24,39
May 2020	$36,63	13.820.040,00	$506.228.065,20	26/05/20	13820	$25,25	$2,3756	$36,17	-$32.830.792,00	0,9999971	$473.397.273,20	$34,25
June 2020	$40,89	27.640.080,00	$1.130.202.871,20	25/06/20	27640	$35,25	$1,1787	$41,05	-$32.579.268,00	0,9999971	$1.097.623.603,20	$39,71
July 2020	$42,81	14.080.020,00	$602.765.656,20	28/07/20	14080	$41,25	$1,7938	$43,22	-$25.256.704,00	0,9999986	$577.508.952,20	$41,02
August 2020	$44,39	24.640.035,00	$1.093.771.153,65	25/08/20	24640	$43,25	$1,1875	$45,86	-$29.260.000,00	0,9999986	$1.064.511.153,65	$43,20
September 2020	$40,95	31.680.045,00	$1.297.297.842,75	25/09/20	31680	$45,00	$0,9792	$41,92	$66.553.344,00	0,9999986	$1.363.851.186,75	$43,05
October 2020	$36,90	25.867.980,60	$954.528.484,14	27/10/20	25867	$41,00	$1,2374	$34,23	$143.111.764,20	0,9999621	$1.097.640.248,34	$42,43
November 2020	$47,17	18.477.129,00	$871.566.174,93	25/11/20	18477	$37,50	$1,7840	$48,61	-$32.962.968,00	0,9999930	$838.603.206,93	$45,39
December 2020	$51,17	29.563.406,40	$1.512.759.505,49	23/12/20	29563	$47,50	$1,9827	$51,20	-$58.614.560,10	0,9999863	$1.454.144.945,39	$49,19

**. It refers to to the number of long put contracts needed to hedge the postion. It is computed as "Crude oil Bbl. / 1000" and each number is rounded down to the nearest whole

**. It is price of the underlying ICE Brent Futures when the options expipire

Figures 48 and 49. Source: personal elaboration on Excel

2019 HEDGING

Hedging Months	Spot Pr. (BFO)	Crude oil Bbl.	Revenues	Option expirations	N° Contracts*	Strike Price	Option Pr.	S_t^{**}	Option Profits	Hedge Ratio	Tot. Revenues	Bbl. Price Realized
January 2019	$60,91	36.025.000,00	$2.194.282.750,00	28/01/19	36025	$52,25	$1,1096	$58,10	-$39.973.340,00	1,0000000	$2.154.309.410,00	$59,80
February 2019	$65,79	13.100.000,00	$861.849.000,00	25/02/19	13100	$62,00	$1,5251	$64,76	-$19.978.810,00	1,0000000	$841.870.190,00	$64,26
March 2019	$67,51	16.375.000,00	$1.105.476.250,00	26/03/19	16375	$66,00	$1,1277	$67,97	-$18.466.087,50	1,0000000	$1.087.010.162,50	$66,38
April 2019	$71,85	19.050.000,00	$1.368.742.500,00	25/04/19	19050	$69,00	$1,6672	$74,35	-$31.760.160,00	1,0000000	$1.336.982.340,00	$70,18
May 2019	$62,93	15.875.000,00	$999.013.750,00	28/05/19	15875	$72,75	$1,0095	$66,45	$83.986.687,50	1,0000000	$1.083.000.437,50	$68,22
June 2019	$64,43	28.575.000,00	$1.841.087.250,00	25/06/19	28575	$64,50	$1,9864	$62,40	$3.246.120,00	1,0000000	$1.844.333.370,00	$64,54
July 2019	$64,13	19.650.909,00	$1.260.212.794,17	26/07/19	19650	$66,50	$2,9941	$63,46	$901.935,00	0,9999537	$1.261.114.729,17	$64,18
August 2019	$59,20	16.375.757,50	$969.444.844,00	27/08/19	16375	$65,25	$1,4387	$59,51	$70.433.787,50	0,9999537	$1.039.878.631,50	$63,50
September 2019	$59,85	29.476.363,50	$1.764.160.355,48	25/09/19	29476	$60,50	$1,7768	$60,21	-$43.824.916,80	0,9999877	$1.720.335.438,68	$58,36
October 2019	$59,55	24.781.071,00	$1.475.712.778,05	28/10/19	24781	$60,75	$1,0040	$59,78	-$842.554,00	0,9999971	$1.474.870.224,05	$59,52
November 2019	$61,34	17.700.765,00	$1.085.764.925,10	26/11/19	17770	$60,00	$1,2135	$64,27	-$21.563.895,00	1,0039114	$1.064.201.030,10	$60,12
December 2019	$66,42	28.321.224,00	$1.881.095.698,08	23/12/19	28321	$62,50	$2,1776	$66,39	-$61.671.809,60	0,9999921	$1.819.423.888,48	$64,24

**. It refers to to the number of long put contracts needed to hedge the postion. It is computed as "Crude oil Bbl. / 1000" and each number is rounded down to the nearest whole

**. It is price of the underlying ICE Brent Futures when the options exipire

2018 HEDGING

Hedging Months	Spot Pr. (BFO)	Crude oil Bbl.	Revenues	Option expirations	N° Contracts*	Strike Price	Option Pr.	S_t^{**}	Option Profits	Hedge Ratio	Tot. Revenues	Bbl. Price Realized
January 2018	$68,83	16.375.027,50	$1.127.093.142,83	26/01/18	16375	$66,75	$1,3512	$70,52	-$22.125.900,00	0,9999983	$1.104.967.242,83	$67,48
February 2018	$64,46	26.200.044,00	$1.688.854.836,24	23/02/18	26200	$69,00	$0,9572	$64,55	$91.511.360,00	0,9999983	$1.780.366.196,24	$67,95
March 2018	$69,13	22.925.038,50	$1.584.807.911,51	26/03/18	22925	$65,75	$2,1596	$70,12	-$49.508.830,00	0,9999983	$1.535.299.081,51	$66,97
April 2018	$74,87	22.050.010,50	$1.650.884.286,14	25/04/18	22050	$70,25	$2,5432	$74,00	-$56.077.560,00	0,9999995	$1.594.806.726,14	$72,33
May 2018	$77,13	25.200.012,00	$1.943.676.925,56	28/05/18	25200	$75,25	$2,9862	$75,30	-$75.252.240,00	0,9999995	$1.868.424.685,56	$74,14
June 2018	$78,60	15.750.007,50	$1.237.950.589,50	26/06/18	15750	$77,50	$2,4658	$76,31	-$20.093.850,00	0,9999995	$1.217.856.739,50	$77,32
July 2018	$73,07	12.260.026,00	$895.840.099,82	26/07/18	12260	$79,50	$3,4565	$74,54	$18.432.910,00	0,9999979	$914.273.009,82	$74,57
August 2018	$77,15	27.585.058,50	$2.128.187.263,28	28/08/18	27585	$74,25	$3,0535	$75,95	-$84.230.797,50	0,9999979	$2.043.956.465,78	$74,10
September 2018	$82,95	21.455.045,50	$1.779.696.024,23	25/09/18	21455	$77,50	$1,5341	$81,87	-$32.914.115,50	0,9999979	$1.746.781.908,73	$81,42
October 2018	$73,86	27.063.328,00	$1.998.897.406,08	26/10/18	27063	$82,75	$1,4252	$77,62	$100.263.002,40	0,9999879	$2.099.160.408,48	$77,56
November 2018	$58,44	23.680.412,00	$1.383.883.277,28	27/11/18	23680	$75,50	$3,7164	$60,21	$274.062.848,00	0,9999826	$1.657.946.125,28	$70,01
December 2018	$51,89	16.914.580,00	$877.697.556,20	21/12/18	16914	$58,75	$1,6023	$53,82	$56.284.717,80	0,9999657	$933.982.274,00	$55,22

*. It refers to to the number of long put contracts needed to hedge the postion. It is computed as "Crude oil Bbl. / 1000" and each number is rounded down to the nearest whole

**. It is price of the underlying ICE Brent Futures when the options exipire

Figures 50 and 51. Source: personal elaboration on Excel

2017 HEDGING

Hedging Months	Spot Pr. (BFO)	Crude oil Bbl.	Revenues	Option expirations	N° Contracts*	Strike Price	Option Pr.	S_t^{**}	Option Profits	Hedge Ratio	Tot. Revenues	Bbl. Price Realized
January 2017	$54,68	25.050.075,00	$1.369.738.101,00	26/01/17	25050	$60,00	$1,5341	$56,24	$55.758.795,00	0,9999970	$1.425.496.896,00	$56,91
February 2017	$55,56	20.040.060,00	$1.113.425.733,60	23/02/17	20040	$55,75	$1,2044	$56,58	-$24.136.176,00	0,9999970	$1.089.289.557,60	$54,36
March 2017	$52,71	55.110.165,00	$2.904.856.797,15	28/03/17	55110	$55,50	$1,5638	$51,33	$143.627.682,00	0,9999970	$3.048.484.479,15	$55,32
April 2017	$50,88	26.520.040,00	$1.349.339.635,20	25/04/17	26520	$52,75	$0,8064	$50,89	$27.941.472,00	0,9999985	$1.377.281.107,20	$51,93
May 2017	$50,08	23.868.036,00	$1.195.311.242,88	26/05/17	23868	$51,75	$0,8759	$50,85	$575.218,80	0,9999985	$1.195.886.461,68	$50,10
June 2017	$48,23	15.912.024,00	$767.436.917,52	27/06/17	15912	$50,25	$1,2080	$46,65	$38.061.504,00	0,9999985	$805.498.421,52	$50,62
July 2017	$52,17	15.675.030,00	$817.766.315,10	26/07/17	15675	$48,00	$0,5682	$51,49	-$8.906.535,00	0,9999981	$808.859.780,10	$51,60
August 2017	$52,41	18.810.036,00	$985.833.986,76	28/08/17	18810	$52,50	$1,1076	$51,89	-$9.359.856,00	0,9999981	$976.474.130,76	$51,91
September 2017	$56,53	28.215.054,00	$1.594.997.002,62	26/09/17	28215	$52,25	$1,2534	$57,44	-$35.364.681,00	0,9999981	$1.559.632.321,62	$55,28
October 2017	$60,94	24.535.296,00	$1.495.180.938,24	26/10/17	24535	$57,50	$1,9989	$59,30	-$49.043.011,50	0,9999879	$1.446.137.926,74	$58,94
November 2017	$62,78	21.468.384,00	$1.347.785.147,52	27/11/17	21468	$61,25	$1,7631	$63,84	-$37.850.230,80	0,9999821	$1.309.934.916,72	$61,02
December 2017	$66,82	15.334.560,00	$1.024.655.299,20	21/12/17	15334	$63,50	$1,1342	$64,90	-$17.391.822,80	0,9999635	$1.007.263.476,40	$65,69

**. It refers to to the number of long put contracts needed to hedge the postion. It is computed as "Crude oil Bbl. / 1000" and each number is rounded down to the nearest whole

**. It is price of the underlying ICE Brent Futures when the options exipire

Figure 52. Source: personal elaboration on Excel

3.3.3 RESULTS

In this section of the paper, the outcomes of the hedging strategy performed for CNOOC Ltd. will be analyzed, with the intention of ascertaining whether the hedging program would have allowed the company to limit its losses when black gold prices decreased over the course of the months.

Since options are purchased with a strike price as close as possible to the price of the underlying futures on the business day prior to the day on which the positions are entered, and since the futures price converges to the spot price[73] which has a high correlation with the BFO, the month-to-month differences in the BFO are considered to check for up and down movements in the crude prices.

In some cases, a hedging strategy may become self-defeating if options are unexercised and the cost for such derivatives significantly reduces the possible gains from increases in crude oil prices. This should be considered when assessing the effectiveness of hedging.

The results for the reference years are reported below.

2021 HEDGING RESULTS

Previous Months	Bbl. Price (BFO)	Months	Bbl. Price (BFO)	Bbl. Price Realized	Amount Saved ***
December 2020	$51,17	January 2021	$54,85	$53,00	-$20.965.872,00
January 2021	$54,85	February 2021	$64,43	$62,75	-$25.412.490,00
February 2021	$64,43	March 2021	$62,41	$62,14	-$13.201.701,50
March 2021	$62,41	April 2021	$66,53	$64,71	-$40.677.227,50
April 2021	$66,53	May 2021	$68,73	$66,63	-$53.569.152,00
May 2021	$68,73	June 2021	$75,12	$73,30	-$28.943.687,50
June 2021	$75,12	July 2021	$75,38	$73,93	-$40.414.710,00
July 2021	$75,38	August 2021	$71,24	$73,25	$80.278.800,00
August 2021	$71,24	September 2021	$78,77	$75,88	-$57.713.355,00
September 2021	$78,77	October 2021	$83,92	$81,59	-$63.871.761,80
October 2021	$83,92	November 2021	$69,75	$77,67	$326.365.388,00
November 2021	$69,75	December 2021	$78,62	$73,59	-$115.063.003,00
TOTAL					-$53.188.772,30

***. The negative values represents the amount the company has lost due to the options costs.

Figure 53. Source: personal elaboration on Excel

In 2021 CNOOC Ltd. would have lost an amount of - $53.188.722,30 if it had implemented a hedging strategy using long put options in each month. This negative result is due to the market conditions experienced and the cost of the strategy, in fact in 2021 the positive monthly variations in oil prices were

[73] Options are purchased on the first day of each month, so the first business day before that date corresponds to the last business day of the previous month. This means that the price taken as a reference for the strike price is the price of the underlying futures on the last working day of the previous month. At expiration, the futures price converges to the spot.

more numerous than the decreases, causing the majority of the options to remain unexercised. This means that the company would have borne the cost of the strategy which would have limited the potential gains from the price increases, leading to a lower realized price per barrel than it would have achieved by selling the monthly production at the occurred spot prices.

Looking at the results, the months in which BFO spot prices decreased compared to the previous month were March 2021, August 2021 and November 2021, while in the other months the monthly changes in BFO spot prices were positive. In the months when prices decreased, the hedging strategy would have been functional, allowing the company to realize a higher price per barrel than the spot price at which it would have sold its production. For example, in the month of November 2021, the BFO spot price was $69.75, but using puts CNOOC Ltd. would have realized a price per barrel of $77.67. In March 2021 the spot price decreased with respect to the previous month, and despite the use of long puts, the realized price would have been $62.14, lower than the BFO spot price ($62.41). This is due to the small difference between the strike price and the price of the underlying futures at the time the option would have been exercised, which would have generated a payoff lower than the cost of the put options, generating a negative profit of -$13,201,701.50.

2020 HEDGING RESULTS

Previous Months	Bbl. Price (BFO)	Months	Bbl. Price (BFO)	Bbl. Price Realized	Amount Saved***
December 2019	$66,42	January 2020	$56,33	$62,31	$105.145.952,50
January 2020	$56,33	February 2020	$50,02	$52,77	$58.088.187,00
February 2020	$50,02	March 2020	$21,47	$43,75	$704.786.674,50
March 2020	$21,47	April 2020	$23,70	$24,39	$18.949.984,00
April 2020	$23,70	May 2020	$36,63	$34,25	-$32.830.792,00
May 2020	$36,63	June 2020	$40,89	$39,71	-$32.579.268,00
June 2020	$40,89	July 2020	$42,81	$41,02	-$25.256.704,00
July 2020	$42,81	August 2020	$44,39	$43,20	-$29.260.000,00
August 2020	$44,39	September 2020	$40,95	$43,05	$66.553.344,00
September 2020	$40,95	October 2020	$36,90	$42,43	$143.111.764,20
October 2020	$36,90	November 2020	$47,17	$45,39	-$32.962.968,00
November 2020	$47,17	December 2020	$51,17	$49,19	-$58.614.560,10
TOTAL					$885.131.614,10

***. The negative values represents the amount the company has lost due to the options costs.

Figure 54. Source: personal elaboration on Excel

In 2020 CNOOC Ltd. would have saved an amount of $885,131,614.10. This significant amount is because the monthly decreases in BFO spot prices were more than in the year 2021, allowing the company to benefit from the available puts by saving money. In addition, in 2020, due to the spread of

the Covid-19 virus and the resulting production restrictions and lockdowns imposed by various governments, the price of Brent Forties Oseberg oil fell to a low of $21.47 per barrel in March 2020. If the company under analysis would have used long puts to hedge against such risks, it would undoubtedly have avoided the dramatic impact caused by Covid-19 on its revenues. In fact, for example, by hedging in March 2020 when the BFO spot price was $21.47, the company would have been able to realize a price per barrel of $43.75, with $704,786,674 saved only in that month.

In October 2020, the hedging results are also significant, with a BFO spot price of $36.90 and the price the company would have been able to realize of $42.43, with $143,111,764.20 saved.

In some of the other months, the company wouldn't have benefited from the potential spot price increases due to the cost of the strategy used, causing the prices per barrel it would have realized to be lower than the spot prices. This results in a monetary amount lost, indicated with a minus sign under "Amount Saved".

2019 HEDGING RESULTS

Previous Months	Bbl. Price (BFO)	Months	Bbl. Price (BFO)	Bbl. Price Realized	Amount Saved***
December 2018	$51,89	January 2019	$60,91	$59,80	-$39.973.340,00
January 2019	$60,91	February 2019	$65,79	$64,26	-$19.978.810,00
February 2019	$65,79	March 2019	$67,51	$66,38	-$18.466.087,50
March 2019	$67,51	April 2019	$71,85	$70,18	-$31.760.160,00
April 2019	$71,85	May 2019	$62,93	$68,22	$83.986.687,50
May 2019	$62,93	June 2019	$64,43	$64,54	$3.246.120,00
June 2019	$64,43	July 2019	$64,13	$64,18	$901.935,00
July 2019	$64,13	August 2019	$59,20	$63,50	$70.433.787,50
August 2019	$59,20	September 2019	$59,85	$58,36	-$43.824.916,80
September 2019	$59,85	October 2019	$59,55	$59,52	-$842.554,00
October 2019	$59,55	November 2019	$61,34	$60,12	-$21.563.895,00
November 2019	$61,34	December 2019	$66,42	$64,24	-$61.671.809,60
TOTAL					-$79.513.042,90

***. The negative values represents the amount the company has lost due to the options costs.

Figure 55. Source: personal elaboration on Excel

In 2019, the hedging strategy would have generated a lost profit of -$79,513,042.90. This was due to monthly BFO price increases that would have left many of the options used unexercised, since the strike prices would have been lower than the underlying futures prices (S_t) at the expiration time of the options. However, the use of put options would have been functional in the months where BFO prices declined. Indeed, in May 2019, the spot price fell from $71.85 at the end of April 2019 to $62.93, with a percentage

decrease of - 12.41%. But thanks to the profit from the options the company would have bought, the price that would have been realized would have been $68.22, with a saving of $83,986,687.50. In July 2019, the percentage change in the BFO was relatively low (-0.465%), but the utilization of the hedge would have provided CNOOC Ltd. with a saving of $901,935. In the month of August 2019, the saving would have been $70,433,787.50, since the put options would have been exercised by the company being in-the-money, enabling CNOOC Ltd. to offset the decrease in the spot price from $64.13 in July 2019 to $59.20 in August of the same year.

In the other months of the year, the hedging strategy would not have saved the company any money, as spot prices between one month and the other grew; on the contrary, it would have eroded the possible gains the company could have made from price increases due to derivative costs. This is reflected in the negative values shown in the table above.

2018 HEDGING RESULTS

Previous Months	Bbl. Price (BFO)	Months	Bbl. Price (BFO)	Bbl. Price Realized	Amount Saved***
December 2017	$66,82	January 2018	$68,83	$67,48	-$22.125.900,00
January 2018	$68,83	February 2018	$64,46	$67,95	$91.511.360,00
February 2018	$64,46	March 2018	$69,13	$66,97	-$49.508.830,00
March 2018	$69,13	April 2018	$74,87	$72,33	-$56.077.560,00
April 2018	$74,87	May 2018	$77,13	$74,14	-$75.252.240,00
May 2018	$77,13	June 2018	$78,60	$77,32	-$20.093.850,00
June 2018	$78,60	July 2018	$73,07	$74,57	$18.432.910,00
July 2018	$73,07	August 2018	$77,15	$74,10	-$84.230.797,50
August 2018	$77,15	September 2018	$82,95	$81,42	-$32.914.115,50
September 2018	$82,95	October 2018	$73,86	$77,56	$100.263.002,40
October 2018	$73,86	November 2018	$58,44	$70,01	$274.062.848,00
November 2018	$58,44	December 2018	$51,89	$55,22	$56.284.717,80
TOTAL					$200.351.545,20

***. The negative values represents the amount the company has lost due to the options costs.

Figure 56. Source: personal elaboration on Excel

The hedging strategy in 2018 would have generated savings of $200,351,545,20. This is reflected in the effectiveness of hedging in February 2018, July 2018, October 2018, November 2018 and December 2018. In these months, the BFO spot price fell from the previous month, meaning that the options used would be in-the-money, producing a positive profit for the company that would have counterbalanced the detrimental impacts of the unfavourable price trend.

In May 2018, the BFO spot price has risen from a value of $74.87 in April 2018 to $77.13, but due to the expensive cost of the put options ($2.9862), the price CNOOC Ltd. would have realized, would have been $74.14, resulting in a loss of - $75,252,240.

In January 2018, March 2018, April 2018, June 2018, and September 2018, the usage of put options would have been dysfunctional due to the positive monthly variations in BFO prices that the company would have positively benefited from in absence of hedging.

2017 HEDGING RESULTS

Previous Months	$	Months	Bbl. Price (BFO)	Bbl. Price Realized	Amount Saved***
December 2016	$60,32	January 2017	$54,68	$56,91	$55.758.795,00
January 2017	$54,68	February 2017	$55,56	$54,36	-$24.136.176,00
February 2017	$55,56	March 2017	$52,71	$55,32	$143.627.682,00
March 2017	$52,71	April 2017	$50,88	$51,93	$27.941.472,00
April 2017	$50,88	May 2017	$50,08	$50,10	$575.218,80
May 2017	$50,08	June 2017	$48,23	$50,62	$38.061.504,00
June 2017	$48,23	July 2017	$52,17	$51,60	-$8.906.535,00
July 2017	$52,17	August 2017	$52,41	$51,91	-$9.359.856,00
August 2017	$52,41	September 2017	$56,53	$55,28	-$35.364.681,00
September 2017	$56,53	October 2017	$60,94	$58,94	-$49.043.011,50
October 2017	$60,94	November 2017	$62,78	$61,02	-$37.850.230,80
November 2017	$62,78	December 2017	$66,82	$65,69	-$17.391.822,80
TOTAL					$83.912.358,70

***. The negative values represents the amount the company has lost due to the options costs.

Figure 57. Source: personal elaboration on Excel

During the year 2017, CNOOC Ltd. reportedly saved $83,912,358,70 by planning to hedge on declines in crude prices.

In January 2017, the spot price went from $60.32 to $54.68, but with the use of derivatives the company would have realized a price of $56.91, cashing in a compensatory profit of $55,758,795. In the following months of March 2017, April 2017, May 2017, and June 2017, the monthly changes in BFO spot prices were negative, causing the firm to offset these losses with gains from the put options in its portfolio. The gains saved would have been specifically $143,627,682 in March 2017, $27,941,472 in April 2017, $575,218.80 in May 2017, and $38,061,504 in June 2017.

The second half of the year under analysis saw, contrary to the first half, positive monthly changes in spot prices, leading to the pool of options that CNOOC Ltd. would hold remaining unexercised. The

cost of the strategy would have negatively impacted the company's revenues, as the prices realized through hedging would have been lower than the spot prices occurred.

HEDGING SUMMARY:

TOTAL AMOUNT SAVED IN 2017 -2021	$1.036.693.702,80

Over the 5 years examined in the conducted counterfactual analysis, CNOOC Ltd. would have saved an amount of $1,036,693,702.80 by using put options that would have counteracted the monthly decreases in Brent Forties Oseberg spot prices.

On the other hand, the risk of this hedging methodology is that options have a steep cost as they give the right but not the obligation to the buyer to exercise them, and in instances where crude oil prices rise, the options would be out-the-money. This would entail that the company would have to bear the costs of such derivative instruments, which would adversely affect the revenues that the company would have been able to achieve with increased oil spot prices.

Accounting and Tax considerations: A further remark is to analyze how such derivative contracts are accounted for and what the relative taxation method is. According to what is stated in section 2.2 “Accounting for derivative contracts”, hedging relationships are classified into fair value hedges, cash flow hedges and net investment hedges according to IFRS 9 (accounting standard CNOOC Ltd. complies with). According to the categorization of derivative contracts, the impact on the profit generated by the company is different.

In the analysis performed for CNOOC Ltd., long put options are considered as a method to compensate for decreases in crude oil prices, which could have negatively affected the company’s financial position. In this case, these derivative contracts should be accounted for as cash flow hedges. A cash flow hedge reduces risks arising from future expected cash flows, where the risks are outside the company’s control. Initially gains and losses on the hedging instrument are taken to a reserve through Other Comprehensive Income; this reserve will be released back to the income statement as the hedged item is realized.

For tax purposes, for hedges and for periods beginning after 1 January 2016, movements through Other Comprehensive Income are not considered for tax purposes as they are not recognised in determining profit or loss, at least until they are transferred to become an item of the income statement.

Accordingly, the taxation of a cash flow hedge will normally follow the debits and credits that flow through the income statement, and no adjustments to the accounting items in the income statement are necessary; amounts that flow through OCI can be ignored.

3.4 DISCUSSION

The analysis depicted in this work aims to assess the effectiveness of using derivatives, and in particular options as a way to protect against injurious movements in crude oil prices. Specifically, emphasis is placed on the monetary savings the company would have obtained by hedging its production, in comparison to the revenues generated by the unhedged position.

Despite the abundance of financial breakthroughs throughout the last thirty years, derivatives are without a doubt the most significant financial developments of this time period. Swaps, futures, and options are just a few of the various types of derivatives. In general, these instruments allow for the pre-determination of the price of buying or selling a specific amount of the underlying asset. They're mostly used for hedging, but they can also be utilized to take risky positions, and for this reason, they have been dubbed "wild beast of finance" (see Steinherr, 1998) or "weapons of mass destruction" (Buffet, 2003).

Nevertheless, if derivatives are used for purposes behind speculation, such as hedging, they are arguably beneficial to the company, allowing it to offset the risks to which it is exposed and increase shareholder value. Indeed, in a recent study by Adams and Montesi (1995), it was found that corporate managers are increasingly concerned about downside risk, which can threaten the financial health of the company. Moreover, Petty and Scott (1981) found that many companies identify risk as the probability of falling below a target return. The solution proposed by the implementation of strategies with derivatives seems to offer a more than valid solution to such perplexities.

Commodity producers, such as the corporation considered in this paper's study, experience revenue uncertainty because two major variables are unknown at the moment resources are committed to production: the selling price of production and the volume of oil that will be extracted. In a world with incomplete risk-bearing markets, the producer's options for reducing the impact of these risks are restricted. McKinnon (1967) demonstrated in a groundbreaking work that the link between production and price uncertainty is a significant characteristic of hedging decisions, above all because the producer faces multiple sources of risk, and a single hedging instrument cannot completely eliminate revenue uncertainty. In previous studies, it has been common to regard futures contracts (or forward contracts, when ignoring basis risk) as the only available hedging instrument (see Rolfo 1980, Newbery and Stiglitz 1981 and Anderson and Danthine 1983). However, since perfect hedging is not possible under conditions of production uncertainty, the producer may wish to use additional risk-reducing instruments. Possible

such instruments are options on futures, which became available for most commodities beginning in the mid-1980s and were the tool for analyzing the hedging strategy performed for CNOOC Ltd.

Concerning the last point, this elaboration considered put options with ICE Brent Futures as underlying, which would have allowed the company to generate a profit when spot oil prices (BFO) had fallen. The analysis of the proposed hedging strategy shows a positive result for the company, even though in some sub-periods of the time sample taken as reference, the hedging strategy was not effective due to the expensive price of the options and the increasing trend of oil prices. This implies that the effectiveness of hedging places a large weight on prevailing market conditions, which are difficult to predict. In certain cases, it would be better to not use hedging because of the price increments that an oil-producing company, such as the one analyzed, would benefit from. Since future market conditions are unpredictable, paying a premium to purchase options that would compensate for downward spikes in the price of oil, even though it might be disadvantageous in some cases, is considered worthwhile prevention, but it is needed to assess, through forecast and prediction, whether the overall benefits are greater than costs.

However, the study conducted in chapter three considers various aspects and assumptions that could impact the generalizability of the method under analysis. These limitations as well as the main points for future research will be discussed below.

3.4.1 LIMITATIONS

This section will set out the assumptions and characteristics of the methodology used, which could create constraints on the validity and generalizability of the results achieved.

- First, the hedging strategy using long put options each month was analyzed for CNOOC Ltd. concerning its crude oil production in China. The company is a leading oil and natural gas oil producer, but since this work focused on the analysis of the oil sector, the objective was to consider the operating area related to crude oil production excluding natural gas production. Furthermore, production in China (which accounts for the majority of the totality of production) was considered with the exclusion of Overseas production. The reasons for this decision are inherent in the use of different benchmark spot prices for Overseas crude oil production (see 3.3.1 Methodology and Data, section "CNOOC Ltd. Crude Oil Production"), which would have made the hedging analysis complex and multifaceted, given the need to consider different options in the market that would allow hedging the price fluctuations of the different crude oil spot prices taken as benchmarks. Obviously, these considerations represent limitations to the asymmetric hedging analysis performed for the company in question, as they do not consider the risks associated with Overseas production and natural gas production that represent relevant factors for the revenues generated.

- Another restriction of the study conducted relates to CNOOC Ltd.'s monthly crude oil production, which was estimated by taking into account the number of quarterly quantities disclosed by the company in its quarterly reports, distributed over the individual months according to specific percentages (is an approximation since the number of barrels of crude oil sold in each month was not available). This has to be taken into account when assessing the validity of the study conducted, as in practice the oil production actually sold by the company may differ from that recorded for the study conducted.

- An additional limitation to consider is the assumption about the day on which the company sells the barrels of crude oil. This day was assumed for all months to be the third working day before the end of the month and to coincide with the expirations of the options. This is decisive for the hedging of the revenues generated by oil sales, allowing a time matching between the time when the oil barrels are sold by the company and the time when the options are exercised. However, the day on which

the company sold the oil barrels may differ from the day assumed for the purpose of the analysis, or the sale may be spread over several days during the month. These considerations must be taken into account as they represent a limitation.

- The underlying of the options used are ICE Brent futures contracts that at expiration converge to a different spot price from the company's crude oil benchmark price Brent Forties Oseberg (BFO). The correlation between the two prices is quite high (see Section 3.3.1 Methodology and Data, "Option Underlying, ICE Brent Futures" section), such that this difference is negligible. However, the correlation (0.9988) is not perfect, implying that, even if negligible, the difference between the BFO spot price and the price of the underlying futures at expiration could affect the effectiveness of the hedging strategy. This needs to be considered because mispricing between the price of the underlying used to calculate the option payoffs and the price the entity must hedge is one of the common problems when it comes to options.

- Options that have ICE Brent Futures as their underlying and were used in the performance analysis are American style, meaning they can be exercised at any time before and at expiration. This work set out to consider the exercisability of such options only at the time when production is sold, thus at option's expirations. This takes the form of considering European-style options, but since they are American, this was accomplished by subtracting the early exercise premium from the price of American options. However, this represents an approximation of the European option prices, which in practice may differ and generate divergent hedging results from those obtained.

- In the hedging analysis applied specifically to CNOOC Ltd., at-the-money put options were considered, that is, with a strike price equal to the underlying price at the time the position is entered. Specifically, the strike price of the options used is determined equal to the price of the underlying futures on the last business day of the month prior to the month in which these derivatives are purchased (see 3.3.1 Methodology and Data, section "Options"). It is worth noting that at-the-money options are expensive for the buyer, and their cost impacts the effectiveness of the hedge put in place. The price of these options is lower than in-the-money options, but higher than out-the-money options. In some cases, it may be appropriate to evaluate the choice of options to use as protection

for risk exposure, based on their cost and how the latter might alter the positive results potentially generated by this method. In fact, in some sub-periods of the analysis conducted, even if the options were in-the-money at expirations, their profits were negative since the cost of the options is larger than the positive payoff obtained.

- A limitation of the study performed pertains to the time horizon covered. The counterfactual analysis was performed for 5 years from 2017 to 2021 due to the lack of available option data for years before 2017. A broader time frame would have allowed for checking how the various events that occurred over the other years would have been offset using options, and additionally, would have allowed for a deeper understanding of the limitations and downsides of the implemented strategy.

- A further aspect that deserves consideration concerns the hedge ratio. The hedge ratio represents in percentage terms the amount of the position hedged and is calculated as the hedged position divided by the total position exposed to risk. As can be seen from the hedge tables for the various years, in most subperiods, the hedge ratio deviates from the value of 1. This is because the number of contracts the firm would have to purchase to hedge its position was calculated as the monthly production divided by the contract size (1,000 bbl..), and the result was rounded down to the nearest whole number. Against this, a portion of the firm's position remained uncovered, generating a less-than-perfect hedge ratio.

- Finally, the hedging strategy developed for CNOOC Ltd. did not consider transaction costs, which refer to the charges associated with the execution of a trade. When the options are purchased or sold, the market participants must pay a fee to the broker or bank acting as a financial intermediate. These costs include:

  - commissions paid to brokerage firms, typically paid on a per option basis. These fees pay for the firm's services, such as executing the order.

  - exchange fees, which compensate markets such as the Chicago Board of Trade for operating a robust and reliable marketplace.

  - regulatory fees, such as those charged by the Securities and Exchange Commission.

3.4.2 FUTURE RESEARCH

Following the delineation of the limitations behind the work conducted in the preceding paragraphs, this paper proposes suggestions for future research. Taking the data collected and the chosen methodology as a starting point, future research could extend the validity of the results obtained and consider additional features that have been missing in the research conducted so far.

As outlined in the section on the limitations underlying the hedging approach carried out on CNOOC Ltd., natural gas production and Overseas production were omitted for the purposes of the hedging strategy. Crude oil production in China represents the hedged item and was fundamental for determining the number of derivative contracts to be purchased and how these would offset declines in oil prices in the various months considered. Although crude oil production is the largest source of income for the company, as is production in China compared to Overseas, the exclusion of natural gas production and Overseas production is limiting in terms of savings for the company generated by the options. This constitutes a starting point for future research, which could also investigate hedging tactics regarding natural gas production, trying to ascertain how the company would be able to compensate for price drops of this commodity. Furthermore, identifying the amount CNOOC Ltd. would have saved on foreign production reflects an interesting insight. This would require the consideration of different types of options with underlying various futures contracts depending on the spot price of oil taken as a benchmark by the company (e.g., Brent is the benchmark for production in Europe, while WTI is the benchmark for the price of barrels of oil produced in North America).

In addition, the prices of the American put options underlying the hedging plan were adjusted by subtracting the early exercise premium to obtain the equivalent European options. However, this is an approximation that could raise questions about the effectiveness of hedging, as it would affect the cost of the options and consequently the profit generated. A cue for future analysis is to consider European options on the market that have underlying futures contracts with prices that have a high correlation with the spot price of crude oil used by the company. A high correlation is a prerequisite to avoid mispricing between the spot price of crude oil and the underlying futures prices used to calculate option payoffs. This would make it possible to consider the price of European options without price adjustments and avoid approximations, obtaining more accurate hedging results with more negligible errors. Associated with the last point, the transaction costs and fees that are required for market transactions in the sale or purchase of options were assumed equal to zero in the performed analysis. Future research could include

these costs to test how the cost of the strategy used would have changed and whether it would effectively be worthwhile for CNOCC Ltd. to hedge.

Regarding the generalizability of the results, some key factors and assumptions prevent their external application validity in every case. The strategy applied for CNOOC Ltd. is consistent with the objectives regarding the use of put options to mitigate the risk of oil price declines and this strategy can be implemented by any market participant exposed to falls in the asset prices to which it is exposed. This is not to suggest that in each case the utilization of such derivatives is efficient and that the final result will be as positive as the one obtained for the company in question. Several factors must be considered. In the case where future forecasts are for higher prices, a hedge against falling prices could lead to less than positive results. This is because options have a cost, and this cost limits the potential profits for the firm that would result from price increases. In such cases, it may be better not to hedge. As shown by the 5-year hedging results for CNOOC Ltd., in some years the total "Amount Saved" is negative, reflecting what is highlighted above. Additionally, the analysis was performed for a narrow time frame with certain assumptions about the spot, production, and other variables (see 3.3.1 Methodology and Data) which limits the possibility of deeper analysis. These years also include the impact of the Covid-19 pandemic, which affected the oil price trend, leading to its sharp decline and causing the hedge to generate a much more than positive outcome. Just as for some of the years considered, the total saved is negative and a broader temporal analysis could have generated negative outcomes in several years due to specific market conditions and resulting in a negative total complex outcome. Thus, it should be emphasized that undoubtedly the use of put options would allow mitigation of the risks to which the entity is exposed, but at the same time various company-specific factors under consideration, as well as the prevailing market conditions must be considered to assess whether the choice to hedge was a well-founded decision. In the face of this, what the author wants to suggest for future research is to analyze the characteristics of the entity to figure out which hedging strategy is most suitable and to look at market conditions as well as future forecasts to determine whether it is better to hedge or not to hedge. This could also depend on macroeconomic variables such as interest rates, exchange rates and inflation that can affect the profit of options:

- *interest rates:* with put options an increase in interest rates leads to a depreciation of these options. This is because an investor prefers to short a stock than to buy a put option, as the former guarantees the investor cash which can be invested at higher rates and the put option requires the payment of a premium. Hence, put option prices are impacted negatively by increasing interest

rates. This impacts the profit calculated as “price of sold + option payoff - initial option cost” as it reduces the cost of hedging borne by the company.

- *Exchange rates:* exchange rates are among the macroeconomic variables that could influence the profits intended as “price of sold + option payoff - initial option cost” generated by the put option hedging strategy. The profit is calculated in dollars, since the monetary unit for Brent crude oil spot prices, option prices and the futures underlying the options is the dollar, however, the profit generated must be converted into Chinese currency (the renminbi) since the company is domiciled in China. The USD/CNY[74] exchange rate could affect this conversion. An appreciation of the renminbi would result in an unfavourable conversion, while on the other hand, a depreciation of the Chinese currency would result in a favourable exchange rate.
- *Inflation:* Crude oil is a major economic input, so a rise in oil prices contributes to inflation, which measures the overall rate of price increases across the economy. Higher oil prices contribute to inflation directly and by increasing the cost of inputs. There was a strong correlation between inflation and oil prices. A study by the Federal Reserve Bank of Dallas in September 2021 suggested that if crude oil prices rose to $100 per barrel for three months before retreating, the spike would boost the annual inflation rate by 3 percentage points in the short term, with the effect fading quickly as oil prices pulled back Federal Reserve Bank of Dallas (see Killian, L. and Zhou, X., 2021). In the short term, higher inflation tends to lead to higher oil prices. In the longer term, if the Central Bank raises interest rates and slows economic growth to control inflation, oil prices could decline as a result. The oil producers, during inflation, gain in a short period since the cost of production does not rise as fast as the price of their product and so there is an artificial margin of profit. As against this, they may also be affected adversely in the long run since when inflation rises, the purchasing power of consumers erodes - in simple terms, they can now buy fewer goods and services than they used to. This means the producer will record lower sales, reducing the total revenue of the business. Hence, the impact of the inflations needs to be monitored to assess whether the total profit is reduced or not, both in the short and long term. Furthermore, the crude oil price increases can also affect the option payoffs since the prices of the underlying futures converge to the spot at expiration (this coincides with the moment in

[74] The renminbi is issued by the People's Bank of China, the monetary authority of the People's Republic of China. The official abbreviation of the international standard ISO 4217 is CNY. ISO 4217 is an international standard describing three-letter codes to define currency names, established by the International Organization for Standardization (ISO), which is commonly used in banking and business, as well as in the trade press.

which the options are exercised) and the payoffs could be reduced due to the lower difference between the strike price and the price of the underlying future. The difference might also be negative, implying the options are out-the-money, leading the company to bear the cost of the derivatives under analysis. Moreover, the option premium is another element influenced by inflation, since the increase in the price of oil caused by this macroeconomic variable implies a decrease in the put option prices due to the lower probability of the option being in-the-money.

Given the relationship between profit intended as "sale price + option payoff - initial cost of the option" and the macroeconomic variables outlined above, future research could aim to run a regression on profit to see how much the latter varies as the macroeconomic variables vary. Indeed, regression expresses a relationship between one or more predictor variables (macroeconomic variables) and a dependent variable (profit), thus expressing whether an increase in X (macroeconomic variables) causes an increase or decrease in Y (profit). But regression can define more than just the direction of a relationship; it can indicate the magnitude of the relationship. In this case, profit representing the dependent variable is linked to three dependent variables: interest rate, exchange rates and inflation. The regression equation is: $Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon_i$.

Where:

- i varies between observations, i = 1, 2, 3...n
- X_{1i}, X_{2i}, X_{3i} are the i-th observations of each of the k regressors[75] (inflation, interest rates, and exchange rates)
- Y_i is the i-th value of the dependent variable (profit)
- β_0 is the intercept, thus the expected value of Y when all X are equal to zero
- $\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i}$ is the regression line
- $\beta_1,\ \beta_2\ and\ \beta_3$ represent the regression coefficients[76]
- ε_i is the statistical error[77]

These represent some of the potential future investigations that could be pursued to provide a more in-depth portrayal of the strategy performed, as well as to broaden the generalisability of the results.

[75] Regressor or explanatory variable, in statistics, term for each of the independent variables identified as significant variables to explain a phenomenon in a regression model

[76] Regression coefficient β indicates the "direction" of the relationship: the positive sign indicates a concordance between the variables (an increase in x corresponds to an increase in y), the negative sign a discordance (an increase in x corresponds to a decrease in y).

[77] Represents the average distance that the observed values fall from the regression line. Conveniently, it tells you how wrong the regression model is on average using the units of the response variable.

CONCLUSION

This work began by debating the relevance of risk management at the corporate level, exposing the ever increasing need to utilise hedging techniques to mitigate risks that pose a danger to companies from a financial, economic and capital perspective, especially with a focus on the crude oil sector. These hedges are in most instances implemented with the use of financial derivatives, including options. The latter enables an asymmetric hedge to be executed, since if market scenarios are suitable, the options will be exercised and generate a positive payoff, otherwise, what the investor loses is limited to the cost paid for these financial instruments.

The objective addressed by this research paper is to highlight the efficiency of hedges in offsetting the risks arising from oil price swings by conducting a practical analysis through the company CNOOC Ltd. This company is a premier oil producer and thus vulnerable to drops in crude oil prices that could sharply diminish the amount of revenues. Nevertheless, CNOOC Ltd. has not adopted any hedging strategy with derivatives so far, therefore, this study explored how much this company could have saved by using long put options each month from 2017 to 2021.

The final result is unquestionably positive since CNOOC Ltd. would have generated a saving of $1,036,693,702.80 if it would have used the strategy proposed in Chapter Three. The outcome achieved was largely impacted by the Covid-19 pandemic, which triggered a large price drop in 2020, making the use of long puts extremely efficacious.

This goes to testify that these instruments are very good solutions in counterbalancing risks, although an eye must be kept on their price. Cost can be said to be the other side of the coin as these instruments are expensive. In certain cases, as happened in some months of the time period under consideration, the cost of such options diminishes the benefits that the company would have gained from oil price appreciations. In fact, when options are out-the-money, their payoff is zero and the cost reduces the total revenues (defined as revenues generated by selling at the spot price + options payoff - options cost), causing the realized price to be lower than the spot price.

For these reasons, proper consideration and analysis of future market forecasts, as well as of strengths and weaknesses of the hedge should be performed each time the intention to use derivative hedges, especially with options, is envisaged.

SUMMARY

CHAPTER ONE:

This research thesis aims to highlight how hedging strategies with commodity derivatives are valuable in smoothing the risks associated with commodity price fluctuations. Among the various commodities, the focus is placed on crude oil. The efficiency of a these strategies is analyzed through an experimental application on the company CNOOC Ltd. This work is divided into three chapters.

The first chapter provides a general overview of the most common derivative instruments used in hedging, their main characteristics, how they work, as well as they are priced. These instruments, as well as hedges, fall within the field of risk management, an aspect that is becoming increasingly important as time goes by. In fact, from the perspective of the corporate world, and beyond, risk management has become an increasingly crucial and essential activity to ensure the continuity of the firm and to avoid the fall-out of random phenomena that can seriously threaten a company's financial health. Indeed, risk refers to the probability that an unpredictable future event may occur and causes a detrimental impact on the firm's financial, economic, and capital standpoint. Consequently, the decisions and analyses carried out by risk management managers are crucial for the company and any estimation errors or wrong decisions can be destructive. This explains the increasing focus on risk management and the need to improve the effectiveness of the business divisions that take decisions to prevent and avoid major economic damages, especially following the increased risk in the economic and financial landscape over time which makes companies more vulnerable to random phenomena. However, the risks to which companies are exposed, are categorized in different ways: - internal and external risks; - systematic and diversifiable risks; and - speculative and pure risks; which entail different treatment within the risk management process, as well as different measures to mitigate their potential negative effects on the company. In addition, four different approaches related to the risks listed above are discussed: - the traditional/insurance approach; - the statistical/financial approach; - the managerial approach; and - the mathematical approach. The classification of business risks and different approaches are fundamental to the risk management process, because for each type of risk, the decisions, processes, and tools may be different, as well as the effectiveness of the measures implemented. Furthermore, depending on the risks to be considered and the area in which these risks may emerge, different approaches for risk management may be identified: - enterprise risk management (ERM); - project risk management (PRM); - traditional

risk management (TRM); - financial risk management (FRM); - risk measurement and control (risk control or RC).

Nowadays having risk management that operates in the best possible way and avoids great economic damage to companies has become of paramount importance and a vital element for their survival. But for risk management efforts to be successful, it is essential to have a well-articulated process that comprises: - risk assessment; - risk reporting; - risk treatment; - residual risk assessment and residual risk reporting; and - monitoring. This entire process is carried out to accomplish different objectives, but one of the main ones is the implementation of prevention measures or hedging measures. Concerning the latter, a practice that has developed greatly in recent decades is the use of derivatives (mainly options, futures, forwards, and swaps) due to the efficiency of financial engineering in creating a wide range of OTC and exchange-traded products and due to the needs in offsetting increasing and ever new risks.

As a matter of fact, the last few decades have been characterized by various phenomena that have increased the volatility of financial markets, the risks associated with conducting economic activities, and the possible tragic effects that could occur in the event of a default of large financial intermediaries as happened in 2007/08. In addition, firms are continually exposed to risks associated with changes in the price of the commodities they use during their ordinary business. In light of this, many companies and their risk management departments have begun to use derivative instruments that can generate a hedge against such risks and avoid the large losses that the company might incur. A financial derivative is a financial contract whose value depends on the value of one or more underlying assets, which can be commodities, interest rates, cryptocurrencies, indices, etc. However, derivatives are traded in Over-the-Counter or Exchange-Traded markets. Exchange-Traded markets are markets in which individuals can trade standardized contracts, that is, contracts in which the expiration date, the quantity of the underlying for each contract, the settlement process, and so on are defined. What characterizes these markets is the high level of transparency and the elimination of counterparty default risk due to the presence of the Clearing House.

Over-the-Counter markets are markets in which the parties conduct transactions independently through so-called bilateral agreements, in which the parties stipulate all the terms of the agreement and the conditions under which outstanding transactions can be terminated, how settlement amounts are calculated in the event of termination, and how collaterals (if any) to be provided by each party are calculated. Moreover, the parties involved in a transaction bargain with each other directly by phone and e-mail or through brokers.

The OTC markets were largely unregulated before the 2007/08 crisis, but then, given the negative consequences that emerged, and the economic/financial and social damage generated in the following years, the OTC markets also underwent a process of regulation and the introduction of various legal provisions.

Among the various derivatives traded, as discussed above, the most common are options, futures, forwards, and swaps:

- Options are contracts that guarantee the right to buy/sell the underlying asset at a predetermined price (strike price) on a specific date if European style or on any date before and at expiration if American style. Options, by granting the right and not the obligation to execute the transaction, require a price to be paid, i.e., the option premium. However, common options are call and put. Call options give the right to buy the underlying asset at the strike price at a given time, while put options give the right to sell the underlying asset at the strike price. The payoff for call options is $Max\,(S_t - K, 0)$, while for put options it is $Max\,(K - S_t, 0)$, both in the case of long positions, i.e., buying the options. For short positions, the investor will sell the call options or put options, collecting the premium and committing to buy or sell the underlying asset if the buyer decides to exercise his right.
- Futures contracts are agreements between two parties - the buyer and the seller - who agree to execute a transaction (sell or buy the underlying asset) at a predetermined price at a future date. They differ from options since futures can also generate a negative profit (it is symmetric). In contrast, options generate an asymmetric profit since in case market conditions are not favourable to their exercise, the only loss for the investor is the option premium. Nevertheless, futures contracts can be classified into two main groups:

  - financial futures: contracts based on financial instruments such as interest rates, indices, foreign exchange and others.

  - commodity futures: these are contracts based on commodities such as oil, metals, grain and others.

  In addition, futures are traded exclusively on regulated markets (the Exchanges), where the contract size, underlying, settlement process and units of trading are standardized. The relationships are managed by the Clearing House, which avoids the counterparty risk. Moreover, futures contracts are settled daily using a process called marking-to-market, where the margin account balance is adjusted to reflect daily settlement.

- Forward contracts allow an individual to buy or sell the underlying asset at a specific price and a specified future date. They are very similar to futures contracts but differ from them because forwards are traded on OTC markets, where the contracts are not standardized and the parties can decide on the quantity, collateral, settlement, and so on. The difference between futures and forwards is also characterized by the different ways in which settlement occurs; in forwards is at the expiration of the contract.
- Swaps are derivative contracts through which two parties exchange the cash flows or liabilities of two different financial instruments. The most common are interest rate swaps, in which the parties exchange future cash flows based on interest rates. These agreements establish the dates when payments will be made and how cash flows will be calculated for each of the parties involved in the transaction. Among these types of contracts, the most common are so-called "plain vanilla" swaps, in which one party exchanges cash flows based on LIBOR and the other party exchanges cash flows calculated with a fixed interest rate (called the swap rate) at specific future dates. In addition, interest rate swaps can be used to transform liabilities from a floating rate to fixed-rate and vice versa or to transform cash flows of fixed-rate assets into floating-rate flows.

When it comes to derivatives, a concept of considerable importance is the pricing of these instruments. Regardless of whether one considers the buy or sell side, pricing these instruments is critical to making sound decisions and knowing how profits might be affected.

Various pricing models are referred to for options, including the binomial model and the Black-Scholes-Merton model. The binomial model is based on the concept of a risk-less portfolio, that is, creating a portfolio that must earn the risk-free rate to prevent arbitrage opportunities. Alternatively, the binomial model can be used to calculate the option price using risk-neutral probabilities, which are risk-adjusted probabilities of possible future outcomes. However, one of the limitations of the binomial model concerns the accuracy of the option price. The greater the number of nodes, the greater the accuracy of the result obtained, since security can assume an almost unlimited number of future values. Calculating the value of options in the presence of an infinite number of subperiods may seem a hopeless task. Fortunately, Black and Scholes have derived a formula that does this "work" automatically. The formula for this model is: C = [N (d_1) x S_t] - [N (d_2) x K x $e^{-r\,x\,t}$].

An explanation of how forwards, futures and swaps are priced is also discussed in this work.

CHAPTER TWO

The scope of this research thesis is to study the validity of hedges implemented at the corporate level to counterbalance commodity risks. Among the various commodities, the focus is on the crude oil sector, analyzing the main characteristics, market data, key drivers on price determination, key aspects of crude oil prices and hedging strategies. A focus will also be placed on how derivative contracts are accounted for in financial statements, as well as the new rules introduced by IFRS 9 and ASC 815 on hedging accounting, determining different methods of consideration for these instruments.

Crude oil is part of a macro sector - the energy sector. The energy sector is a market in which the economic actors engage in the production and supply of energy and is of paramount importance since it has and continues to play a leading role in industrial growth and in powering the economy.

Companies in this sector, however, manage not only vast volumes of energy, but also many types; in fact, the main differentiation that emerges is the division into: - renewable energy such as solar energy, wind energy, hydropower, and biofuels such as ethanol; - non-renewable energy including oil and petroleum products, gasoline, natural gas, diesel fuel, and nuclear.

Furthermore, in the energy sector emerges the Oil, Gas & Consumable Fuels Industry which includes companies mainly involved in the production, transport, or processing of raw materials whose principal end goal is energy generation. Three subcategories of operators can be recognized in this industry based on their involvement in the supply chain: - upstream companies are at the top of the supply chain and handle all operational processes from which the production process originates; - midstream companies represent the intermediate stage of the supply chain and manage all the procedures for liquefying resources, transporting them from the extraction site to the refining site via pipelines or tankers and storing the products; - downstream companies deal with the processes of refining oil and regasifying natural gas, as well as distribution and sales. Nevertheless, crude oil represents the main form of energy consumed and accounts for 33% of the totality, followed by coal (27%) and natural gas (24%). Moreover, is important to highlight that the primary energy consumption showed an ever-increasing trend from 2000 to 2020, despite the last year where the Covid-19 has impacted negatively on the consumption level.

A focus must also be placed on other market data trends. The refinery capacity increased from 1965 to 2019, but the growth hasn't been constant for all countries, and while it has remained more or less stable for some countries (e.g., the USA), others such as the Asia Pacific have seen a substantial increase. Proved reserves also increased over time despite the various crises and concerns about the scarcity of oil

fields and the risk of a decrease in supply, with the majority of these reserves coming from the Middle East (48,3%). At the end of 2000 the total amount recorded was 1300,9 million barrels (tmb), while at the beginning of 2020 it was 1,734 tmb. Another meaningful indicator that explains crude oil sector expansion is the Reserves/Production ratio, also known as R/P, which indicates how long (in years) a country's remaining reserves would last if production continued at current levels. This index is sensitive to macroeconomic changes during the reference period, as well as the development of renewable energy sources or decreases in oil demand, and for this reason, it should be considered with great caution. In fact, when considering this index in 2005, the values suggested that the reserves would be sufficient for 41 years of consumption at the production levels of that time, while the results calculated in 2021 suggested an increase to 50 years. Moreover, both production and consumption have shown an increased path from 1995 to 2020, apart from the last year where the Covid-19 reduced their level.

Subsequently, a description of key drivers of price determination is discussed in order to provide more information on how the price of crude oil is determined and how the various variables cause its fluctuations, since this is important for a better understanding of the hedging strategies implementation and results.

The major variables with the potential to affect the price of crude oil are classed into three main categories: - variables related to the macroeconomic scenario; - variables related to the geopolitical context; - variables related to the supply chain. These variables influence the price of crude oil, causing its up and down movements over time.

About the latter, this paper provides in-depth information. The crude oil price trend from 1950 to 2020 is described, highlighting how historical events have affected its path. Subsequently, the delivery price with its characteristics, crude oil benchmarks among which Brent and WTI stand out, and the price approaches are described. The latter refers to the various methods that can be used to price crude oil contracts: - floating price: means that the price or a factor of it, agreed upon in the transaction, is based on a specified index; - official selling prices: many state-owned oil companies (NOCs) price crude oil sales to long-term customers using an official selling price (OSP) for each of their major crude oil streams; - fixed price: the price is determined bilaterally between the parties and held constant over a long period; - differential to a crude oil benchmark: the price is set as the difference between listed oil and oil benchmarks; - exchange of physical commodities: in the case of transactions between the parties with physical delivery of the underlying commodity, the price is determined on the basis of the futures market.

This research thesis provides examples of hedges that can be implemented to mitigate the risks of crude oil price fluctuations through the use of futures, options, and swaps. Since options are the subject of the empirical analysis on CNOOC Ltd., several hedging strategies were analyzed. These strategies can consist of the implementation of a collar that involves the use of puts and calls with the strike price of the put lower than that of the call, a long call strategy that consists of the use of long call options to offset the risk of rising crude oil prices, and a bear put spread that is characterized by buying put options and shorting put options at the same time, with the strike price of the put options bought higher than the one of the put options shorted. An overview of a long put strategy is given at the end, which involves using long puts to offset the risk of falling crude oil prices. This is also the strategy executed for CNOOC Ltd. in the counterfactual analysis.

In the last part of chapter two, an overview of how derivative contracts are accounted for in companies' financial statements is provided, as this has several implications on how these instruments are considered and how they affect a company's profit.

The two main regulatory sources for accounting for derivative instruments are currently IFRS 9 and ASC 815.

IFRS 9 (International Financial Reporting Standard), published by the IASB (International Accounting Standards Board), deals with financial instruments and is divided into three main topics - classification and measurement of financial instruments: - impairment of financial assets and - hedge accounting. This accounting standard became effective in January 2018 with early adoption possible, replacing IAS 39 "Financial Instruments - Recognition and Measurement", which was considered too complex, inconsistent with the way entities manage their businesses, and inefficient because it postpones the recognition of credit losses too late in the credit cycle. The IASB issued updated versions of IFRS 9 as each phase was finalized or modified; entities had the option of adopting the updated version. The final standard was issued in July 2014.

In the United States, the accounting standards issued are US GAAP (General Accounting Accepted Principles) emitted by the Financial Accounting Standards Board (FASB). One of the earliest standards for accounting for derivative instruments was FASB No. 133 (Accounting for Derivative Instruments and Hedging Activities, 1998), which requires companies to measure all assets and liabilities on the balance sheet at fair value. This standard has been amended several times in the intervening years, with more than 170 interpretive documents issued to address the various problems related to this standard.

For these reasons of uncertainty, these standards were replaced by the Accounting Standards Codification (ASC 815, Derivatives and Hedging).

Both IFRS 9 and ASC 815 on derivatives consider the main aspects of what falls under hedge accounting. Hedge accounting aims to closely align accounting with the economics of risk mitigation initiatives by identifying the effect of the derivative instrument in the same period that the underlying hedged asset or liability affects the entity's financial results. By aligning economics with financial accounting, hedge accounting reduces earnings volatility without altering the economics of the underlying transaction. The purpose of hedge accounting is therefore to represent in the financial statements the effect of risk management activities that use financial instruments to manage exposures arising from particular risks that could affect profit or loss (P&L) or other components of comprehensive income (OCI).

CHAPTER THREE

After handling derivatives and focusing on the crude oil sector, in the last chapter, the thesis's task is to test the efficiency of a hedging strategy using long ATM put options each month of the period under consideration in hedging exposure to crude oil price declines. A large Chinese oil producer (CNOOC Ltd.) that has not adopted any derivative's hedging strategy is considered, and a counterfactual analysis is conducted to see how much it would have saved if it had engaged in the use of long puts over the period of 2017-2021.

CNOOC Ltd. (China National Offshore Oil Corporation) is China's largest producer of crude oil and natural gas and one of the largest independent oil and gas exploration and production companies in the world. The company's main business is the exploration, development, production and sale of crude oil and natural gas. The company's main competitive advantages are: - a large and diversified asset base with significant exploitation potential; - vast operating areas off China's coast with proven exploration potential; - a track record of independent exploration and development success; - PSCs in offshore China that provide access to cash and technology, as well as reducing risk; - a competent management team and a high standard of corporate governance; - large and diversified assets with great potential for exploitation.

However, CNOOC Ltd. has a track record of success in exploration, independent development, and expansion of its oil and natural gas supply base, both independently and through production sharing

contracts (PSCs). In recent years, the company has increased its revenues and production mainly due to these achievements.

In addition, the company's strategy is to: - focus on expanding reserves and production; - maintain a sound financial strategy; and - expand the natural gas business. The company aims to increase reserves and production through exploration and development, as well as through value-oriented acquisitions.

The company, however, faces several risks that may have an impact on its revenues, capital structure, as well as from an economic and financial perspective. These risks are considered and analyzed with the aim of providing a more delineated picture of the company, although exposure to downward fluctuations in oil prices is the main risk on which the hedging strategy performed is based. Indeed, as CNOOC Ltd. is a large oil producer, any price declines result in lower revenues, decreasing the company's Gross Profit, as well as the Net Income generated. Since CNOOC Ltd. has not implemented any hedging strategy related to commodity price risk, a counterfactual analysis is performed to see how a potential hedging strategy could have been efficient in covering losses from monthly price declines over the five years 2017 - 2021.

The hedging approach is to purchase put options each month, which expire toward the end of the same month in which they were purchased (on the same date of the crude oil sale), renewing this strategy for the following months of the year.

The purpose of the hedging strategy is, thus, to benefit from the payoffs generated by the options when prices fall below the strike price, thereby reducing the company's losses and realizing a higher price per barrel than it would have achieved in the absence of hedging. Long put options are purchased on the first business day of each month and expire three business days before the last trading day of the underlying futures, which occurs on the last business day of the second month preceding the contract month. For example: to hedge the production month of January, the company will purchase the put options at the beginning of January with expiration towards the end of the month, on the same date on which production is sold. The options will have as their underlying the March futures, since these futures will expire on the last business day of January and the option will expire three business days before the future's last trading day.

Brent Forties Oseberg was taken as the spot price to determine the selling price of each barrel of its crude oil production. The latter was taken into account by referring to quarterly company reports and distributing the total amount of each quarter in the three months according to specific percentages.

Overseas production and natural gas production has been excluded from the analysis.

Options with underlying ICE Brent futures were chosen for the hedging strategy pursued in this paper. The ICE Brent Crude futures contract is a deliverable contract based on EFP (exchange of futures for physicals) delivery with a cash settlement option. However, the hedging strategy established by the author of this paper wants to consider the option's exercisability only on the day of their expiration and not at any time before expiration. This would mean considering European options instead of American ones, but since the options with underlying ICE Brent Futures are exclusively American, an adjustment was made to the price of American options to obtain the equivalent European options. The adjustment was made by subtracting from the American option price the early exercise premium, which is the additional price of American options to compensate for the fact that they can be exercised at any time before expiration.

All put options at the time the company enters the position are at-the-money. The ATM strike price is the value closest to the previous business day's settlement price of the underlying contract. Since each long-put position is opened on the first day of each month, the settlement price of the ICE Brent Futures on the last business day of the month prior to the month in which the long puts are entered is considered for the ATM strike price.

Subsequently, calculations were performed to verify the results of the hedging analysis, calculating the profit of the options, in cases where they are in-the-money, as [(K - S_t) x contract size (1,000 bbl.) x n° contracts – the cost of the strategy (option price x contract size x n° contracts)]. If the prices of the underlying futures are higher than the strike price, the options are not exercised, and the profit is equal to: - option price x contract size x n°contracts.

Total revenues were calculated by incorporating revenues from monthly crude oil production sold at the BFO spot price plus profits from options used.

Over the 5 years examined in the counterfactual analysis conducted, CNOOC Ltd. would have saved an amount of $1,036,693,702.80 by using put options that would have counteracted monthly decreases in Brent Forties Oseberg spot prices.

The last part provides a discussion about the limitations behind the analysis conducted as well as suggestions for future research.

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