UNIVERSITY OF PIRAEUS
DEPARTMENT OF INTERNATIONAL AND EUROPEAN STUDIES

MSc in Energy: Strategy, Law and Economics

PORTFOLIO HEDGING IN ENERGY MARKETS FOR RISK MITIGATION

By

Alexandros-Sotirios Sorotos
AM: MEN20031

MSc Dissertation

submitted to the department of International and European studies of the University of Piraeus in partial fulfilment of the requirements for the degree of Master of Energy: Strategy, Law and Economics

Piraeus, Greece
January 2022

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Abstract

The purpose of this paper is to present an integrated approach to hedging. It seeks to integrate the concept of hedging in such a manner that all key elements are taken into account. In most situations, hedging papers and techniques focus almost entirely on specifics (particular models, specialized instruments), leaving out the most crucial aspect: the overall picture. The paper's most important argument is that it highlights the flawed assumptions that existing techniques and tools have, which lead to relatively unrealistic outcomes, and secondly, it emphasizes long-term risk reduction. Most firms tend to protect themselves against short-term risks and volatility, but they are left vulnerable to severe occurrences that are unusual but have long-term devastating consequences and can even lead to the company's bankruptcy.

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1. Introduction

The initial idea as the central topic for this paper, was risk mitigation in the energy markets, via the use of diversification. Although the term of diversification exists in the bibliography of energy markets, the notion of diversification is not the same. In general, as the modern portfolio theory suggests, an investor aims to reduce the idiosyncratic risk, by building a portfolio with assets that are not perfectly correlated with one another. In the case of energy, one cannot easily create a portfolio that the correlation coefficient will not be equal to one. In the future it might be a more realistic as a scenario when energy commodities will be more independent from one another.

Example of the above, is the crude and gas markets which are not fully independent yet, as still gas can still be considered oil based priced in several locations, and does not completely consist of its own market, only in the cases of the natural gas hubs. In the same causal effect, electricity cannot be separated from gas fluctuations, as electricity is simply a byproduct of gas or oil. These and many more similar effects, tend to bring the correlation coefficient close to 1, which makes diversification not effective.

However, many papers discuss about diversified energy portfolios, but what they actually mean is that investors are taking an opposite position from the original that they hold – simply put, hedging. Nevertheless, in theory, this is diversification as well, as when one of the assets loses, another one gains, and it offsets the losses. The bibliography of hedging is vast, there are numerous theories of strategies that can be used, numerous econometric models which can be implemented, numerous tools and derivatives, and on top of all of these, each industry has its own unique specifications that make the combination of the right strategy-tool-model an extremely complicated procedure, but also completely crucial. How to efficiently manage risk is a critical problem for the financial and commodity markets. One of the challenges is estimating the volatility of financial and consumption asset prices, as well as determining the best hedging ratio.

The aim of this paper is to make an integrated approach on hedging. It attempts to consolidate the notion of hedging in a way that all important factors are taken under consideration. In most cases, hedging papers and strategies tend to focus almost solely on details (specific models, specific tools), setting aside the big picture, which is the most important. The most crucial point of the paper is that it presents the faulty assumptions that the existing strategies and tools have, which lead to rather unrealistic outcomes, and secondly, it gives emphasis in the long-term risk mitigation. Most companies tend to protect themselves from risks in the short term, and short-term volatility, however they are left exposed to extreme events which are rare, but have long-term catastrophic effects, and can lead even to the bankruptcy of the company.

The methodology is a thematic analysis of the existing quantitative and qualitative data as well as existing case studies, which have been filtered and cross analysed. It should be mentioned it is not a paper specifically focused on the gas market, however in a few cases when a specific point is developed, the gas market is taken as an example. This is done so, as it is pointless to broadly talking about hedging, as each industry has its own characteristics and produce different outcomes. In this regard, it does not intend to be specifically a paper on the gas market, but rather on hedging in energy markets.

The first section of the paper analyses the market risks that the energy sector and all the financial challenges that firms need to overcome in order to survive over time. It also includes the main derivatives which companies use to build hedging strategies. The second section of the paper develops the main hedging theories that exist, which companies choose to further develop and tailor them according to their characteristics. The third section analyses the main theories that exist in the bibliography of hedging, discusses in the notion of hedging ratio, and explains why it is the central issue when trying to create a hedge. It also presents the basic econometric models, namely OLS, GARCH and VaR, which are used when trying to forecast the price range so to calculate the hedge ratio. The fourth segment of the paper focuses on the notion of risk aversion, which brings to the table the idea that hedge should not be common for every firm, but rather should be a procedure based on the profile of the company who implements it, and its risk tolerance. It also examines whether it is necessary to include basic factors in evaluating price returns and volatility. Incorporating a time-varying hedge ratio increases hedging efficacy significantly. Furthermore, including market fundamental elements considerably increases hedging efficacy. It is critical to include basic market characteristics when studying commodity price movement and enhancing hedging efficacy. The last section is focused on the so-called fat tails, the unrealistic assumptions on the current econometric models and the ramifications that these results produce to the firms, as well as the black swan events that require an all-weather approach to hedging, rather the hopeless effort of "trying to forecast everything" that most companies still do.

2. Literature Review

2.1 Introduction

Before all, it is essential to present and analyze the market risks that the energy sector faces, as well as all the financial hurdles that businesses must overcome in order to survive in the long run. In addition, there are included the most common derivatives and their characteristics, which are used by businesses to construct hedging strategies.

2.2 Market Risks

Before begin discussing about hedging strategies and tool it vital firstly to understand and development the actual risks that a company is embedded in. Hedging is a procedure which focus, is to eliminate financial risks that might arise, so their analysis prior to everything else, is essential.

Risk and reward are inextricably linked in finance. Risk raises and increases the probability that traders or investors may some or all of the value of his portfolio investment. Therefore, risk management is the act of identifying, analyzing, and deciding whether to accept or mitigate the uncertainty inherent in investment decisions. Thus, risk management may be viewed like a defensive mechanism for the investment, ensuring its long-term viability. (Aven, 2016) Various risk management tools can be implemented to ensure that changes in the prices of the underlying assets do not significantly affect the portfolio as a whole. For example, the Greeks (option pricing tools) , evaluate "the sensitivity of the value of a portfolio to small changes in various parameters" (Cotter, 2010). "Greeks" options, offer critical information for risk management, as well as they are a beneficial tool for energy players who seek to protect their assets against unfavorable market movements.

Generally, energy market participants fulfill several of the following functions:

- “Transmit/ distribute Energy”
- “Generate Energy”
- “Market Energy”

Below, there are listed five general types of business risks that affect participants in the energy market. (Mack, 2014)

Credit Risk

This type of risk, relates to the risk that the borrower may be unable to fulfill its commitments, creating this way a loss of capital. The evaluation of credit risk is based on the potential ability of the borrower to repay its debt.

Liquidity Risk

It is about the level to which an asset or a derivative instrument, can be sold or can be bought, without affecting its price. Liquidity risk is also known as marketability. Basically, when we refer to “liquid assets”, we mean assets which can be converted in cash easily and quickly, without losing their value.

Market Risk

Market risks are risks that do not only exist in the level of a given company, or a given industry, but exist in a macro level, affecting all companies and all sectors. It is also called systematic risk. Systematic risk cannot be cancelled out thought diversification, however it can be hedged up to a level, and in accordance with the will of every specific company to give away expected returns. (Markus Burger, Bernhard Graeber, 2014)

Operational Risk

Operational risk is described as the possibility of loss caused by people or systems, as well as insufficient or failing procedures, which may be internal or external.

Political Risk

It is well known how large the ramifications of political changes or instability can be generated within the country, to the extent that it can be serious threat to an investments’ returns. Political instability can be originated to a change in regulations, government, other foreign policy makers, and in the most extreme of events can even lead to military control.

In table 1, there are listed the risks according to the identity of a participant in an energy market, as well as the position (long / short) which they have given their activities.

Table 1: Risks according to the identity of a participant in Power Markets

Power Market Participant	Risk Exposure	Power Position
Generators	▪ "Generators generally include utilities, federal power authorities, qualifying facilities (these are little power production and cogeneration facilities), merchant power plants, and on-site industrial plants" (US. Federal Energy Regulatory Commission, 2012) ▪ These companies own a power plant. Thus, their electricity position is long. ▪ The value of the generator and power prices, move along, so both either increase or decrease simultaneously.	Long
Marketers	▪ What marketers do, is buying and reselling power.	Long or Short
End Users	▪ End consumers might be industries, commercial shops or even homes. ▪ End users are mainly "short". Consumers profit from price declines and suffer from rising prices.	Short

Source:(Mack, 2014)

Price risk

Accounting Standards Codification 815 (ASC 815) sets the framework and all the requirements for accounting as well as valuing the derivatives (Ernst & Young, 2019) . ASC 815 requires that market participants make public the following four things:

1. "Exposure environment "
2. "Context for the use of the derivatives "
3. "Strategy to achieve hedging objectives "
4. "Derivatives categories according to the liquidity levels "

Source: (Council, 2014)

Participants in the energy market are extremely conscious to risk from market price as a result of the volatility of energy prices. As an example, in the last couple of decades, volatility in natural gas prices, has increased the importance of risk management by the participants, no matter the stage on the commercial chain that they have, from producers until retailers. The price of natural gas sets the price in many power markets, thus the ramifications of the volatility of natural gas has large impacts in other markets as well (Long, 2003). The most prominent effect of the above fact are the daily fluctuations and the spikes that happen in electricity prices. Exposure, which is not controlled, can lead to serious consequences for the wider power market.

Basis risk

Basis risk is the principal risk which is associated with futures contracts when they are used to hedge commodity risks. Basis is in essence, the difference between the price of the futures and the spot price of the commodity which is to be hedged. (Wisner, 1997). As the futures contract gets closer to expiration date, the futures price often moves towards the spot price. This happens, as the futures contracts becomes less and less a "futures contract" as it reaches the present. However, this is not always the case, and thus it should be taken under consideration in order to not act as a surprise to the hedger. (CFI, 2021) Basis risk is considered a systematic risk.

2.3 Introduction to hedging

It has been revealed through the analysis of financial reports, that various oil and gas companies use a wide variety of financial engineering products and strategies (Hale et al., 2002). Such strategies include the use of derivatives in order to manage any risk related to commodities prices and fluctuations. The derivatives products, when they are understood properly and utilized in the proper way, they are beneficial to assist participants in the energy market, to manage risks through trading and structured hedging strategies.

In this way, hedging is an investment which acts by reducing the risk of the adverse price movements in an asset. In more detail, a hedge is consisted of two investments, in two assets that have negative correlation (the price of one asset has opposite movement that the price of the other asset).In the case that a market participant utilize a hedging strategy, he may have to settle his a tradeoff between risk and return, which means that he has to be willing to give up possible future returns in order to build a position with lower risk in the market.(Alexander and Barbosa, 2007)

In order to get a better understanding, hedging could be paralleled to insurance. As players in the energy or financial markets employ hedging methods, they are effectively insuring their assets against adverse outcomes. Hedging does not entail that a negative occurrence is prevented from occurring. However, if the adverse event occurs and the market player is adequately hedged, the adverse effect of the adverse occurrence is mitigated. Nonetheless, hedging as a technique of execution is significantly more sophisticated in the financial and energy markets than paying insurance premiums.

An important factor that may play a critical role in hedging strategies implemented by companies, are the regulatory rules (Deng and Oren, 2006) What's more, firms have additional reason to use hedging strategies which is to maximize the company's value, by reducing the possibility of financial distress and ensuing costs, and in addition, by reducing the variance of the incomes which are taxable and associated with the present value of future tax liabilities. However, it should be noted once more, that the procedure of entering a hedge position, might imply reduction in profit by a great amount, as depending on the hedging strategy it may require a ceiling in expected profits. Despite the short-term costs of hedging, hedging is considered a wise move, as the minimization of the losses due to systematic or unsystematic risks, will usually offset the cost of the hedge in the long-term.

2.4 Financial Derivatives

Financial derivatives are the primary hedging mechanisms that enable enterprises to manage the risks associated with the continual volatility and high unpredictability when pricing the energy commodities. Derivatives contracts are a type of secondary market contract that, rather than providing direct possession with all the associated rights, and they “derive their value from an underlying asset or commodity”. (Whaley, 2003) Derivative contracts have a wide range of use, but the main use is to reduce the price risk exposure effectively. This is done so, by transferring the total risk exposure to another party in exchange for potential profits.

In essence, it is a transaction of risk and profits, one party settles with a certainty of a fixed income in a fixed period, while the other party accepts the bet of the fluctuation of the markets, undertaking the according risk, with the faith that the profit margins will spread towards their favor. The party which accepts the risk, will face a loss equal to the contact size plus the asset value drop, if the price moves in the way that the first party was worried, confirming this way the reason they choose to give away the risk. Derivative contracts have an extremely important role in the energy markets, by ensuring participants from extreme price risk. It should be noted that not only energy markets participants like producers need this insurance from extreme shocks, but also industries which are dependent on high demand of energy commodities. (Dewally and Marriott, 2008)

The special characteristics of energy commodities provide organizations with more flexibility when confronted with significant energy price risk, while also providing the required stability and assurance regarding future cash flows. (Trafigura, 2018).

2.4.1 Futures

“A futures contract is a standardized legal agreement to buy or sell an asset at a predetermined price at a specified time in the future, between parties not known to each other. “The transacted assets are mainly commodities or financial instruments, and their price is predetermined by the parties that will make the transaction (forward price). The delivery and payment will occur in a specified time in the future (delivery date).

Contracts for futures are negotiated on futures markets, which they act as a marketplace between those who want to buy and sell. The party which buys a contract is the long-position holder and the selling party is the short-position holder.(Adele and Fouda, 2019) Both parties of the transaction have the risk that their counterparty might simply walk away if the price will go against them, so there is a possibility that the contract might involve that both parties lodge a margin of the total value of the futures contract to a third party that they both trust. This margin is also subject of the volatility of the market of the underlying asset.

Originally, futures contracts were designed to hedge against price and exchange rate volatility by allowing counterparties to predetermine values or rates in advance. This way, a party who wanted to protect itself from future payment in different currency, could be financially guarded by entering a futures contact. (as they might have anticipated that the value of the currency that they would get paid would drop). However, following the same logic, a trader who predicts this kind of future fluctuations and margins, might use the very same contracts not to protect himself from a position, but might take the opportunity to speculate in a margin that he predicts there will be, and thus acquire a profit. Specifically, if the speculator can yield a profit, this means that the commodity was able to be stored in a period of surplus, and be sold later, offering the markets and thus the consumers a better distribution of the underlying commodity over time. (Patel and Tkac, 2007)

Futures contracts trade in standardized units in a highly competitive, deeply visible and never-ending open auction. In order this market to operate in an efficient way, it must hold three criteria.(Halkos and Tsirivis, 2019) Firstly, there must be a very large number of participants in the market, the commodities which are the underlying assets must be volatile, and underlying physical products must be fungible / interchangeable, which means that the commodity is not unique, and a similar one in a different location can be used instead, to complete the trade, subject to keeping its quality and specifications the same.

At this point, it should be noted that futures contracts are mainly used as financial instruments and very rarely reach the point of completion of the trade, with the actual delivery of the commodity taking place. In the case of energy for example, less than 1% (NYMEX, 2000) of the futures contracts, are delivered.

2.4.2 Spot vs. Futures Price Relationships

Cash price, also called spot price, are the prices that the commodities are sold at each market around the world. Essentially, the price of the futures, represent the anticipation of the market participants of how much the commodity will worth, in a specified time in the future. Under normal circumstances where there is adequate supply, the price of the commodity for delivery in the future, equals to the present spot price, plus the costs for transportation and storage until the month that the trade is to be delivered. The above costs (carrying charges) are equivalent to the premium charged on futures contract. Therefore, it is safe to assume that the longer the duration of the contract, the higher its price.

This market feature is known as contango, and it is common for many futures markets. In addition, in most markets that have to do with physical assets, the main element that differentiates the price between two contracts months, is the storage cost. (Nicolau and Palomba, 2015). Arbitrage is what allows dealers and financial institutions to keep intact, the contango structure of the futures markets. Typically, futures markets are contango markets, however, the seasonality and its fluctuations, play an important role in the energy market.

An example illustrating the above, is the case of heating oil, which during the months of the summer, the futures for heating oil raise, as the market gradually begins to build inventories for the winter period. On the other hand, there is the case of backwardation, during the opposite happens. The month closer to the spot market, trades at higher prices than the longer-term futures. The main reason that this phenomenon appears, is due to tightness of supply, or when seasonal factors predominate. (Gabillon, 1991)

2.4.3 Options

An option is a one more derivatives instrument, and it also derives its value from the underlying value. Options provide great flexibility, regarding the trading and investment strategies that its holder can implement, such as leveraging and risk management. The main difference from the futures contracts, is that options give to the buyers, “the right but not the obligation, to buy or sell energy, at agreed- upon price during a certain period of time or on a specific date ”. (Mack, 2014)

Options can be traded privately, OTC (over the counter), in a tailored way that suit the parties that create them, or they be traded in a standardized form, like futures contracts. The latter form allows them to be highly liquid, as they have standardized form and terms, which make them easy to switch hands, contrary to OTC options. (Ang, 2015)

There are two main types of option contracts, these are puts and calls. To begin with, the buyer of put options pays a so-called premium for the right, but not the obligation, to sell energy at a specific price at a specific point in the future, also called as floor, as it is the lowest price that will receive shall he exercise his right the option. On the same grounds, a holder of a call option, has the right but not the obligation to use the call option to establish the highest price that an asset or commodity, will be bought, in a specific time in the future. (Mack, 2014)

An additional distinction between options, are their origin. European options and American options, which they share common characteristics, but at the same time important differences. "A European option can only be exercised at the expiration date, while the American style option, can be exercised any time before the expiration date, at the will of the holder". (Christensen et al., 2020)

European options are most often over the counter traded, while American style option are usually traded over a market. Whether an option is an American or a European option depends explicitly to the option holders' right to exercise the option at his will or at the pre-decided expiration date. It should be noted that, European-style options bear special risks for options traders, and they must be carefully planned to avoid systemic exposures. (Christensen et al., 2020)

2.4.4 Swaps

Swap contracts is the latest tool that was added in the financial derivatives market and the rationale behind this tool, is that it was constructed in order to provider a lower cost alternative to the option contracts. Swap contracts, in contrast with all the rest of the derivatives, do not contain any form of physical delivery of the commodity, as it essentially is an agreement between two companies to exchange future cash flows. This exchange is based on the changes of the price of the underlying commodity (or generally asset). (Vitale, 2001)

Swaps are contracts that are not standardized, as they as customized to the cash flows and positions of the two companies, thus they are not traded in exchanges, they are solely over the counter positions. (Ernst & Young, 2019) Because of the fact that no amount is originally transacted, and no physical delivery takes place, the various future cash flows are determined upon a principal base or notional amount. This notional amount can represent the market value that the two assets currently have, which are to be swapped between the two parties of the deal, or it can represent the quantity that a specific underlying commodity will have, and its price fluctuations, which the cash flows will be based on. Generally, swaps have many commons with future and option contracts, and their main advantage is that they do not require its holder to also acquire and hold the underlying asset in actual physical form. (Kumar, 2014).

Nevertheless, because swap contracts are negotiated one by one, it allows the parties involved in the trade, to have greater flexibility, and in return, to better manage the individual risks that they have to deal with, in order to pilot the company as stably as possible and ensure the future and viability of the firm (Ernst & Young, 2019). However, the problem arises because of the lack of certainty, as there is no clearing house to act as middleman and ensure the completion of the swap contact. One of the parties might always default and not be able to fulfill its commitments, leaving its counterparty hanging, exposed to credit risk. This situation frequently results in swap contracts that are less liquid, as the parties to the agreement renegotiate all of the relative contractual terms in great detail before deciding to terminate the swap agreement prior to its expiry. (Faizan and Malik, 2015)

2.5 Conclusion

Hedging is a method whose goal is to minimize financial risks that may arise; thus, it is critical to analyze them first. There are several types of financial and general risks that a company is embedded into, which can be identified and hedged based on a wide range of financial derivatives. The main derivatives can be categorized into futures, options and swaps, however according to the industry and the underlying asset, there is a large number of subcategories and strategies of cross usage.

3. Hedging

3.1 Introduction

This chapter analyzes the key hedging theories in the literature, explores the concept of hedging ratio, and explains why it is the most important factor to consider when attempting to design a hedge. It also covers the fundamental econometric models, such as OLS, GARCH, and VaR, which are used to forecast price ranges to determine hedging ratios. Basically, hedging is a purely quantitative technique, thus these models consist of the main instruments of risks managers when accounting the hedge of their positions.

3.2 Hedging strategies

Although, in theory there might be a vast amount of hedging techniques, strategies and combinations of tools that a company can utilize according to their positions, one might distinguish five main hedging strategies in the bibliography: the traditional one to one hedge, the beta, the delta hedge, ¬the minimum variance hedge, and the expected utility maximization methodology.

It should be mentioned that none of the strategies is perfect. Each one has its pros and cons, operate under assumptions (some strict, other not so), and none can be described as extreme accurate, all-weather type tool. After all, the global economy is a vastly complex system, with zillion parameters, with rare and unpredictable events, which can change the route of the economy in moments. No tool and no prediction model can incorporate these, and thus, no one can feel confident enough, no matter how sophisticated the method – strategy might look like. Nevertheless, the use of them is proved superior from an unhedged portfolio.

All techniques require that the best hedging ratio h* be determined. Energy price risk management has become more critical for all enterprises and investors working in a direct or indirect manner with that market, since the volatility of energy commodity prices and the price of financial derivatives is unquestionably the highest of any asset class. (Deloitte, 2018).

During last decade, oil, gas, coal, and renewable energy technologies such as biomass, geothermal, hydro-electric power, hydrogen, solar, wind, ocean energy and energies had the highest standard deviation of 20.3% based on returns from the Energy Select Sector Index

.(S&P Global, 2020)The energy sector, saw extreme volatility in prices of oil, during the 2010 decade, when the spot price of crude oil plumed from $113.93 per barrel on April 29, 2011, to $88.19 on Sept. 12, 2011.(EIA,WTI Spot Price FOB)

However, different parties decide to deal with energy price risk in different ways, and they develop a relative hedging strategy according with their incentives and relative tools, subject to their activities and know how. Hedgers in the energy derivatives market are usually driven by numerous and quite often opposite motives (Deloitte, 2018).

In the existing literature, hedgers usually are divided in two main groups which include on one hand, short hedgers which are most often representing the position of an energy commodity producer, with their deepest worry to be a potential price decrease, and on the other hand long hedgers, which are generally dependent to a large extend on their inputs, which are the energy commodities, and are mainly worried about possible price increases(Stoft et al., 1998). It is evident therefore, that the two groups are worried about the exact opposite sides of the return distribution. According to research from the oil futures market, the vast majority of short hedgers, hedge only the "difference of their present production, to the minimum economic production level and the extreme correlation between oil producers' profits and actual prices strongly indicate that producers hedge only a small portion of their overall production".(Halkos and Tsirivis, 2019)

Two more aspects need to be considered, which are firstly, if producers were trying to hedge a large amount of their production, then the price of the future and forwards contracts would decline dramatically. Secondly, a further reason why it is not wise for producers to hedge large proportions is that the largest amount of risk would be transferred solely to financial institutions, whereas in this case, the risk is handed over to the end users of petroleum products. (Devlin and Titman, 2004)

Lastly, the returns of a hedge are often vulnerable to the risk produced by unanticipated differences between the overall price of the hedged position and the futures contract. Hedging can only be implemented when there is no perfect correlation.

Many attempts have been made in order to define which is the optimal hedging strategy, and below they are listed the main five main strategies which have been distinguished from the bibliography.

The very first, and maybe most often used technique, is to determine the ideal hedging strategy by minimizing the return volatility to the extent possible. The Minimum-Variance hedge ratio is the term used to describe this ratio. Nevertheless, if the constraints of the aforementioned approach are not taken into consideration by the hedger, the results of the strategy may be highly unrealistic and, in some situations, even incorrect. (Dewally and Marriott, 2008). The limitations, require the assumption that firstly the expected return will be zero, on the futures contract, and secondly, the hedger has infinite risk aversion when it comes to risk, which is a quite critical hedging parameter considering that there may be substantial alternations of this factor between the two distinct groups of hedgers. (Halkos and Tsirivis, 2019)

Traditional theory strategy gives emphasis to the potential of futures contract to be used to reduce risk. This is a fairly simple strategy and it involves the adoption of a hedge ratio which is equal to the amount of the position but with opposite sign of the spot position ($h = -1$).Traditional theory holds the rather restrictive assumption that if the futures market is a perfect match with the price changes, then this strategy will be enough for the elimination of the risk. However, this is not always the case firstly because of the basis risk, and secondly because very often hedgers cannot utilize the futures, which is of the exact underlying asset, as it might not be liquid enough, or it might not even exist. For example, in aviation industry, firms in order to hedge jet fuel prices, they typically use futures of heating oil, as it is a derivative with the closest correlation to jet fuels prices, and it has a much larger and more liquid market. (Brown, 1985)

The beta hedge strategy has few similarities with the traditional theory however it is used in the case that the cash portfolio which must be hedged does not correspond exactly to the portfolio underlying the futures contract. Hence, the calculation of the optimal ratio is made by the negative of the beta of the cash portfolio. As expected, the two strategies will have the same hedge ratio if the cash portfolio is the same as the one which underlies the futures position. (Nadler and Schmidt, 2019)

Nevertheless, scarcely ever do the futures and spot prices move exactly in a parallel way, and as a result a hedge ratio which is calculated from the traditional or beta hedge strategy will diminish risk. In more detail, it has been shown, that mispricing appends 20% to the volatility of the futures contract (Alexander and Barbosa, 2007). Given that, the volatility of the futures contract is higher than the underlying index, the portfolio might end up being over-hedged if beta will be used as a sensitivity adjustment.

Nonetheless, minimum variance takes under consideration this defective correlation and incorporates it in the hedge ratio. However, the hedge ratio of the Minimum Variance (MV) is in general not consistent with the framework of the mean-variance. In order to be so, it needs to be assumed that either the expected returns of the futures will be zero, or that the investors have an infinite risk aversion, which means that they will abandon an infinite amount of expected return in order to have an indefinitely small risk reduction. This kind of assumption is not a realistic one, however the minimum variance hedging technique is a useful tool as a benchmark of hedging effectiveness of the rest of the methods. (Castelino, 1992)

Several research on the estimate of the ideal hedge ratio have been done, and they use a variety of methodologies. If spot and futures prices are not cointegrated, it has been demonstrated that a fixed optimum hedge ratio may be calculated using the regression slope coefficient h:

$$\Delta St = \alpha + h^* \Delta Ft + \varepsilon t.$$

Where ΔSt is the difference in sport prices between time t1 and t2, a is the point where the regression line intercepts with the y-axis, h* is the optimal hedging ratio, ΔFt is the difference in futures prices between time t1 and t2 and εt is the error.

In the case of stocks, returns generally exhibit time-varying conditional heteroscedasticity, and so the data do not corroborate the hypothesis that the variance-covariance matrix of return is constant. To enhance the estimate of the hedge ratio, we must include the potential of time-varying nature in the models. As a result, hedging methods based on GARCH (generalized autoregressive conditional heteroscedasticity) models have been presented. These models accept time-varying conditional variances and covariances as inputs to the hedging ratio. (Baillie and Myers, 1991)

The fourth and most often used hedging technique is predicted utility maximization, which is applicable to both financial and energy risk management. This technique takes risk aversion seriously and using a utility maximization framework to determine the appropriate hedging ratio. (Dewally and Marriott, 2008).

Holders of positions seek to secure their portfolio's spot positions through the use of financial derivatives; thus, the optimal hedging ratio indicates the precise mixture of investments in the spot and futures markets which would smooth out the volatility of the overall portfolio value or at the very least minimize it to the smallest degree possible. (Dewally and Marriott, 2008). Subsequently, taking a long spot market portfolio of As assets and a short futures portfolio of AF assets, PSt and PFt denoting the spot and futures prices at a specific time t and rSt and rFt to be the net returns for a single period from t − 1 to t, then the total return of the hedged portfolio rh can be estimated as:

$$r_h = \frac{A_S P_S r_{S_t} - A_F P_F r_{F_t}}{A_S P_s} = r_{S_t} - \delta_{h_{t-1}} r_{F_t}$$

where δht−1 denotes the hedge ratio and is actually defined as the ratio of the futures position value to the value of the spot position in a given time t – 1 and shows how many currency units have been invested in the futures market for each unit that has been invested in the spot market. (Halkos and Tsirivis, 2019)

However, despite the fact that the optimal hedge ratio has a key role in every effective hedging strategy, it is of critical importance to point out that its estimation is always “subject to the specific objective function that needs to be optimized based on the chosen hedging methodology” (Hung et al., 2006Thus, the ideal hedge ratio can be either static or dynamic, and it can be defined as a strategy that reduces the variation of the portfolio's value, or it can maximize a specific utility function based on the risk preferences of the investor or it can be in accordance with the prespecified VaR level (Castelino, 1992).

3.3 Hedge Ratio

The hedge ratio compares the amount of a hedged position in regard to the total value of the portfolio. A hedge ratio may also be an assessment tool of the value of derivatives contracts purchased or sold to the entire value of the cash commodity which is hedged.

In order to compute the hedge ratio, one divides the hedged position by the total shareholding in the company. Hedge ratio is a crucial risk management statistic that is used to analyze the extent of any risk that may be caused by the usage of different hedging instruments in an open position. Hedge ratios which is close to 1 indicate that a position has been "fully hedged." An "unhedged position" occurs when the hedge ratio approaches 0. (Hedge Ratio, CFI) The formula for the ratio is shown below.

$$\text{Hedge Ratio} = \frac{\text{Hedge Value}}{\text{Total Position Value}}$$

Types of hedge ratio:

1. Static hedge

A static hedge occurs, when the hedge remains unchanged during the whole duration of the contract, no matter how much the price swings of the hedging derivative.

2. Dynamic hedge

On the other hand, dynamic hedge, consist of the hedge which is constantly changing by adding or reducing the number of contracts. This way it stays always close to the optimal hedge ratio. (TOMPKINS, 2002)

3.3.1 Optimal Hedge Ratio

An ideal hedge ratio is a risk management investment ratio that specifies the percentage of a hedging instrument, that a firm needs to hedge. The minimal variance hedge ratio is another name for this ratio. It is most commonly utilized with the technique of cross-hedging.

$$\text{Optimal Hedge Ratio} = \rho \times \frac{\sigma_s}{\sigma_f}$$

Where:

- ρ = The correlation coefficient of the changes in the spot and futures prices
- σ_s = Standard deviation of spot prices
- σp = Standard deviation of futures
  source:(CFI, hedge ratio)

A mathematically optimum hedging ratio attempts to minimize the variation of the value of a possible position. It assists in determining the optimal number of futures contracts to buy or sell in order to execute or hedge a bet. The following formula calculates the best number of futures contracts to buy or sell. An optimal hedging ratio seeks to reduce the volatility of a potential position's value statistically. It aids in determining the "optimal" quantity of futures contracts to be purchased or sold in order to carry out or hedge a position (Howard and D'Antonio, 1994). To find the best number of futures contracts to buy or sell, we need to multiply the optimal hedge ratio with the number of positions hedged and the sum of this, to be divided by the futures contracts size.

$$\text{Optimal No. of Contracts} = \frac{\text{Optimal Hedge Ratio x No. of Positions Hedged}}{\text{One Futures Contract Size}}$$

3.4 Econometric Methodology

An econometric model is one of the many instruments that economists use to anticipate future economic trends. Econometric models are essentially statistical models that are utilized in the field of econometrics. In the most basic terms, econometricians examine previous correlations between variables such as consumer spending, household income, tax rates, interest rates, employment, and so on, and then attempt to estimate how changes in one variable will impact the others.

Prior to these calculations, econometricians usually start with an economic model, which is a description of how various economic elements interact with each other. An econometric model defines the statistical connection that is thought to exist between several economic parameters relevant to a certain economic phenomenon. An econometric model can be generated from a deterministic economic model by accounting for uncertainty, or from a stochastic economic model. It is also feasible to utilize econometric models that are not based on any economic theory. (Asteriou, Dimitros; Hall, 2011)

In this section, it will be shortly presented the two main models which are more frequently used when trying to forecast the markets in order to find the optimal hedging ratio, plus VaR, an essential tool of businesses to measure the overall risk of a portfolio.

3.4.1 OLS Hedging

Regression investigates the connection between a dependent variable (y) and several explanatory factors (x_i.). It is an effort to explain changes in y by changing the explanatory variables x_i..

The following linear equation summarizes the OLS hedging regression.

$$\Delta S_t = \mu + \delta \Delta F_t + u_t;\ u_t \sim iid(0, \sigma^2)$$

where is the dependent variable (changes in spot prices), ΔF_t is the explanatory variable (changes in futures prices), μ is the constant term, δ is the coefficient of the explanatory variables, i.e., the hedge ratio, and u_t the error term.

Because the error term cannot be observed, the dependent variable is stochastic. The primary problem with linear regression is that the estimation approach, ordinary least squares (OLS), has several extremely strong assumptions in order to give impartial and efficient estimations, which are readily broken. (Kovlaka, 2020)

3.4.2 GARCH / ARCH Hedging

As previously mentioned, volatility is a critical issue, and as a result, there is a strong interest in modeling and predicting standard deviation. This makes sense given that it fluctuates throughout time, with a time interval of high volatility followed by a time interval of low volatility, often known as a volatility cluster. The Autoregressive Conditional Heteroscedasticity (ARCH) model is the most widely used approach for doing so (Engle, 2001). Unlike the other techniques, this model permits the error variable to be heteroscedastic, or to fluctuate with time. If y_t is the variable to be investigated and σ_t^2 is the associated variance, then an ARCH model is written as follows:

$$y_t = \beta_1 + \sum_{i=1}^{n} \beta_i x_i + u_t$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2$$

where n denotes the number of the explanatory variables, x_i are the explanatory variables, q is the lagged number of the error terms and α_i ,β_i being the corresponding coefficients.

The ambiguity of q, on the other hand, causes some challenges, either because there is no adequate way for defining it yet, or because using a large number of lags may result in overfitting. This problem was encountered by the development of the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model. GARCH permits the variance to be influenced not just by the lagged value of the squared error term, but also by its own prior delays, as represented as:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2$$

That said, the hedge ratio can be reformulated so that it is conditional on the knowledge at time t, i.e.: (Konstantina, 2020)

$$b_t | \Omega_{t-1} = \frac{\sigma_{sf,t}}{\sigma_{F,t}^2}$$

3.4.3 VaR – Value at Risk

The principles and working methods of risk management have their roots in the financial industry. In a firm whose activities are in the financial sector, the main focus of the risk management is the overall value that the portfolio holds, and more exclusively the assets and liabilities that it is consisted of. This particular focus is apparent from the fact that banks and generally the majority of the financial institutions have adopted the metric of Value At Risk, also known as "VaR", in order to measure the overall risk of the portfolio. "Value at risk is a statistic tool which quantifies the extent of possible financial losses within a firm, portfolio, or position over a specific time frame". VaR calculations can be applied to individual positions or whole portfolios, or they can even be used to measure firm-wide risk exposure. (CFI, 2020)

However, there are critical distinctions between financial and non-financial companies when it comes to portfolio management. In particular, the assets held by financial companies are in their majority financial assets, like derivatives, stocks, bonds, cash, CDs, and bank deposits, while on the other hand, the majority of the assets that non-financial firms hold are actual-real assets, which hold a physical nature. (Gourieroux, 2014)

The central issue of financial assets is that in normal markets conditions they have high liquidity, which means that they can be easily sold in very short notice, with minimum procedures and relative costs, close to the market value. In contrast, the real assets are not liquid, which means that the procedure of liquidation is long, as well as costlyAs a result, although selling assets may be an appropriate method of raising capital for a financial institution, it is frequently a very unappealing method of raising capital for a non-financial institution. Therefore, non-financial enterprises have an added incentive to monitor, quantify, and manage unpredictability about the cash flows generated by their operations as effectively as possible, and thus depend more frequently on cash flow at risk ("CFaR") metrics. (Oral and CenkAkkaya, 2015)

It is not that easy to set a fine line between non-financial and financial companies. A considerable amount of energy marketing and trading companies have very similar practices with banks from a financial perspective. (Baptista Da Silva, 2014) On the other hand, many power firms have in their possession generation resources and other physical assets, which they are usually combined with long-term supply contracts which are bounded up with obligations of attendant volumetric and operational risks and price risks as well. It is therefore clear that several firms in the electric power industry are primarily concerned about managing the uncertainty of cash flow as well as the uncertainty generated from the value of their business portfolios.

3.5 Conclusion

We can distinguish five main hedging strategies in the bibliography: the traditional one to one hedge, the beta, the delta hedge, the minimum variance hedge, and the expected utility maximization methodology. All the strategies seek to find the optimal hedging ratio. The latter, compares the amount of a hedged position regarding the total value of the portfolio and the methodology to find this ratio, comes with the assistance of the econometric models such as the OLS, the GARCH, and the VaR, which are used to forecast price ranges to determine hedging ratios. Basically, hedging is a purely quantitative technique, thus these models consist of the main instruments of risks managers when accounting the hedge of their positions.

4. Tailored hedging

4.1 Introduction

The following chapter firstly concentrates on the notion of risk aversion, which implies that hedge should not be a standard operation for all organizations, but rather a method adapted to the risk tolerance of the organization adopting it, presenting the utility- based hedging techniques. When assessing price returns and volatility, several features should be taken into account. The second part of the chapter takes as an example the gas market and builds the point that hedging efficacy is considerably improved by integrating market fundamentals such as macroeconomic news, storage reports, and weather factors. When looking at commodity price movement and improving hedging efficiency, it's important to consider the basics characteristics of the market.

4.2 Risk Aversion

Getting the optimal hedging approach for energy commodities like oil and natural gas is critical for hedgers in energy markets, given their significance in the global trade chain and their vulnerability to price fluctuation. (Regnier, 2007) The risk attitude of the hedgers, as reflected by their utility function, plays an essential role in determining what is considered ideal from a hedging standpoint. Cotter and Hanly (2010), investigated the influence of different risk perceptions and risk management on optimum hedging strategies.

In most situations, it is assumed that investors have infinite risk aversion, which is for certain not a realistic scenario, since unlimited risk aversion implies that portfolio holders pick the strategy that utterly eliminates risk, setting aside any potential rewards. This is not true even in pension fund portfolios. Furthermore, a very important, if not the most important point of risk, is that risk aversion is not and should not be seen as a constant across time since it can fluctuate based on the stage of the economy. In addition, major events very often have a significant impact on portfolio managers as well as the holders, as they suddenly tend to become overprotective with their portfolios.

Cotter and Hanly assessed and analyzed the various utility-based optimal hedging approaches based on the risk preferences of energy market participants. By addressing the disparate risk attitudes of energy hedgers, it raises an issue of critical importance for all types of energy market participants, at a time when energy price swings are becoming increasingly unpredictable and risk attitudes have shifted dramatically in response to global financial shocks such as the corona virus. They develop a technique that incorporates time-varying risk aversion and applies it to time-varying hedging ratios adjusted for a variety of utility functions. Additionally, they use this method to both crude oil and natural gas.

The methodology, which is used to calculate the hedging ratio, is by the use of ARA and CRRA variables, as measurement of the risk aversion of the hedger, while at the same time not leaving aside the level of wealth of the investor. ARA is the “absolute risk aversion”, and it gauges the hedger's reaction to changes in wealth in dollars. CRRA, on the other hand, considers the investor's present level of wealth, and it simply records the percentages of investments in risky assets relative to percentages of investments in risk-free assets. (LEVY, 2020) It is used to show the hedger's attitude with a simple number, as it must be put into hedging models as the hedger's specific preference.

When incorporating these variables in the models, there are considerable disparities in hedging tactics based on risk attitudes of energy hedgers as expressed by the different utility functions. These discrepancies are most noticeable for non-normal data, which is characterized by skewness and kurtosis. Because this often applies to energy assets such as oil and natural gas, the conclusion for hedgers is that they should optimize their hedges by expressly bringing their own risk perception and utility into consideration. The findings also show that players in the energy market have risk aversion that is generally comparable to that observed in the asset pricing literature, particularly in the equities market. Moreover, investors' risk views tend to change with time, and this is especially true for the most recent era. In addition, it is observed that these shifts in risk attitudes are especially relevant to energy hedgers, and more research in this area might give new insights into strategies, to meet the hedging demands of energy market players. (Cotter, 2010)

This section investigates the significance of using basic economic factors to explain price returns and volatility in order to increase hedging efficacy. It mainly focuses on the rapidly increasing industry of the natural gas.

4.3 Determinants of Natural Gas Prices

Understanding how to correctly estimate gas price and volatility is a critical step in sustaining an effective hedging strategy. To that aim, it is worth examining the fundamental factors of the market into the price and variance equations and when estimating the market outcome, keeping them as control variables, we can find the optimal hedge ratio utilizing the DCC-MGARCH models to account for hedge ratio non-linearity and non-constancy. Natural gas storage, crude oil prices, meteorological information, and macroeconomic news are among the specific aspects evaluated. This highlights the relevance of these variables in determining natural gas pricing and volatility, as well as how hedging efficacy may be enhanced. The empirical findings indicate that various basic market determinants had a major impact on the level as well as volatility of the gas price, and that the optimal hedging ratio varied over time. Hedging efficacy might be considerably enhanced by adding time-varying hedging ratio models and market fundamental factors, highlighting the need of using increasingly complex econometric models and market fundamental elements to properly manage commodities risks.

Storage Impact

The effect of natural gas storage on gas prices is both a theoretically viable thesis and an experimentally observable pattern. Since Holbrook Working's storage theory was published in 1933, the link between storage and commodity prices has been debated. In 1958 a connection was established between the value of a storage commodity and the amount of commodity in storage, emphasizing the significance of how storage affects the yield of keeping the commodity. Later though, an expansion of the idea of storage was proposed, claiming that the changing amount of a commodity in storage might cause price volatility.

A study of (Chiou-Wei, Chen and Zhu, 2004) concentrated on the conditions of natural gas supply and demand as expressed in storage injections or drawdowns. They evaluated the influence of gas storage infusion or drawdown on the residual volatility in the prices of natural gas futures. Furthermore, in the last decade, empirical data have been published that support storages' strong effect on natural gas pricing and volatility. During the same time period, they were examining the projections in the market of natural gas storage and the role of analysts in promoting price forecasting in futures markets. They discovered that the market moved along the expectations for a weekly storage release on analyst estimates, and that it appeared to place more significance on analysts the long-term accuracy than on their short-term accuracy. (Gay et al., 2009).

The announcements of the inventory have also had a significant impact on the price dynamics of energy derivatives. The impact of oil and gas inventory announcements on energy prices was investigated and was found that changes which are not expected in inventory, affected energy prices more significantly (Halova et al., 2014). Furthermore, using intraday data from January 1990 to January 2008, it was detected that increases in daily futures prices and intraday surges surrounding crude oil, heating oil, and natural gas inventory announcements. They discovered that substantial jump components were frequently connected with the dates of the Energy Information Administration's inventory announcements, and volatility and the volume that was traded were larger on days with a jump at the announcement than on days that a jump had not occurred at the announcement. (Bjursell et al., 2015)

Oil price

Because they are both hydrocarbons, oil and natural gas are inextricably linked. They are close substitutes in consumption because oil and gas may be used interchangeably to some extent in both industrial production and consumption processes. On the production side, oil and gas are likewise linked. Associated gas is frequently produced by oil wells. Natural gas liquids are also thought to be good alternatives for oil. Oil prices have always been linked to natural gas prices. For example, there were persuasively established the links between oil price and gas price and there was demonstrated evidence that oil price remained a significant influence driving natural gas price even after 2008, when oil and gas prices showed some clearly contrasting patterns (Roberts, 2008). According to Perifanis and Dagoumas (2018), there are considerable price and volatility spillovers between the oil and gas markets. As a result, it is of extreme importance to consider the impact of oil price on gas price. (Perifanis and Dagoumas, 2018)

Weather Factors

Weather is clearly behind the pricing of many agricultural and energy commodities. The relationship between weather and commodity prices has been long studied, in order to extract the causal linkage. It is analyzed, not only for the climate and its evolution and how the variable of temperature influences the market prices, but also for isolate events, and their ramifications. As an example, it has been shown, that a particular weather event, El Niño–Southern Oscillation, influenced the production of crops and has been associated with low grain yield (Hansen et al., 1998). Industries like the agricultural and energy have been marked as weather sensitive industries. Both industries, are highly dependent on weather, which means that their profit margins, their costs as well as their demand is highly correlated to the fluctuation of the weather (Lee and Oren, 2009). However, in this case, weather should not be understood as seasonality. Jet fuels and gasoline have high fluctuations according to which season it is, however, it has nothing to do with temperature. The sectors of electricity, the heating oil, and the natural gas, are strongly correlated due to the sensitivity to temperature. In addition, it has been proved that electricity prices are directly influenced by the weather. (Hong et al., 2013)

Despite the fact, that weather has direct and large effects on prices of natural gas, not many studies have been made to explicitly analyze and measure this fact. It is, besides, one of the critical reasons, why natural gas market is one, if not the most, volatile markets.

In the hedging effectiveness analysis that is following, in order to be captured the impacts of weather in natural gas prices, there are used several weather variables, like humidity and temperature, and hold the assumption that they affect the demand in a direct way. This assumption is obvious, as one of the main uses of natural gas is augmented energy needs for heating spaces (it should be added that it does not matter if it used directly to produce heat or indirectly, as electricity that will be used for heating)

Macroeconomic News

The effects of macroeconomic news in commodities prices were acknowledged from early on. Already from the 80's, studies determined the influence of monetary factors and discovered that interest rate shocks and decreases in money supply, drove commodity prices to rise. (Frankel and Hardouvelis, 1985) In addition, it has been shown that announcements of economic news have a key influence in prices and quantities traded when the news hit the market, and this stands true especially in periods that there is high uncertainty. (Fleming and Remolona, 1999)

The "employment situation summary" elicited the strongest financial market price responses to macroeconomic news releases. (Hautsch and Hess, 2004) while data supported the notion that commodity prices were subject to market-wide shocks, and they argued that macroeconomic pronouncements had a significant impact on the prices of commodities. More recent studies, however, suggest that the ramifications of these announcements, have quite constant effects overtime, as well as they were relatively symmetrical. Nevertheless, the influence of the good news was different from the influence of bad news. (Kilian and Vega, 2011)

Another aspect that was investigated, was the time-varying volatility and ripple effects in energy markets (natural gas, heating oil and crude oil) by adding changes in key macroeconomic factors, such as major political and meteorological events, in the conditional variance equations. The finding discovered suggests that there are asymmetric effects in random disturbances but also in macroeconomic factors, and crude oil volatility was observed to rise following important financial, natural events and political events.(Karali and Ramirez, 2014).More precisely, in the case of the United States, it was investigated the impact of monetary policy shocks on energy prices and discovered a strong correlation of energy prices to sudden changes in the target rate of the federal funds in the intraday period immediately after the monetary announcement. (Basistha and Kurov, 2015)

Findings suggest that there is a correlation and macroeconomic announcements can spike natural gas prices and thus have a strong impact at energy volatility. Regarding the findings that will be discussed further below, the variables which have been taken under account and have been incorporated into the models, are only a small number of representative economic news announcements, advance retail sales, business inventories, changes in nonfarm payroll, home starts, industrial production, and construction expenditure to determine the impacts of economic news announcements on gas price levels and returns, with a focus on hedging efficacy.

4.4 Hedging Effectiveness

Following Ederington, hedging effectiveness is defined as "the gain or loss in the variance of terminal revenue due to price changes in an unhedged position relative to those in a hedged position". (Ederington, 1979)

Zhu, Chen, and Chiou-Wei developed five forecasting models for empirical estimate, which have the following structure: The first model is the main model for comparison with the error correction model term and the values of lagged futures and spot price return in the conditional mean and conditional variance equations added. The second model is based on the first model specifications with the variable for lag in storage. The third model is built on the second model, and it features delayed weather shocks. The fourth model is based on the third model and contains macroeconomic news factors that are lagged. Lastly, the fifth model is built on the fourth model and adds the lag in WTI spot oil price returns. The basic market factors are included in both the equations of mean and variance.

Table 2: Hedging effectiveness under different model specifications

Model Specifications	Mean of Hedge Ratio	Variance of Unhedged Portfolio (%)	Variance of Hedge Portfolio (%)	HE (Hedging Effectiveness)(%)
Panel A. Weekly data				
Model [1]	0.9244	0.5665	0.1977	65.1039
Model [2]	0.9551	0.5665	0.1478	73.9121
Model [3]	0.9624	0.5665	0.1194	78.9160
Model [4]	0.9855	0.5665	0.1041	81.6262
Model [5]	0.9905	0.5665	0.0862	84.7795
Panel B. Daily data				
Model [1]	0.3312	0.5210	0.3465	33.5012
Model [2]	0.4183	0.5210	0.3224	38.1260
Model [3]	0.4239	0.5210	0.2951	43.3663
Model [4]	0.4812	0.5210	0.2388	54.1635
Model [5]	0.5253	0.5210	0.2141	58.8996

Note: Model [1]: Base model. Model [2]: Base model with storage, weather factors and macroeconomic news in conditional mean equation. Model [3]: Base model with storage and weather factors in conditional mean and variance equations. Model [4]: Base model with storage, weather factors and macroeconomic news in conditional mean and variance equations. Model [5]: Base model with spot WTI crude oil return, storages, weather factors and macroeconomic news in conditional mean and variance equation.

Source: (Chiou-Wei et al., 2020)

As table 2 suggests, for weekly data, they discovered that the mean hedge ratio from DCC-MGARCH varies from 0.9244 (Model 1) to 0.9905 (Model 5). The average hedging ratios for daily data, on the other hand, are much lower, ranging from 0.3312 (Model 1) to 0.5253. (model 5). This implies that the co-movement of spot and futures prices is substantially smaller on a daily basis than it is on a weekly one. The standard deviation of unconditional volatility spans from 0.2145 (for Model 1) to 0.4256 (for Model 5) for the case of weekly data but from 0.2131 (Model 1) to 0.2653 (Model 5) for daily data. For any hedge ratio series, the skewness coefficients are positive. All the calculated hedge ratio series have kurtosis coefficients greater than three.

The variations and hedging ratios of daily and weekly data fluctuate significantly. This is attributed to the fact that daily price variations are greater than weekly average price fluctuations because the weekly average price has removed more extreme daily price volatility.

The main findings are provided in Table 2 and are centered on variance reduction of the portfolios which are hedged relative to positions which are not hedged, under various model configurations. The dynamic hedging technique employing DCC-MGARCH models without including any market fundamentals worked for the natural gas market, reducing variation by more than 60% for weekly data. Accounting for the time-varying nature of the hedging ratio in daily data would result in a 33% decrease in portfolio variance. The hedging efficiency rises when more market fundamental factors are incorporated in the model (in the order of Model 2 to Model 5). Simply adding the storage reaction variable in the mean and variance equations would increase the hedging effectiveness from 65% to 73% for the case of weekly data and from 34% to 38% for the case of daily data. When all factors are considered, the hedging effectiveness rises to 85 percent for weekly data and 59 percent for daily data. Incorporating economic factors boosts the hedging effectiveness by more than 20% for both weekly and daily data cases.

The price risks that investors in financial assets confront might be significant. This is especially true for players in the energy industry, such as investors, producers, and consumers. How to successfully manage risk is a constant concern.

The impact of including fundamental elements in commodity pricing models is examined, with a specific focus on the natural gas market. Natural gas price and volatility have been estimated using a variety of basic parameters such as storage news, oil price, meteorological information, and macroeconomic news announcements. According to the modeling results, including these parameters enhances model performance and leads to more accurate calculation of the ideal hedge ratio.

The calculated findings also show that the optimal hedge ratio varied quite a bit over the study period. There were also structural breakdowns in the predicted hedge ratios. Therefore, hedging against price risks in the energy market, and especially in the case of the natural gas sector, necessitates portfolio hedging that is dynamic. The examination of hedge efficacy using various models reveals that hedging with a fixed hedge ratio might result in mediocre hedging performances, but dynamic hedging with time-varying hedge ratios guided by the theory can greatly increase hedging efficiency.

Even though dynamic hedging and integrating all economic information can considerably increase hedging efficacy, there may be certain practical challenges associated with its implementation. One such concern is the cost of dynamic hedging because of continual portfolio rebalancing, which is predicted to significantly raise transaction costs. The second difficulty is that in order to accurately estimate the price and volatility of asset values, one must have solid fundamental data. In the gas market, accurate information on the basic market factors, including at least the variables represented in this work, is required. In practice, reliable estimates of these factors are required for successful price and volatility modeling. While reliable estimates might be difficult to get, market players should actively seek this data. (Chiou-Wei et al., 2020)

4.5 Conclusion

To summarize, hedging should not be a standard process for all firms, but rather a method tailored to the risk tolerance of the organization adopting it, with utility-based hedging strategies being presented. In addition, while evaluating price returns and volatility, various factors should be considered. Furthermore, taking the gas market as an example, it is demonstrated how market fundamentals like as macroeconomic news, storage reports, and weather conditions can significantly boost hedging efficacy. It's critical to evaluate the fundamental characteristics of the market while looking at commodity price movement and enhancing hedging efficiency of the market.

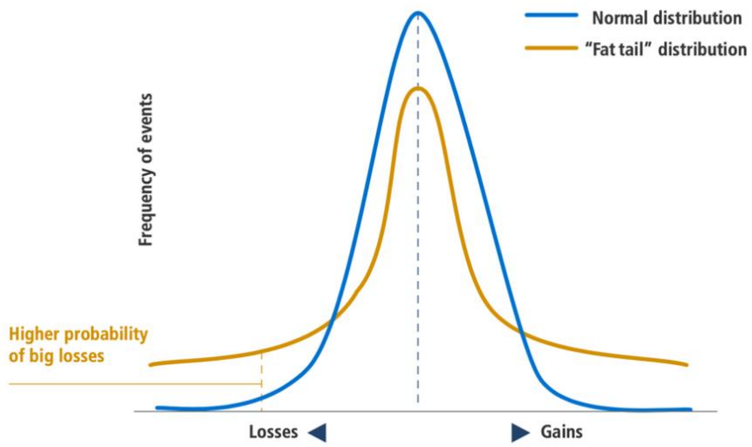
5. Concept of tail risk

5.1 Introduction

Tail risk implies that the probability that an investment will go beyond three standard deviations from the mean, is higher than the one from a normal distribution. When constructing an asset portfolio, it is commonly assumed that the distribution of returns would follow a normal distribution. However, it has been proved that this is not the case.

Based on this hypothesis, the likelihood that returns will shift between the mean and three standard deviations, either positively or negatively, is 99.97 percent. That indicates that the likelihood of returns deviating more than three standard deviations from the mean is 0.03 percent, or nearly zero (Brereton, 2014). However, as illustrated in Figure 1, the idea of tail risk implies that the distribution has wider tails, rather than being normally distributed. The larger the tails, the more likely it is that an investment will go beyond the highly improbable.

Figure 1: Normal and Fat Tails distributions



Source: (Hoffmann and Djordjevic, 2020)

Generally, investors, including certain tail risk hedge funds, have purchased low-cost, long dated put options, which have given them the option to sell a security in the future. Such trades are by far out of the money and provide a significant discount to the current spot price. The position can be financed by obtaining premiums for selling put options in the short term, which provide the buyer the right to sell at a price close to the spot market price. Because of the short time length, the payment before expiration is limited. The strategy's drip feed of tiny losses in steady market circumstances leads to a significant profit when markets sell down rapidly. (Nasdaq, 2015)

After the 2008 Financial Crisis, traditional financial theories were called into question for their failure to describe risk in a realistic manner. (Gadea Rivas and Perez-Quiros, 2015) Traditional asset pricing methodologies frequently depend on a typical bell curve to create market assumptions; however, markets do not operate in this manner. A normal distribution has the overwhelming amount of asset variance inside three standard deviations of its mean, which understates risk and volatility.

Interestingly, history suggests that financial markets do not often behave in this manner, but rather have broader tails than it is generally assumed. Fat tails are statistical phenomena characterized by high leptokurtosis. This increases the chance of occurring dramatic events such to the financial crisis. Left tail occurrences may have a catastrophic influence on portfolio returns since the size of fat tails is so difficult to forecast. As a result, adequately preserving a portfolio necessitates tail risk hedging against unexpected market shocks.

5.2 Normal Distribution

To comprehend the relevance of tail risks, one must first comprehend the concept of a normal distribution and its flaws. If we have enough observations, a normal distribution assumes that all values, will have an equal distribution above and below the mean. Because 99.7 percent of all variances lie within three standard deviations of the mean, there is only a 0.3 percent chance that an extreme event will happen. Many econometrical models, including Modern Portfolio Theory, Efficient Markets, and the Black-Scholes option pricing model, all presume normal distribution. Yet, the market is far from flawless and is heavily impacted by unexpected human behavior, leaving us with large tail risks.

5.3 Fat Tails and Financial Crisis

The aftershocks of the 2008 Financial Crisis exposed the flaws in traditional financial thinking. Even when everything appears to be regular or well-planned, unexpected occurrences might nevertheless pose a hazard. These potentially disastrous incidents show the continued importance of fat tails in the financial industry. (Nasdaq, 2015)
As previously discussed, fat tails are distributions of probabilities which happen more often than in the case of normal distribution, in the part of the three standard deviations and further. Even prior to the financial crisis, times of financial stress occurred in market conditions characterized by larger tails. This is significant because normal distributions overstate asset values, stock returns, and risk management measures.

A variety of events, including subprime loans, credit default swaps, and high leverage ratios, contributed to the 2008 Financial Crisis. Consequently, significant corporations failed (Bear Sterns, Lehman Brothers), markets fell, and the international economic system's base was weakened. Before this, financial organizations looked to be functioning without risk due to the flaws of normally distributed models. Because 99.7 percent of fluctuations occur within three standard deviations of the mean, the notion of apparent gains and invisible losses created a particularly risky financial climate. To manage tail risk effectively, modeling must include how asset performance relates to and contributes to future fat tails.

5.4 Tail Risk Hedging

Being aware of severe occurrences linked with fat tails is insufficient to safeguard an investment against economic volatility. The optimal portfolio will not only deliver a reasonable return for each unit of volatility but will also offer some protection against tail risk. Tail risk hedging necessitates a conscious preference for minimizing downside risk at the price of higher profits. Liability hedging and diversification are two ways for reducing tail risks.

Diversification is the perhaps an essential idea in investing, and it entails holding a variety of uncorrelated asset types. Derivatives and, in particular, the CBOE Volatility Index, which may be leveraged to scale risk exposure, are attractive assets for diversifying against tail risk. In fact, this method has its drawbacks since it might be tough to close off derivatives holdings under certain market situations. (Ibragimov and Prokhorov, 2017)

There are good reasons why we cannot count on forecasting models. Evidently, there is no basic theory that may offer a distributional model for returns, and the issue is mainly statistical. Nonetheless, a large number of empirical studies conducted since the 1950s yields the following stylized facts: (Stoyanov et al., 2011)

1. Volatility clustering occurs when big price fluctuations are followed by huge price swings, and modest price changes are followed by modest price changes.
2. Autoregressive behavior — price movements are influenced by previous price changes, e.g., positive price changes are likely to be followed by positive price changes.
3. Skewness – The positive and negative possibilities of price fluctuations are asymmetric.
4. Fat tails are situations in which the chance of extreme gains or losses is significantly higher than indicated by the normal distribution. The thickness of the tail tends to vary from asset to asset.
5. The temporal behavior of tail thickness - the chance of extraordinary gains or losses varies with time; it is lower in routine markets and considerably higher in tumultuous markets.
6. Tail thickness changes with frequency: high-frequency data has thicker tails than low-frequency data.

Any statistically valid time-series model able to detect and incorporate these stylized facts and an adequate risk measure can serve as the foundation for a risk measuring approach.

Aside from comprehensive distribution modeling, another way for simulating extreme occurrences exists. It is derived from the extreme value theory, which was established to simulate extreme phenomena in nature such as severe winds, temperatures, and river levels, but it only gives a model for the distribution's tails. This model has already had some applications in insurance and finance from 1997 (Zachary, 1999).

Though it appears to be broad consensus in the post-crisis period that financial assets are fat-tailed but also that asset portfolio managers must account for severe events as part of their daily risk management operations, the view in academia is not as uniform. There are productive efforts underway to identify factors trying to explain tail events that can possibly be hedged (Stoyanov et al., 2011) or to confirm whether the observed trends in correlations during market shocks are not creations of the implied assumption of normality (Harvey, 2009). In striking contrast, other articles, argue that fat-tailed models must be avoided in favor of Gaussian-based models due to parsimony.

Although simpler models that describe all stylized characteristics of the data are favored over more complicated models from a statistical standpoint, representation should not be traded for simplicity. To put it in other words, models must be as simple as possible without being too simplistic.

5.5 BLACK SWAN events

Tail risks consist of two types of events. The ones which are rare but are anticipated some unknown time in the future, and the ones someone has not even imagined of, no matter how simple or complex their nature might be.

The black swan concept, also known as the notion of black swan events, is a metaphor that represents an event that is unforeseen and happens with great surprise, has a significant impact, and is frequently poorly justified after the fact with the advantage of hindsight. The word is derived from an old proverb that assumed black swans did not exist — a proverb that was reinterpreted to convey a different lesson following the first European experience with them (Taleb, 2008).

Nassim Nicholas Taleb created the idea to explain the disproportionate importance of high-profile, difficult-to-predict, and uncommon occurrences in history, science, finance, and technology that are beyond the sphere of typical expectations. No one could have predicted an event like the 9/11, no matter how obvious (at least some of them) look in a retrospective way. Of course, anyone can explain it after it happens, and since its explanation looks so simple, people fail to understand that it does not matter if this will happen again. What matters is that the world is full of this kind of random events, by definition, impossible to forecast, which huge ramifications. However, black swans should not be mixed up with extremely rare events. For example, corona virus, does not meet the criteria for a black swan event, as it is an event, which is not unknown to human beings, as we have encountered quite a few in our history as a species. It is simply an event that appears very rarely, and it is wrong to try to classify it and statistically measure it, as no one can say that the next one will be in a year, a decade, or in a century from now (Taleb, 2008).

For the very same reason, there is a total inability of scientific methods to compute the likelihood of important rare events (due to the nature of low probability). Due to extremely low number of occurrences, there cannot be a statistical representation of these events, when realistically talking. Lastly, the psychological biases mislead people, both collectively and individually, to uncertainty and the tremendous impact of a rare occurrence in historical affairs, over-reacting after the occurrence and over estimating the probability of the event happening again, if it happened recently, and underestimating the event if it hasn't happened for so long. Examples of the above are the fear of entering a plane after a plane crash has been on the news, and on the contrary, the fact that no one took seriously a person like Bill Gates, when 3 years prior to the appearance of corona virus, he was warning us that we are not prepared, for such an event.

5.6 Preparing for the unpredictable

Tail risk hedging may be an effective approach for assisting investors in achieving their goals without having to drastically change their risk or return expectations during a crisis period. Traders can use tail risk hedging in a variety of ways. Limiting asset allocation risk by weighting portfolios toward less volatile industries is one strategy. Another approach is to maintain consistent asset allocation while supplementing it with tactics such as equity puts, credit protection, currency, and interest rate options. Derivative-based strategies pose unique risks. In some market situations, it might be hard to close down derivatives contracts, and with particular derivatives, it is possible to lose more than the initial investment. Given the complexities of actively maintaining and executing these hedges, experience is essential, which is why many investors and financial advisers turn to professional investment managers to incorporate such a strategy into their investment plans.

5.7 Cost of tail risk hedging

Hedging strategies can incur some short-term expenses, but they are intended to increase return potential over the long term of the company's lifetime. The way this happens is by minimizing losses in the event of a market shocks, and by offering liquidity in periods of crisis which allows investors to acquire assets at fire-sale prices while others are obliged to sell. In addition, it allows trader to undertake larger risks in different part of their portfolio structure. Lastly, it is a safety net that can be proven to be critical for the existence of the company. It is obvious so far, that market shocks can be fatal for companies, especially for the ones which are not considered as the giants in their industries. The latter ones may -and usually do have- second chances, as they usually get state aid or additional loans from their banks, as they are too big to fail. Anyone who does not belong to this category, basically most of the companies, ought to hedge the risk of these rare events, whose consequences are vastly greater and more destructive, than any normal short-term “hiccups” of the markets.

5.8 Conclusion

Tail risk is a type of portfolio risk that happens when the probability of an investment moving more than three standard deviations from the mean is greater than what a normal distribution suggests. When constructing an asset portfolio, it is commonly assumed that the distribution of returns would follow a normal distribution. However, it has been proved that this is not the case. Most firms tend to protect themselves against short-term risks and volatility, leaving them vulnerable to severe occurrences that are unusual but have long-term devastating consequences and can even lead to the company's bankruptcy. Companies must invest in the long term and hedge accordingly, for uncommon situations, including black swans, that cannot be predicted, and will essentially establish a limit that the company will never have to surpass under any circumstances, ensuring this way its long-term minimization of losses.

6. Conclusion

The purpose of this work is to present an integrated approach to hedging. It seeks to integrate the concept of hedging in such a manner that all key elements are considered. In most situations, hedging papers and techniques focus almost entirely on specifics (particular models, specialized instruments), leaving out the most crucial aspect: the overall picture.

Portfolio managers employ several econometric models in order to monitor and adjust the hedging ratio. An ideal hedge ratio is a risk management investment ratio that specifies the percentage of a hedging instrument, that a firm needs to hedge. The most widely used models are OLS and GARCH, although they have significant drawbacks and limiting assumptions that appear to lead to inaccurate conclusions.

Among the hedging techniques and strategies, it is proposed that hedging should be a procedure tailored to the profile of the business implementing it and its risk tolerance, rather than a standard operation for all firms. It is also presented whether basic characteristics of each industry, like macroeconomic news, weather reports and storage reports (in the case of gas) should be incorporated into price returns and volatility calculations. It is essential to incorporate basic market elements into the models, while assessing commodity price movement to enhance hedging effectiveness.

The paper's most important argument is that it highlights the flawed assumptions that existing techniques and tools have, which lead to relatively unrealistic outcomes, and secondly, it emphasizes long-term risk reduction. Most firms tend to protect themselves against short-term risks and volatility, but they are left vulnerable to severe occurrences that are unusual but have long-term devastating consequences and can even lead to the company's bankruptcy.

Fat tails are typically ignored since most models evaluate just short-term variations, ignoring unusual occurrences that might have devastating consequences for the organization. This is understandable, as no model that just reflects the past can forecast the future. What can be done is to employ a "dual" hedging strategy. On one hand, one strategy for short-term hedging, which may be based on current models and their results while also adding the critical characteristics of the market on which the hedge is based (for example, in the case of gas, storage, weather, macroeconomic news, and so on). On the other hand, the second parallel strategy which will focus to hedge the firm in the long-term, for uncommon situations, including black swans, that cannot be predicted, and will essentially establish a limit that the company will never have to surpass under any circumstances, ensuring this way its long-term minimization of losses.

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