

## Department of Business and Management

Master thesis in Advanced Corporate Finance

# ENERGY DERIVATIVES AND RISK MANAGEMENT

SUPERVISOR: Prof. Raffaele Oriani CANDIDATE: Alessia Gidari 643081

CO-SUPERVISOR:

Prof. Simone Mori

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## Abstract

This thesis aims to provide an overview about the relevance of risk management practises and energy derivatives for the energy companies.

The energy sector, characterized by a high degree of uncertainty, is particularly interesting to study this topic, because its business is highly dependent on commodity price risk exposure. The research conducted in this work will be oriented to find out how companies operating in this sector may deal with risk, and the instruments available to hedge against it.

Energy derivatives will be regarded as the main hedging instruments, but if on the one hand companies may take advantage from their use, they can also become source of volatility, if they actually contribute to increase the exposure. Thereby, this thesis is also committed to describe risk management systems and quantitative tools that companies necessarily need to use in tandem with derivatives, in order to control their exposure.

The goal will be that of showing the benefits that risk management may provide to energy companies and, under which conditions, energy derivatives may be effective hedging instruments.

## Introduction

Energy markets are a collection of commodities, such as oil, gas and electricity, differing in composition but all having in common a high degree of volatility. A high level of uncertainty, strengthen by deregulation in most of energy markets, comes from the commodity price risk exposure, related to the consequences that commodity price fluctuations could cause to the companies operating in the energy sector, both from the offer and demand sides. It is sufficient to imagine the consequences that an *oil shock* would cause to the energy companies' profits if they did not care about risk. Indeed, despite their differences, "today's energy markets follow the same impulses: energy producers and users alike wish to hedge their exposure to future uncertainty [...]" (Pilipovic, 1998).

Given the magnitude of energy risk, the energy sector becomes an interesting focus for the aim of this thesis, that is studying the use of risk management practises, and in particular of derivatives, to hedge against risk. This focus leads to discuss about a particular kind of financial instruments used as hedging tools in the energy markets, that are the energy derivatives. Energy forwards, futures, swaps and options, their combinations and the strategies built with them, are the most intuitive tools applied by the energy companies to hedge against energy risk. Nonetheless they are only a part of the risk management systems that many energy companies built to deal with risk, made by organizational practises, risk culture, risk department and CRO figures in some cases, as well as quantitative tools, risk metrics, to keep control of risk and to use in tandem with energy derivatives. In fact, if on the one hand energy derivatives are applied for a hedging purpose; on the other hand, they can lead to increase the exposure if incorrectly used: metrics, like VaR, need to be used as well, to provide a measure of the risk involved in an energy derivatives portfolio.

Although they will be shown as useful financial instruments to take an opposite position to that of the risk in the market, so to mitigate it, the role of derivatives in the current crisis is widely documented (Oldani, 2012). As a result, they need to be used in an integrated risk management system within the enterprise.

In order to discuss the above mentioned topics, and to answer to a research question, requiring to illustrate the benefits of energy derivatives and risk management for the companies operating in the energy sector, this thesis follows a logical process spread out five chapters.

After this short introduction, the beginning of the work, in the first chapter, is made of a general definition of risk. Risk definitions from literature, applied to the enterprise, are provided to the reader, because to deal with something, it is essential to have a knowledge about it. Together with risk definitions, the most known risk measures are illustrated, starting from the elementary variance and standard deviations, to arrive to the models linking risk to return, such as CAPM, APT and Fama and French models. Then, the role of risk in corporate finance and capital investment is treated, as well. The analysis of risk from different points of views is necessary to introduce the reasons why firms hedge. Moreover, a paragraph is devoted to the shift from hedging to risk management, made essential by the volatility of some businesses (like the energy one), where risk may be perceived not only as a threat but also as an opportunity (Damodaran, 2007). This last step is *ad hoc* to forecast the topic of the second chapter. The second chapter is about risk management within the firm, the so-called Enterprise risk management (ERM). Several definitions of this system have been found, but all agree about the fact that ERM is an integrated system of actions that companies take to deal with risk. It is generally put in practise within a framework (like COSO's one), usually made by the phases of risk identification, assessment and response, followed by monitoring activities. Hedging and energy derivatives belong to the risk response phase, in the case a company decides to pursue the mitigation strategy. A more practical part of the chapter is devoted to concrete examples of how energy companies apply ERM, found in literature or taken from some energy companies' websites. The usefulness of the given examples relies in the willingness of this thesis to

show the practical benefits of risk management practices for the energy companies, that are becoming important supports for strategic decisions, as well.

The ERM is not only made by organizational practices, but it also needs to be supported by quantitative tools, to quantify and measure the risk. Indeed, the third chapter provides an overview about the quantitative methodologies used with this purpose. VaR and similar measures are proposed as the main risk metrics to use in tandem with energy derivatives, because they also evaluate the risk involved in a portfolio of derivatives. Among all the techniques to compute VaR, a particular mention is for the Monte Carlo method, because it seems to be the most suitable technique to simulate the price fluctuations in a highly changing environment, like the energy one.

In the fourth chapter, the focus is on a specific tool of risk management, which is that of the energy derivatives. An introduction of derivatives in general forecasts the description of energy forwards, futures, swaps and options, with some indications about their evaluation and of the markets where transactions take place (in Exchanges or over-the-counter). Then, numerical techniques for the valuation of derivatives, such as Monte Carlo simulation and trinomial trees, and numerical techniques to hedge the exposure, are described, as well.

Finally, after a long work with the ambition of providing a complete descriptive overview about the central topic, an applicative fifth and last chapter follows.

Some applications of the practise of hedging against energy risk are proposed, in order to give the reader a concrete idea about the use of energy derivatives. Simple numerical examples for each commodity (oil, electricity and gas) are given, in order to observe how the financial instruments studied in theory actually work, and to capture the gaps among commodities, as well. Moreover, some concrete case studies, coming from geographically different markets or sectors directly or indirectly related to commodities, are mentioned. This further step is done in order to have an evidence of the benefits, but also the pitfalls, derived from the concrete application of these instruments.

The final part of the thesis includes some criticism, that makes the core discussion of the research to emerge. If on the one hand, energy derivatives are source of benefits for energy companies, because they allow to hedge against energy risk; some cases, like the Enron one, show that a misleading use of them may cause the opposite effect. Thereby, the debate of the work, as follows, shows which are the conditions, the methodologies and the practises, that may forecast a correct use of energy derivatives, so that they can produce the beneficial effects companies may take advantage from.

## **Chapter 1**

## **Risk management**

#### 1.1. A brief historical background

It is not an easy task to provide a unique definition of risk management. In the financial literature, there is a plenty of definitions (Crockford, 1982).

Furthermore, the origins of this phenomena are not of the modern age: even the Egyptians cared about risk (Froot, Scharfstein, and Stein, 1994).

Despite the interest that this argument may have had in ancient times, the historical step we are most interested in, for the purpose of this thesis, is the use of "risk management as a formal part of the decision-making process within the companies, traceable to the late 1940s and early 1950s" (Dickinson, 2001). Since then, companies demonstrated an increasing care about risk, such that "since the mid-1990, enterprise risk management has emerged as a concept and as a management function within corporations" (Dickinson, 2001).

The "Enterprise risk management" (ERM), that will be depth later on, is the use from the managers of methods and processes to manage various types of risks within the organizations.

The evolution of risk management led the multinationals to be "the principal users of risk management instruments" (Froot, Scharfstein, and Stein, 1994).

There are different methods they have historically used and they can choose to manage the risk. They can mitigate the risk through their investment decisions, through financing choices; they can alternatively choose to buy insurances for specific types of risks (catastrophic events, for instance); finally, they can transfer risk through derivatives (Damodaran, 2007). These latest, that will have a dedicated analysis, are the instruments I have decided to focus on as the tools of risk management, with a particular application to the companies operating in the energy sector.

#### 1.2. Risk definition and measurement

Before dealing with the risk management process, it is worthwhile to spend a word about what we mean for risk. To exist, risk must be characterized by two elements: uncertainty and impact on utility (Holton, 2004).

In finance, the risk may be considered as the probability of the potential loss.

"Two measures of the risk of a probability distribution are its variance and standard deviation" (Berk, DeMarzo, 2011). We mean for variance the expected square deviation from the mean, while the standard deviation is the square root of the variance.

Variance and Standard Deviation of the Return Distribution:

$$Var = E[(R - E[R])^{2}]$$
  
= 
$$\sum_{R} p \times (R - E[R])^{2}$$
  
-

When there is no risk, the variance is zero.

These are the most common measures of risk, despite they do not distinguish between downside and upside risk. In fact, as we will see in the further chapters, risk may be considered not only as a threat, but also as an opportunity (Damodaran, 2007). Nevertheless, they are not easy to interpret from the investors' perspective, more interested to the probability of loss than to volatility.

The VaR models are able to estimate the potential losses, through the variancecovariance methodology (Brown & Reilly, 2008).

$$VaR = R - k \times \Theta$$

where R is the average return; k is the confidence level we choose and  $\Theta$  is the standard deviation.

A big change in the risk consideration was introduced by Harry Markowitz, who linked the risk of a portfolio to the co-movement with the individual assets in that portfolio, and found out a set of optimal portfolios at specific risk levels, called "efficient frontier" (Damodaran, 2007). Since Markowitz's theory, what matters is not the volatility of an asset by itself, but its correlation with the portfolio. The intuition behind it is that, through diversification, it is possible to reduce the risk of the overall portfolio by joining assets moving independently one from the others. In a completely diversified portfolio, you have eliminated the specific risk of the assets and you only have the systematic one. From this assumption, the well known CAPM takes origin (Damodaran, 2007).

In the CAPM, the relevant risk measure for an individual risky asset is its covariance with the market portfolio, and its return is calculated from this risk measure related to the volatility of the market portfolio. If we call  $\beta$  the ratio of the covariance of the asset with the market portfolio to the variance of the market portfolio, here it is the final equation of the CAPM:

$$E(R) = RFR + \beta(Rm - RFR)$$

This model was even improved by the Arbitrage Pricing Model (APT).

The APT links the return of a stock to multiple factors and goes beyond the single market factor proposed by CAPM.

Macroeconomic indicators may be a starting point to build risk factors returns.

Chen, Roll and Ross (1986) introduced a set of macroeconomic variables capturing the effects of:

- Industrial production growth (business cycle risk factor);
- Default premium (confidence risk factor);
- Slope of the term structure (time horizon risk factor);
- Inflation dynamics (inflation risk factor).

Another proposition of the multi-factor model is the microeconomic-based risk factor model, where the risk is specified in microeconomic terms capturing the effects of some characteristics of securities.

This is the equation of the Fama and French three factors model (Fama and French, 1993):

$$r = R_f + \beta_3(K_m - R_f) + b_s \cdot SMB + b_v \cdot HML + \alpha$$

Where SMB stands for "small minus big" and is the return to a portfolio of small capitalization stocks less the return to a portfolio of large capitalization stocks; HML stands for "high minus low" and is the return to a portfolio of stocks with high ratios to book-to-market values less the return to a portfolio of low book-to-market value stocks.

This model was extended by Carhart (1997), who included a fourth common risk factor, called "momentum factor".

Another proposition of the multi-factor model is the "BARRA Characteristic-based risk factors". In this third model, a specific set of common N risk factors must be identified, and the risk premia for the factors must be estimated, as well as the sensitivities of the stock to each of those N factors. In this way, starting from the risk factors (volatility, momentum, size, size nonlinearity, trading activity, growth, earnings yield, value, earnings variability, leverage, currency sensitivity, dividend yield, non-estimation indicator), it is possible to get the return of a stock.

The illustration of the most common risk models has been useful to understand how companies measure risk and include it in their evaluation about stocks, and this is a basic point for the following analysis about risk management.

#### 1.3. The risk in corporate finance

"The role of risk management is to ensure that a company has the cash available to make value-enhancing investments" (Froot, K.A., Scharfstein, D. and Stein J.C., 1994). The meaning behind this statement is that companies create value only when they make good investments increasing their cash flows, but if they want to do that, they necessarily need to make financing decisions. According to the Modigliani-Miller postulate (Brealey, Myers, Allen, 2006), financing decisions should not alter the value creation. As a result, risk management strategies should have no implications too. Nevertheless, equity is commonly perceived as risky and debt can be costly and sometimes lead to distress and bankruptcy. Indeed, companies often prefer to use

internally generated cash flows and retained earnings to invest in projects, so that they can at the same time reduce risk and the cost of capital.

With this aim, risk management has the task to ensure that companies have enough cash to invest.

From here, you can ask why a company might not have cash. The answer is simple: because of risk. The fundamental facets of risk are: business risk, financial risk, liquidity risk, exchange rate risk and country risk, that are part of the systematic risk and are measured by the beta of the already mentioned CAPM.

Each industry and company is characterised by a certain level of uncertainty and systematic risk. Multinational companies are, more than the others, exposed to the exchange rate risk, due to the fact of operating in different currencies. An interesting example for the subject of this thesis, is the case of the oil companies, whose main risk is the oil price, directly positively related to their revenues. The goal of risk management, in this case, should be that of ensuring companies and investors against the oil price movements, and to make that oil companies have enough cash to undertake value-enhancing investments when they need.

"Risk management enables companies to better align their demand for funds with their internal supply of funds" (Froot, K.A., Scharfstein, D. and Stein J.C., 1994). In this way, they can reduce the imbalance of the lack in supply of some periods with the excess supply of some other periods. This strategy is called hedging.

#### 1.4. The reasons for hedging

As already told in the last paragraph, the reason why companies should hedge is "to better align the demand for funds with their internal supply of funds" (Froot, K.A., Scharfstein, D. and Stein J.C., 1994), and to reduce the imbalance caused by risk factors (exchange rate for multinationals or oil price for oil companies).

Anyways, companies must be aware that hedging strategies are not equal for all of the companies, because they vary with the different kinds of risks faced by industries and, even in the same industry, not all the firms necessarily must adopt the same hedging

strategy. Furthermore, managers should decide how much hedging according to the imbalance that a specific risk factor is expected to cause: it means that they do not necessarily need to hedge aggressively if a large imbalance is not projected; otherwise, it may be counterproductive. (Froot, K.A., Scharfstein, D. and Stein J.C., 1994). Finally, a cost-benefit analysis should be done, so that hedging is undertaken only if its costs do not overcome its benefits (Damodaran, 2007).

To understand what essentially drives the firms' hedging policies, we must look at the financial literature. The determinants of firms' hedging policies, that would explain why some firms hedge and some others do not, and why some risks are hedged and others are not, have been found to be three: taxes, cost of financial distress and managerial risk aversion (Smith, C.W. and Stultz R.M., 1985).

Hedging is convenient for tax purposes because hedging firms reduce the variability of pre-tax firm value, so that the expected tax liability is reduced and the post-tax value is higher (assuming a not large hedging cost).

The relationship between cost of distress and bankruptcy and hedging is positive, because firms can ensure and persuade the bondholders to finance them through the hedging policy.

Finally, managerial risk aversion is intuitively a reason for hedging especially when managers own part of the firm.

A definition for hedging is "the acquisition of financial assets that reduce the variance of firm's payoff" (Smith, C.W. and Stultz R.M., 1985). These financial assets are in the market of futures, forwards and options. The so-called "derivatives" are the tools of hedging and, for the greatest part, of risk management: they will have a dedicated analysis in the following chapters.

#### 1.5. The risk in capital investment

Risk has a strong impact on investment evaluation. Although it is already included in the cost of capital computation (for example applying the CAPM) and it is used to evaluate the investments applying the NPV, this may be not sufficient for situations characterized by a high degree of uncertainty (Hertz, 1964).

A more realistic measure of the risks involved in such a situation is obtained by examining different alternatives of actions: scenario analysis, simulations, decision trees ad real options are some tools to do it.

These methods may adopt mathematical formulas to compare the results of various investments, by varying the "inputs" behind the results. Indeed, "a simulation of the way these factors may combine as the future unfolds is the key of extracting the maximum information from the available forecasts" (Hertz, 1964).

Each of the outcomes is associated to a certain level of confidence and probabilities, and this helps to compare and evaluate the opportunities of investments in a more realistic way, respect to the simple NPV perspective.

In fact, this approach comes from the discovery of the pitfalls of the NPV model, that is not suitable to provide a fair evaluation when the investments have a high degree of uncertainty. NPV can be misleading for two reasons: it assumes that investments are irreversible and cannot be delayed (Dixit, Pindyck, 1995). Actually, most of investments are reversible and can be delayed.

Considering the investments as "opportunities" to invest, that a company can decide to exploit or less, may provide a more realistic evaluation. Investments become "options", whose value is higher for higher uncertainty and volatility, whose evaluation is worthwhile to understand when it is more convenient to exercise the option (Dixit, Pindyck, 1995). An interesting example about the use of the options to evaluate investments, especially for the argument of this thesis, is the evaluation of "Investments in Oil reserves" (Dixit, Pindyck, 1995). A company that buys a deposit faces the uncertainty to develop it immediately or later. The opportunity to develop the reserve is an option. Let's try to figure out what would happen if the evaluator

applied the simple NPV: a projection of the investment based on the current oil price would surely provide a wrong estimation, given the volatility of this input, that is why options are more suitable in such a situation. Using options, it is possible to know the timing when it is more convenient to invest. We know that "most of investment projects allow for the possibility of revaluating the decision to invest at a later point in time" (Berk, DeMarzo, 2011). Graphically, options may be represented as a "decision tree", representing the future decisions with the related uncertainty. You can apply the NPV to evaluate the project, by computing the probabilities with the possible outcomes at each node of the tree. Uncertainty and flexibility are the conditions for the existence of the option.

The Black-Scholes (Black and Scholes, 1973) formula is a mathematical model to price the option premium.

#### The Black-Scholes formula

 $C = SN(d_1) - N(d_2)Ke^{-rt}$  C = Call premium S = Current stock price t = Time until option exercise K = Option striking price r = Risk-free interest rate N = Cumulative standard normal distribution e = Exponential term s = St. Deviation

In = Natural Log

$$d_{1} = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{s^{2}}{2}\right)t}{\sqrt[5]{t}}$$
$$d_{2} = d_{2} - \sqrt[5]{t}$$

The Monte-Carlo simulation is another method to provide mathematical solutions for option valuation issues. It exploits the fact that "the distribution of stock prices is determined by the process generating the future price movements" (Boyle, 1977). The simulation is made through sophisticated softwares predicting the stock price trajectories; in this way, a set of values is obtained to calculate the option value.

#### 1.6. From hedging to risk management

It is very common to consider risk management as a synonym of hedging, such that the goal of risk management is considered as the minimization of the variability of cash flows.

On the other side, the evidence shows that "[...] some firms should hedge all risks, that other firms should not worry about risk at all, and finally, that some firms should worry only about some kinds of risks. Some firms have a comparative advantage in taking some types of risks; others do not..." (Stultz, 1996).

This means that the existence of a risk does not necessarily means that this risk must be hedged, because this is not automatically a threat. In order to understand if a company should hedge its risk, it is necessary to separate the risk management definition from the hedging definition, and to consider hedging as a tool and not as a consequence of risk management, that may be applied or less according to the contingencies. To study the contingencies, it is essential to devote much more attention to the other phases of risk management preceding hedging, which are: risk estimation, risk evaluation and risk control.

Damodaran (2007) outlined the main differences between risk hedging and risk management. They first have two different views of risk: for the former it is a threat; for the latter a threat but also an opportunity, especially for the firms that can earn a competitive advantage taking the risk. As a result, the objective is protecting from the downside for the former, and exploiting the upside for the latter. While hedging is financial oriented (focused on derivatives); the risk management process is strategic, because it is a cross-functional process. We can conclude that risk management is suitable for volatile businesses, with high potential of excess returns. In these cases, it may be used not only to prevent the downside risk through hedging, but also to create value by exploiting the upside opportunities.

It is not easy to answer to the question asking when a firm should hedge or not and how it should put in practice its risk management. We cannot say "ex-ante" what is the

optimal risk management application for each specific company, though it is not difficult to figure out the necessity of hedge for distressed companies, for instance. The risk management practices, with some applications, case studies and practical examples of enterprise risk management within some companies, illustrated in the following chapter, will be helpful to understand how this process is adopted and its contribution to the value creation. A particular focus will be devoted to the companies operating in the energy sector.

## **Chapter 2**

## Enterprise risk management

#### 2.1. Definition

"Enterprise risk is the extent to which the outcomes from the corporate strategy of a company may differ from those specified in its corporate objectives, or the extent to which they fail to meet these objectives" (Dickinson, 2001). These risks may come from internal or external sources, and may be under the control of the company or less: what matters is the possibility to measure and manage them.

Some actions companies take to deal with these risks are: pursuing a less risky strategy, outsourcing, buying insurances or hedging through derivatives.

In a broad meaning of the enterprise risk management, insurable and financial risks should be viewed as parts of the enterprise risk, because if there were no insurance and derivative markets, they would be treated like all the other kinds of risk (Dickisnson, 2001). This consideration has an important implication: before recurring to the derivative market as the place to deal with the financial risks, we necessarily need to put in practice the enterprise risk management process. Furthermore, being financial and insurance risks parts of the enterprise risk, the enterprise risk management is "a framework within they can be evaluated and managed" (Dickinson, 2001).

"Enterprise risk management describes the set of activities that businesses undertake to deal with all the diverse risk that face it in a holistic/ strategic/ integrated method" (Dafikpaku, 2011). It means that it is a process regarding the whole organization and it is a cross-functional process, affecting its strategy.

Since we are more interested in the financial implications of the enterprise risk management, a particular focus will be devoted to this aspect, that is the reason why most of the organizational peculiarities of the application of this process within the companies, will be left out from this analysis.

One more financial consequence of the ERM is that, as already mentioned in the last chapter, risk is considered not only as a threat but also as an opportunity: "the goal of risk management is to achieve the best possible balance of opportunity and risk" (Dafikpaku, 2011). The new conception of this approach is that, while before the aim was avoiding losses, now it means considering and managing all the types of risk at all levels in order to create awareness of the risk and, at the same time, protecting from the downside and exploiting the upside.

#### 2.2. Implementation

Frameworks are commonly used to implement the ERM within the organization: the COSO ERM integrated framework is one of them, developed by the Committee of Sponsoring Organizations of the Treadway Commission (COSO), in order to identify, to assess, to manage risk and to keep organizations focused on risk management. Of course, the framework provides a structure within building a company specific ERM, then determined by size, complexity, industry and peculiarities of each company (Dafikpaku, 2011).

COSO framework has been developed for companies to evaluate and improve their risk management in order to comply with their objectives but also with regulation. This framework implies a phase of "event identification", where the potential risk and opportunities are first viewed, followed by the "risk assessment". Once assessed risks and probabilities, a "risk response" must be formulated, according to the firm's "risk appetite". Finally, "control activities", "information and communication" and "monitoring" of the ERM should be performed in order to check the effectiveness of the process implementation. Being a process-driven approach, it is transversal in the organization and exploits the functional interdependencies (COSO, 2004).

The *risk assessment* is a critical phase because it classifies the risks by weighting their "likelihood of occurrence" and "relative impact" : in this way, risks are ranked from the less stringent to the most urgent, of course according to the profile of the company. As we know, one risk can be very dangerous for a company but irrelevant for another

one. The weighting system consists in setting priorities: a priority is low when either the likelihood of occurrence or the impact is below moderate (lower than 3 in a scale from 1 to 5); it is medium where both are between 2 and 4; it is high where they are both above or equal to 4. As a result of ranking, some response strategies, in the *risk response* phase, are formulated, by relying on a "risk response matrix" (Fig.1), according to the kinds of risk found in the preceding step. Generally, a "risk acceptance" is recommended when the severity of impact and the probability of occurrence of the risk are both low; avoiding the risk is necessary in the symmetrically opposite case. A mitigation or reduction of the risk should be pursued when the probability of occurrence is high while the expected impact is low; finally, sharing or transferring the risk should be done when the impact would be high but it is not very likely to occur (Dafikpaku, 2011).





A particular area of application of the ERM is the project management. As already told, risk has a role in evaluating projects, since it invalidates the simple NPV application for projects characterized by high uncertainty, forcing evaluators to apply decision trees, simulations and real options. For projects, risk management applies in three stages: risk identification, risk analysis and risk responses. Risk in a project can be costly and compromise the final achievement, so that the goal of risk management is to provide a "decision support system through risk analysis" for completing the project in time, within budget and in line with the objectives (Dey, 2001).

In a new project management framework, a risk management phase is double placed immediately before and after the phase of design and engineering, so to assess and manage the risks "ex-ante" and "ex-post".

The phase of risk-response, as in the integrated framework, is the most critical, because it uses quantitative tools in order to formulate risk response strategies. Some of them are the probability analysis and Monte Carlo simulation. "The analytical hierarchy process (AHP) is a multi-criteria decision-making methodology" that considers subjective and objective factors in the project risk analysis. It consists in formulating the decision problem in a hierarchical structure, weighting the alternatives, and normalizing the outcomes. The decision tree analysis is a tool of AHP used to select risk responses (Dey, 2001).

The general principles of the framework and of the "decision support system" may be very helpful for the companies bearing many different risks, but this guide does not provide a recommended specific implementation for each user. The users of risk management are many diverse organizations, which may have anything in common, that is the reason why they are very likely to implement ERM in totally different manners. This means that the most suitable way to draw some conclusions is not a general research, but a focus on a specific industry, through a study of the cases of a specific population of organizations. The focus is chosen to be the *energy sector*. By the way, it would be impossible to provide an ex-ante ERM for each company, especially in a so complex environment made by many diverse organizations facing plenty of risks. This is the reason why the general overview about risk management practices will be followed by the analysis of some cases in which the system is implemented. The study of some concrete applications will be helpful more than the models to become aware about how companies apply the ERM and the benefits they enjoy from it.

Cases studies treated in existing literature and empirical observations will be the sources of the analysis conducted in the next two paragraphs.

#### 2.3. Case studies in literature

Before picking the single units of analysis, it is necessary to provide a general overview about the risk management culture in the energy sector.

Since 1999, the necessity of "shifting from an 'avoid risk culture' to a 'think risk culture'" emerged in the power industry, due to the globalization, privatization and deregulation. (Clarke, Varma, 1999). This means that in a matrix made by the nature of the business and the risk management capabilities, the power sector needs to shift from the position of mature environment where the risk management is poorly averted, to a changing and speculative business where the risk management is increasingly adopted.

In the paper of Dafikpaku (2011), the ERM implementation is supported by two case studies. One of the analyzed companies is *Rolls-Royce*, whose activity is diversified in different sectors (aero civil, defense, marine and energy). The presence in the energy sector (11%) is growing and it is related to the usage of gas fuel to generate electricity. The risk appetite of the company is defined to be medium, since they are used to share very high risks with partners, while never to avoid or accept the total responsibility. The framework of risk management is applied to Rolls-Royce: risk assessment is the first phase. Due to diversification, different topics for different risk categories must be assessed: we will focus on commodity risk, the one related to the energy sector. It is a financial risk identified in the possible loss due to fluctuations in the price of the fuel: the objective of risk management is that of minimizing the impact of the price fluctuations. A medium priority is assigned, as its likelihood of occurrence and its impact are both rated with 3. After the assessment, a risk response strategy is put in place: in the case of commodity risk, the strategy of mitigation or reduction of the risk is pursued, since the probability of occurrence is high but the severity of impact is not so high to decide to avoid the risk. The action that was taken by Rolls-Royce to reduce

the commodity risk is hedging using commodity swaps up to four years. The consequent benefit of this strategy is a stabilization of the fuel price.

Rolls-Royce case shows how, even in a diversified company, energy risks, very likely to occur, may have a negative impact on profit, and they need to be managed to avoid losses. As risk cannot be avoided, the mitigation is pursued by using derivatives, tools of hedging and risk management.

In Porthin's publication (2004), the risk management process in an *electricity retailer* case study, among the others, is described. The framework is the usual one; what is different respect to the other case studies in the paper (about health, mining and pensions) are the methods.

Given the high uncertainty of the energy sector, and the fact that most of its risks cannot be avoided, and given that for the daily operations it is essential to manage them, hedging is the solution, introduced by value tree analysis, scenario analysis, variance-covariance matrix.

The criteria to choose the risk management tools are: information utility, costs and usability. In particular, six methods were evaluated according to these criteria: position reporting, deterministic scenario analysis, variance-covariance matrix, simulated value at risk, maximum loss model. To represent the options, two models were used: the traditional value tree analysis and the Rank Inclusion in Criteria Hierarchies (RICH). At the end, it was decided to use them in a sequential way: in the first phase, the low cost *position reporting* to collect basic risk information; secondly, the cost efficient *scenario analysis*; in the third phase, one among *simulation VaR*, *variance covariance matrix* and *maximum loss*.

This case illustrates what are the most common tools of a risk management process for an energy company. It has an important implication: being mainly related to financial risks (for example, fuel price fluctuations), most of the methods are financial tools, respect to some other sectors where risk management may also apply non-financial tools.

This conclusion is confirmed by another paper (Bjorgan, Fellow, Lawarrée, 1999) about the *financial risk management in the electricity market*, that will be practically shown

in the chapter about derivatives. Given the risk of the fluctuating market prices that may influence the result of the contracts for an electricity retailer, the authors demonstrate how risk management can reduce the uncertainty through futures, forwards and options contracts.

The importance of risk management during the projects has been already mentioned. A particular case of project where risk management becomes an essential part is that of oil and gas related projects.

Some examples of incidents experienced by pipeline operators are included in Dey's paper (2001). The author aims to provide a clarification about the consequences that the lack of risk management may cause in this kind of projects, in terms of cost and quality. From here, the stringent need to renew the project management model by including risk management. The multi criteria methodology called "analytical hierarchy process" (AHP) and, more specifically, the decision trees using calculations of the expected monetary value of each alternative are supposed to be the best process to evaluate uncertain outcomes in a project. The decision tree approach has the advantages of providing: a logical structure for risk management, a basis for quantitative risk management and also management perceptions.

The most interesting part of the paper is the application of the model to a *petroleum pipeline project in India*. A risk management team was formed to address the risk issues; it identified the main risk factors related to the project: technical, calamities, financial, economical and political, organizational and statutory clearance. Severity of impact and likelihood of occurrence, calculated through statistics, for each risk and sub-risk were assigned, so to rank the issues. Some risk responses, in the form of contingency plans, insurance and technology, were projected for each kind of risk. Each response was associated with a cost, a severity and a probability of failure and then, they were represented in a decision tree. From the tree, it was possible to calculate the monetary value for each alternative decision, and to evaluate if the risk responses strategies cost overcame the value of the project.

The main benefits that risk management produced in this context are: the identification of the problems during the planning phase that made possible the

responses formulation; the possibility to conclude the project without any extra-costs; a control for the implementation; a rational basis for stakeholders to evaluate the probability of failure; a risk mitigation through the decision tree; the quantification of the risk through probabilities and its awareness, despite the impossibility to eliminate it.

Dey's case underlines the benefits of risk management methods, allowing to deal with uncertainties, despite the effort of calculating probabilities and getting precise quantitative data about risk.

The challenges of applying quantitative methods and of dealing with many kinds of risks in the oil and gas industry, are also mentioned in a paper of Aven, Wiencke and Vinnem (2005). The case study is about *Total*, that has to evaluate two options about the disposal or less of a large gas-based structure. Risk management has the tasks of estimating the probability of failure, the costs, the consequences of each alternative, and to provide an overview with enough information about risks and probabilities, for facing the trade-off.

This case has been useful to support the importance of risk management in project management, not only with the purpose of hedging financial risks (already shown in electricity case study), but also as essential part to support decision making in quantitative and qualitative terms, especially in highly uncertain situations.

The case studies found in literature provided a great support for this thesis, because they made clear how fundamental is using risk management and hedging through derivatives for financial risks in a very uncertain environment, like the energy one. A further support will be provided by empirical observations of some energy companies who successfully apply ERM.

#### 2.4. Empirical observations

A further contribution to this analysis comes from some observations within the energy world of companies who successfully implement ERM and hedge their risks

through derivatives. The source of information of the following units of analysis are the companies' websites.

The first example is *Eni<sup>1</sup>* (www.eni.com), an integrated company in the energy sector, whose activities include: transportation, research, production and commercialization of oil and gas. The main risks that Eni faces are:

Market risk, deriving from exposure to fluctuations in interest rates, foreign currency exchange rate and commodity prices. The commodity risk, caused by fluctuations in oil and gas prices directly related to operations is managed by each business unit with Eni Trading & Shipping, one of Eni's subsidiaries, created with the aim of trading and hedging risk through derivatives. Derivatives are used by Eni to minimize the risk exposure coming from exchange rates, commodity price fluctuations and interest rates, nor to speculate. The risk management process operates in the following way: a maximum tolerable level of risk exposure is determined by Finance departments; once overcome this limit, they decide how to manage the risk. For instance, commodity risk tolerable exposure is measured in terms of "Value at risk"; it is monitored, and Eni evaluates from time to time the opportunity to mitigate the risk through hedging. Mitigation is done in order to pursue a stabilization of margins. Eni uses derivatives traded over the counter (swaps, forward, contracts for differences and options) where the underlying commodity is crude oil, refined products, electricity, or on organized markets such as ICE and NYMEX (futures). Derivatives' evaluation is done at a fair value on the basis of the market or by brokers. Value at risk is daily calculated on the basis of a historical simulation technique. Derivatives are also used for the interest rate risk (in particular swaps), and for the exchange rate risk (currency swaps, forwards and options), although compared to commodity risk in terms of value at risk, they have a much lower volume.

<sup>&</sup>lt;sup>1</sup> The information about Eni risk management is taken from the official company website, in a dedicated area: (http://www.eni.com/en\_IT/investor-relation/strategy/risk-management/strategy-risk-management.shtml)

- *Credit risk*, related to the possible losses in case of insolvency from the counterparty.
- *Liquidity risk,* for which risk management is performed to maintain a stable level of liquidity.
- *Country risk,* coming from the legal, political, economical conditions of all countries where Eni operates.
- *Operational risk,* related to environmental, safety and health causes.
- *Risks factors related to the Natural Gas Market*, in particular to the gas demand and to its price.
- Specific risks deriving from exploration and production activities, due to the uncertainty related to the physical characteristics of oil and gas products and reserves.
- *Risks associated with the cyclicality of oil and gas sector,* whose demands and projects are directly linked with the economic cycles.

Because of the high dependence of the company production with the oil price, a sensitivity analysis is constantly performed to estimate the projected production in relation with the estimated oil price scenarios.

A particular mention is for Eni Trading<sup>2</sup>, a business unit created by Eni in 2012 for the integrated commodity risk management and for the "asset backed trading". It has the aim of optimizing Eni asset portfolio management and its resources, such as gas, oil and electricity. By integrating the risk management of commodity prices, which are more and more volatile and correlated, Eni aims to achieve: best practises and solutions for risk management, an excellent risk control, gains from new and sophisticated trading opportunities, advanced price models and benefits for its strategic decisions too. The institution of this "ad-hoc" business unit, as well as the crucial importance that risk management has for Eni, is a great example of the benefits that risk management and derivatives in the energy sector may provide to the energy companies.

<sup>&</sup>lt;sup>2</sup> Eni Trading description is contained in the area of Eni website about Eni Group divisions http://www.eni.com/it\_IT/azienda/attivita-strategie/trading-shipping/trading/trading-shipping.shtml.

The second unit observed is **Enel**<sup>3</sup> (www.enel.com), one of the major Italian energy companies, that has been adopting a risk management system since 2009.

The implementation consists in a Governance for risk management, as well as risk control Committees and monitoring figures. Similarly to Eni, it is an integrated system shared all over the group, with a strong risk culture.

The main breach is the *Commodity Risk Management*, related to commodity prices but also to volume, influenced by the volatility of some sources, especially renewable. The process is similar to Eni's one: a tolerable exposure is established, according to the company risk appetite, and once identified the risk factors, they are divided into relevant and irrelevant: the former are managed, the latter are monitored. There are two kinds of portfolios: industrial, related to core business, and trading one, related to the activity of hedging the exposure and exploiting the opportunities caused by price of commodities fluctuations.

*Country risk management* consists in analyzing, measuring and monitoring the risk of each country where the company operates, especially the most relevant ones. Risk is measured through a home-made model, the Country Valuation Model, able to predict the riskiness of the countries.

*Credit & counterparty risk* management checks the probability of default of the counterparties; *environmental risk management* measures and manages the environmental risks.

*Enterprise risk management* in Enel is a formal structure created to provide the Board of Directors an overview about all the risks. ERM is a centralized function, supported by centres in each business unit: reporting is periodical. The principal phases of the process are: setting targets and KPI; risk factors and risk drivers identification; modelling through scenario analysis or stochastic models; measuring the impact on the objectives of the Strategic Plan; identification of the most relevant risks at each business unit level; monitoring mitigation actions.

<sup>&</sup>lt;sup>3</sup> Similarly to Eni, Enel has an area of its official website dedicated to risk management (http://www.enel.com/it-IT/investors/our\_business/risk\_management/), where all the types of risk are included.

*Financial risk management* monitors: exchange rates, liquidity, credit, interest rates, and measures the exposures for each of them. Furthermore, it has the task of deciding about models, financial instruments and hedging strategies, and monitoring their application.

*Industrial risk management* is related to operations and risk of malfunctions, that may be mitigated through maintenance and preventive actions.

Enel has a unit of *insurance* to transfer the risk and a "reinsurance agency".

*Strategic Risk Management* collaborates with the other units of Risk Management in order to set the risks that may affect the budget and the Strategic Plan, and to evaluate their implications on the risk-return analysis of the investments. The cooperation is favoured by shared models and measures.

To estimate and measure the risk, the methodology used by Enel is PAR (profit-at-risk), integrated with VAR (value-at-risk). While VAR is calculated at the maturity of contracts from forward curves; PAR is estimated at the end of a fixed period (3 or 6 months) and the expected value of the portfolio is based on the projection of the future spot prices. Enel Group adopts many software for its subsidiaries: for example, Enel Fuel, Trading and Logistics uses ICTS online; production subsidiaries mainly use Contango, while at the Corporate the company has a home-made software (Davidson, 2002). Software may vary for specific needs, although the basic methodologies to be supported are always the same: Monte-Carlo and historical simulations, PAR and VAR. According to Girino, Enel Corporate Risk Manager, Monte-Carlo simulation is very suitable for commodity risk, despite its complexity<sup>4</sup>.

**ExxonMobil**<sup>5</sup> (www.exxonmobil.com), one of largest publicly traded oil and gas company, providing energy, is also specialized in providing estimations about the expected energy scenarios in the long and short term. Despite its detailed projections,

<sup>&</sup>lt;sup>4</sup> The discussion about risk methodologies applied by Enel and the interview to Paolo Girino, Enel Corporate Risk Manager, are contained in Clive Davidson's paper: *Enel e gestione del rischio (2002)* (http://db.riskwaters.com/global/risk/foreign/italia/August2002/enel.pdf)

<sup>&</sup>lt;sup>5</sup> ExxonMobil risk management description is contained in the presentation called *Managing Risk for Superior Returns,* signed by Andrew P. Swiger, Senior Vice President of the company, found in ExxonMobil official website.

it is aware about the uncertainty of the sector and the role of the risks of various type (technical, environmental, financial, geopolitical). According to ExxonMobil risk culture, risk can be managed, but not eliminated: prevention and response are the ways to manage it. ExxonMobil's operational system is called OIMS 11 (Operations Integrity Management system), made by 11 elements, where risk management plays a fundamental role. Safety and health are guaranteed by taking actions to prevent accidents; technical risks are quantified through data collection and analysis; geopolitical risks are managed through portfolio diversity; financial risks are managed through portfolio diversification.

The benefits that ExxonMobil declares to gain from risk management are a responsible satisfaction of energy needs and delivery of superior shareholder returns in the long run. The important implication is that a positive correlation between risk management and value creation is proved.

A practical example of the benefits deriving from risk management has been provided by **Shell Global<sup>6</sup>** (www.shell.com), one of the largest hydrocarbon companies in the world.

The newness of its risk management system is the introduction of a "fixed price" policy for contracts, despite the volatility of commodity prices. Offering fixed price for bitumen to contractors, through its Price Risk Management Department, it allowed the clients to pay a predictable price and to stabilize their costs and margins, despite the price fluctuations. In this way, Shell built its competitive advantage in bitumen business in the contracts with road construction companies.

The evidence shows that by controlling the commodity prices fluctuations, it is possible to achieve a stabilization that may not only avoid losses but also contribute to the value creation. A risk management system, allowing to identify, measure and manage all the risk factors, and the adoption of some response strategies, such as mitigation

<sup>&</sup>lt;sup>6</sup> Shell Global Fixed Price Risk Management is widely described in the Risk Management brochure (http://www.shell.com/global/products-services/solutions-for-businesses/bitumen/risk-management.html#), made available by Shell Global in its official website, in the area dedicated to its

management.html#), made available by Shell Global in its official website, in the area dedicated to its division Shell Bitumen.

using hedging through derivatives, are the instruments to achieve the goal. The energy companies mentioned in the section of the empirical observations, as well as the cases in literature, have been supports to this evidence.

#### 2.5. Evolution of risk management

To wrap up, all the companies mentioned in the case studies follow, more or less, the same steps of the risk management process, that are synthesized in the following graph:

#### Risk Risk **Risk response** Monitoring identification assessment Market risk Likelihood of occurrence Acceptance, avoiding, mitigation/reduction, Commodity risk \* impact = Ranking, Hedging Credit risk priority and exposure transferring/sharing Exchange rate risk Use of quantitative tools, such as: scenarios, Etc. Monte Carlo simulation, decision trees, VaR Models, derivatives (in case of mitigation)

#### Fig. 2 The risk management process

The most recent document about the evolution of the Enterprise Risk management is a very interesting McKinsey publication of last December (Pergler, 2012), about the changes in this process and its causes. In term of risk culture, companies may decide to adopt four "stages of maturity of risk management": an initial stage of compliance with regulation; a systematic risk reduction to avoid losses; a risk return management approach, to improve performance; or even using risk to reach a competitive advantage.

It has been already explained how energy companies are moving from an "avoid risk culture" to a "think risk culture", and how they are perceiving risk not only as a threat but also as an opportunity. This the reason why in McKinsey paper, they are told moving to the stage 3, since they are making an increasing use of mature liquid commodity markets or managing their portfolios (Eni trading is a very suitable example), in order to improve their ROE and to face competitive pressures. Again, the applied quantitative tools are scenario analysis, simulation, value-at-risk (VAR) models. They recur to derivatives not only to hedge commodity price fluctuations that may affect their production, but also for project evaluations. For example, if they are developing a reserve, they have a "non-linear" exposure to oil prices. Even when they are toward the end of the project, a sudden drop in oil price may make that it becomes out-of-the money. A real option is the only instrument that may provide a fair evaluation, because it considers the likelihood that when the oil price will increase, it will be in-the-money. Non-linearity of risk exposures and diversity of risks, make difficult to provide a detailed framework for risk management that is suitable for all the companies. Even companies operating in the same sector, like the energy ones, may develop different projects in different areas that a risk response strategy could be optimal for one but not pursuable for another one. This consideration is not obvious, but it is crucial to understand why an energy company needs to spend resources to implement ERM, instead of only hedging commodity risk in derivative market.

ERM implementation requires governance and best practices, but the role of the risk group in an organization depends on the complexity of risk and on the confidence managers deal with it. For example, not all the companies think the figure of the CRO (Chief Risk Officer) is necessary within the organization: while Enel has already appointed one; Eni has just included it in proposals; ExxonMobil does not believe in maintaining a separate risk organization, because it already uses a sophisticated risk management. Despite divergent points of view, several petroleum companies are gradually moving from an "aggregate risk insight model", where managers care directly about risk, supported by a central risk team integrated within the enterprise; to models where the risk group is leaded by a CRO who participates to strategic decisions, toward a more active risk management. This shift may be due to the complexity of the

oil related risks, that may make difficult to sustain an "aggregate risk model", and necessary the figure of the CRO.

In the first part of this thesis, the objective of showing the importance of risk management within the companies, especially the energy ones, has been achieved. It has been observed how and why they use it, and the necessity to implement it, because of the complexity of the risks in the sector.

In the second part, the focus will be on the quantitative tools of risk management for the energy companies and on the energy derivatives, as means to hedge the commodity risk. Their application and effectiveness will be assessed.

## **Chapter 3**

## The quantitative tools of risk management

Derivative instruments such as forwards, futures, swaps and options are used to offset the risk in a quick, easy, tailored way, at a low cost. While they will be shown to be very efficient hedging instruments, they may be also applied for speculative and arbitrage aims. Indeed, these instruments knew a proliferation and a complexity, such that it is not obvious to define how much risk is included in a derivatives portfolio. This is the main cause of the creation of quantitative tools of risk management, such as "value-at-risk" (VaR) methodologies, and of summary risk metrics to trade derivatives. The introduction to these methods, that are the quantitative tools of the above discussed risk management, forecasts the analysis of the energy derivatives.

#### 3.1. The Black-Scholes model

Before introducing VaR methodologies, as the most used quantitative tools of risk management, it is interesting to go back to the origins. The Black-Scholes model and its variants are at the foundation of the management and measurement of volatility: they had the effect of disseminating probabilistic and statistical tools to quantify and measure volatility throughout financial institutions (Linsmeier and Pearson, 1996).

The Black-Scholes formula has been recalled in the first chapter in order to price call and put options, but this is not its unique application. It can be also applied for pricing forwards, considering them as options that will be surely exercised. Furthermore, it is applied to estimate the volatility from historical data and the implied volatility in options prices.

Volatility has been already defined in the first chapter as the uncertainty about the future rates of return of a stock: it is measured by the standard deviation of the rate of return ( $\sigma$ ), increasing proportionally with the square root of the time horizon. In order to estimate the volatility of a stock price, according to Black-Scholes, you may use the historical series of the rates, registering the price from time to time, so to observe its

variations. A common practice is that of observing the daily closing prices for a historical period equal to the maturity of your financial instruments. For example, if you are estimating the volatility of a one-year option, you should look at the closing prices of an option for the last year.

One alternative approach is the implied volatility one. Given that you cannot observe directly the volatility of a stock, you can solve the Black-Scholes equation by substituting the observed spot price, strike price, time, rate, to find  $\sigma$  consistent with the current option market price. This approach is interesting to know the market expectations about the volatility of a stock, and also to price less negotiated options from the implied volatility of actively negotiated ones (Hull, 2006). Nevertheless, the implied volatility approach results to be misleading in some cases. One of these cases was found out by Doran and Ronn (2005), who applied Black-Scholes implied volatility methodology to energy options. Similarly to equity markets, they found out in options contracts an upward bias in the implied volatility. From their empirical research collecting data from oil and gas futures contracts, they proved that futures prices are upward-biased predictors of spot prices in energy.

As a consequence, the implied volatility methodology deriving from the Black-Scholes model is not a good estimator of risk in the energy market.

Actually, the main drawback of the Black-Scholes models is linked to the assumption of the constant volatility of the underlying factor. Volatility is variable but, since it cannot be directly observed, considering it as a constant, as in the Black-Scholes model, is not a real assumption.

Indeed, other methodologies, like VaR, will be analyzed as more suitable tools of risk management for the energy companies than Black-Scholes and its descendants.
## 3.2. The main VaR methodologies

The concept of value-at-risk (Fig. 8) is relatively recent: it was introduced in 1980's and it knew most of its expansion in 1990's. JP Morgan RiskMetrics<sup>™</sup> system, released in 1994, was an incentive to its growth. It became quickly the most adopted risk measurement system by financial institutions and regulators, such as Basle Committee, as well. The reason why it knew such a great expansion has to be attributed to its attempt to resume in a single number several specific risk measures (delta-gamma-vega), in order to estimate the risk of a portfolio of financial instruments as a whole. Furthermore, as told in the first chapter, it is easier to understand for investors than volatility measures, because it expresses the potential loss, in a time horizon, for a certain level of confidence. It is a measure of normal market risk; if a loss has to be defined abnormal, it depends on its established probability of occurrence that may vary according to the risk management system (5% or lower). On the other hand, it is a summary measure that needs to be supplemented by stress tests, scenario analysis and other information provided by delta, gamma, vega risk measures to provide a more detailed analysis for risk managers.

As far as concerns its implementation, the main methods for computing VaR are three: historical simulation, the variance-covariance method and Monte Carlo simulation. A common procedure to all these methods is identifying the market factors affecting the value of the portfolio: for example, if you have a portfolio of energy derivatives, you need to decompose it in simple instruments and find out the market risk factors (such as commodity price fluctuations). Then, you estimate the statistical distribution of the market variables and the potential future changes. Value-at-risk is a measure of the potential future changes in the portfolio's value, that will depend on a limited number of market variables (Linsmeier and Pearson, 1996).

Fig. 3 Value-at-risk (Source: www.riskmetrics.com).



3.2.1. The Historical simulation

The historical approach consists in using historical changes in market rates and prices to design a distribution of future portfolio profit and losses, and computing VaR as the loss that is exceeded only 5% of the times.

The process is made of five steps. For instance, in the case of an energy forward contract you have to:

- Identify the market factors and express the forward contract value in terms of these factors, that means expressing the forward contract value in function of the spot commodity price;
- Obtain the historical value of the market factors for the last N periods, that means collecting the spot commodity prices for the last N periods;
- Calculating the profit and losses, that is assuming a X potential loss if similar changes to those of the last N periods will occur in the next N periods;
- Order the mark-to-market profits and losses in a range of values from the largest profit to the largest loss, from the distribution of spot commodity prices found in the preceding steps;
- 5) Select the loss occurring 5% of times: this is the Value-at-risk using a probability of 5%.

VaR is positively affected by: more variable market factors, higher number of contracts, larger contracts, and contracts with greater sensitivities (Linsmeier and Pearson, 1996).

## 3.2.2. The Variance-covariance or analytical method

The variance-covariance approach assumes a multivariate Normal distribution for the underlying market factors, according to which profit and losses are normally distributed as well. The value-at-risk will be equal to the z-value for a certain level of confidence times the standard deviation of a change in portfolio value. Taking the same example used for the historical simulation, we can find the VaR with the following formula:

VaR= 1,65 × standard deviation of change in portfolio value,

Given that in a Normal distribution, 1,65 corresponds to 5% of probability.

In the variance-covariance approach, also known as analytical method, the *risk mapping* is a procedure conducted to find standardized positions associated to each market factor for each instrument. So, before computing the standard deviation and the value-at-risk of a portfolio, you need to map it into a portfolio of standardized positions. The steps of this approach are essentially four:

- Identifying the market factors and the standardized positions related to these factors. You should map the energy forward contract onto the standardized positions, through its decomposition into different contracts for different spot price values;
- Assuming that changes have a Normal distribution so that variability is captured by the standard deviation of the Normal distribution, and the comovements by correlation coefficients;
- Using standard deviations and correlations of the market factors to find the standardized positions ones, as the products of σ of market factors times the sensitivities of the standardized positions to changes in the market factors;

 Calculating the standard deviation of the portfolio from the standard deviations of the standardized position through the formula of the standard deviation of a portfolio. Finally, VaR is computed using σ<sub>portfolio</sub> value (Linsmeier and Pearson, 1996).

The greatest difficulty of this approach is estimating distribution parameters and a covariance matrix, process that becomes even more complex in the energy markets. This is the reason why algorithms for forecasting covariance structure are adopted. The models used in the energy risk management, applying the analytical method, to forecast volatility are essentially two: the exponentially weighted moving averages (EWMA) and the generalized autoregressive conditional heteroscedasticity method (GARCH), (Eydeland and Wolyniec, 2003). Their main feature is that, differently from the Black-Scholes, they recognize the variability of volatility.

EWMA consists in calculating volatility as a weighted average of rates of return during a period, whose weights decrease exponentially going back in time. Each weight is equal to  $\lambda$  times the preceding weight.

This approach has the advantage of considering the variability of volatility and, at the same time, to give higher weight to the most recent variations.

The *RiskMetrics* database, released by JP Morgan in 1994, uses an EWMA with  $\lambda$  equal to 0,94 to refresh daily variations.

GARCH model assumes the existence of a medium-long run volatility. It is not so different respect to EWMA but, further to assign an exponentially decreasing weight to the rates of return, it assigns a weight to long run volatility, as well. It assumes a mean reversion property for the variance, in the long run (Hull, 2006).

GARCH and EWMA descend from the ARCH-type class models (autoregressive conditional heteroscedasticity), whose relevance and performance was tested on commodity markets by Giot and Laurent (2003). In the mentioned paper, VaR models result to be relevant for commodity traders who have long and short trading positions in commodity markets. Applying ARCH-type models to Brent Crude oil and WTI crude oil prices, it has been observed how they are able to predict VaR for a longer horizon than one day.

### 3.2.3. The Monte Carlo method

Monte Carlo method is similar to historical simulation but it differs because, instead of conducting a simulation using the data from the past, it generates a statistical distribution approximating the future changes of market factors. For example, in the case of an energy forward contract, it generates thousands of changes in spot commodity price so to construct a portfolio of hypothetical profit and loss: VaR is computed from this distribution.

The steps are five:

- Identifying the market factors and expressing the value of the financial instrument in term of these factors, that in our case means expressing the energy forward contract in term of the spot commodity price;
- Assuming a statistical distribution for the changes in market factors: risk managers are free to choose any distribution that they believe approximating the future changes (observed past changes, beliefs may influence it);
- 3) Using a random generator for N hypothetical changes in market factors (N may exceed 1000 or even 10000) to generate N portfolios of profit and losses;
- 4) , 5) are the same as in historical simulation (Linsmeier and Pearson, 1996).

The drawback of Monte Carlo method is that simulations result to be slow, since portfolio has to be revalued many times.

Whichever method you use, VaR calculation is often accompanied by *stress tests*, to verify the portfolio performance during extraordinary events, such as the most extreme situations of the last 10-20 years. In the case of oil companies, it could be represented by an oil shock. Another common procedure is the *back-testing*, to verify VaR reliability on the basis of historical data. For instance, in our case we assumed a 95% confidence level: we can be satisfied about our methodology if, looking at historical data, losses exceeded VaR not more than 5% of times.

Deciding which of the described VaR methods is the best one is not an easy task: it depends on the risk management system. As a consequence, it is interesting for this

work to come up with a choice of the most adequate method to measure risk in a portfolio of energy derivatives.

Clewlow and Strickland (2000) examined the three methods that energy companies use to compute VaR in a portfolio of energy derivatives and outlined the main advantages and disadvantages of each of them.

The variance-covariance method results to be widely used especially in a portfolio without a large option component; it is simple to understand and efficient. Anyways, its drawbacks descend from the Normal distribution assumption, that is not realistic for the energy market. This too simplistic assumption is not appropriate for an energy derivatives portfolio and leads to VaR underestimation.

Historical simulation is simple to understand, intuitive and straightforward; further, it applies to all the types of risk. On the other hand, it can create some problems in changing environments, such as the energy one, since it assumes that past changes will reoccur in the future. This is a great drawback, especially in the short run.

Finally, Monte Carlo, despite its complexity, allows to incorporate in its simulations the energy prices jumps and volatilities, seasonality, and all the other important effects, included the knowledge about future events, in a straightforward way.

For all these reasons, Clewlow and Strickland (2000) recommend the application of Monte Carlo method to a portfolio of energy derivatives, better if supported by the historical approach, so to have a complete knowledge including past changes as well.

However, Monte Carlo simulation is not only applied to calculate VaR for an energy derivatives portfolio but, as anticipated at the end of the last chapter, also to value derivatives.

Although Monte Carlo has been assessed as a good method to calculate VaR for energy derivatives, there exist some alternative measures to VaR that may result more appropriate in some situations: they will be discussed in the next paragraph.

## **3.3.** Alternatives to Value-at-risk

Despite its popularity, VaR has some drawbacks. First of all, it can be insufficient when there are big changes, that is it does not tell us what happens in 5% of cases, when the potential loss exceeds the threshold. VaR is not able to provide information about the magnitude of the loss, when the 95% confidence interval is violated, a likely scenario in the energy markets. Another pitfall is the lack of "sub-additivity": "VaR of a two assetportfolio can be greater than the sum of individual VaRs of these assets" (Eydeland and Wolyniec, 2003). It means that it may be not coherent with the diversification principle, according to which diversification should reduce the risk of the portfolio. In order to correct these pitfalls, the conditional Value-at-risk (CVaR) has been introduced.

*CVaR* is a weighted average of VaR and the conditional expected losses exceeding VaR (Eydeland and Wolyniec, 2003). CVaR corrects VaR because it can estimate the loss exceeding VaR and it is sub-additive, since it considers the risk reduction effect of diversification. CVaR and VaR are very close: the former is an improvement of the latter.

Two alternatives to Value-at-Risk are: sensitivity analysis and cash flow at risk. While the former is less sophisticated than VaR and suitable for simple portfolios, the latter is even more sophisticated than VaR (Linsmeier and Pearson, 1996).

If a portfolio is exposed to few market factors, the *sensitivity analysis* consists in trying to figure out the hypothetical changes of them, and to compute the value of the portfolio given these changes. It is easy to understand how it may become complex when there are many market factors varying at the same time, whose changes are not easily predictable. As a consequence, it is not a suitable method for a portfolio exposed to multiple factors, like the energy derivatives one.

*Cash-flow at risk* is more sophisticated than VaR and particularly adopted by non financial institutions, to manage the risk in operating cash flows. Cash flow at risk can be estimated through Monte Carlo method, too. Anyways, its application is different, because the simulation is done for a longer time horizon, and the focus in on cash

flows, since the goal is assessing the impact of risk and derivatives on operating cash flows. Each factor impacting on cash flows is considered, rather than only market factors, as in VaR. They must be aware of more drivers of risks, operating as well, and include them in the statistical distribution. In addition to price and volatility factors, growth, technology, demographic and macroeconomic factors need to be included. Much more computation than VaR has to be conducted. As a consequence, a great knowledge is required to those implementing a risk measurement system based on cash flow at risk, not only about the factors, but also about their interactions. On the other hand, if well applied, an ambitious risk measurement system like this has a great efficacy, especially in the long term.

Another risk measure, not as competitor but complementary to VaR, is *Credit VaR*. It has the specific aim of measuring the credit risk, that is the risk that the counterparty will not meet its contractual obligations. Two popular systems of Credit VaR are: *CreditMetrics*<sup>TM</sup> by JP Morgan and *CreditRisk++*.

The implementation is similar to VaR, but credit risk, whose drivers are probability of default and rating (internally generated or provided by rating agencies), have to be included, as well. Monte Carlo simulation, adding credit risk events to market risk factors, may be also applied to Credit VaR.

To wrap up, we can say that nowadays VaR is the most popular technique for risk management in energy companies. It is very straightforward and provides satisfying results for risk management and energy derivatives. Among the techniques to apply it, Monte Carlo results to be the most suitable for a changing environment like the energy one, allowing to incorporate changes, multiple risk factors and volatility jumps in its simulations.

On the other hand, some other risk measures are more efficient in some cases. CVaR is helpful in correcting some VaR drawbacks and to improve its performance, but it cannot be considered an alternative, rather a complement. On the contrary, Cash flow at risk is a VaR competitor, especially for non-financial institutions like the energy companies, since it provides a more complete overview about risk, including a wider range of factors in its analysis. However, because of its complexity, it is adequate only

in some situations. To provide an example about the energy field, if you have to evaluate a huge investment in a power plant, an analysis of the factors influencing operating cash flows is surely more complete than VaR, considering only market factors. At the opposite, taking the example of an energy company trading futures for electricity furniture day by day, VaR can provide a quicker answer than Cash-flow at risk. In such a situation, it is not only more immediate, but also more focused on market risk factors, that in this case are more relevant than all the other factors affecting operating cash flow, taken into consideration by Cash-flow at risk.

In conclusion, we cannot say *ex-ante* which technique is the best for energy risk management, but this is left to energy companies discretion, that has to weight attributes as ease of implementation, efficiency, efficacy and so on, according to their contingencies.

# **Chapter 4**

# **Energy derivatives**

## 4.1. Markets for commodities

In the last chapter, it has been understood *why* companies, and more specifically the energy ones, use risk management. In this chapter, the focus will be on *how* they deal with risk. Before introducing the energy derivatives as the main instruments to hedge the energy risk, it is important to understand *where* the energy transactions take place and *what* kind of risks they involve.

Historically, energy commodities are divided into three groups: fuels (oil, gas, coal, and their derivatives); electricity; weather and emissions. Each kind of commodity and each sub-category has a market.

Crude oil is one of the most important and demanded commodities (80 million barrels a day), whose supply was at first negotiated over-the-counter, through swaps exchanging fixed price oil with variable price one. Due to the wide fluctuations of the oil price (Fig. 3), both stock exchanges and OTC market satisfied the need of more sophisticated financial products to hedge against the risk of the oil price. Derivative contracts related to oil, such as swaps, forwards, options and futures were traded on the market (Hull, 2006).



#### Fig. 4 Crude oil prices from 2000 to 2012 (source: Shell internal data, 2012)

The crude oil market is the largest commodity market in the world: the "Brent" is the global benchmark, while in USA it is the West Texas Intermediate (WTI). (Eydeland A. and K. Wolyniec, 2003).

Despite their differences, oil and gas producers are exposed to the same risk of commodity prices volatility, that is why they hedge through the same methods. Futures and options for both crude oil and natural gas are traded on the New York Mercantile Exchange (NYMEX), while forward and swap contracts are traded in over-the counter market. (Haushalter, G.D., 2000).

Natural gas industry has been affected by a deregulation eliminating the monopolies, so that independent suppliers have now to face the issues related to the daily gas supply. Derivative contracts are the instruments to negotiate gas supply.

The difference between fuels and electricity is the storability, whose consequence is the risk of mismatching between demand and supply: "[...]since electricity cannot be stored, instantaneous supply and demand must be always in balance; otherwise the integrity of the whole system might be compromised" (Eydeland A. and K. Wolyniec, 2003). The most direct consequence of the impossibility to store electricity is a wide fluctuation in its spot price. Deregulation affected electricity too, and this process has been accompanied by the development of a derivative market (Hull, 2006). In NYMEX, futures are traded; while forwards, options and swaps are traded over-the-counter. In general, all contracts have in common the fact of negotiating the monthly supply of electricity, in a specific place, at a given price, in a given amount.

The contracting structures for power markets are divided into: pools, formal established cash markets, such as Nordic Pool, NEPOOL and CAISO; and bilateral markets, where the counterparties are two independent markets, such as ERCOT, ECAR and SERC. Furthermore, in the *energy forward markets*, the parties contract for the delivery of energy in the future.

Other markets have to do with: emissions, due to compliance with regulation; weather, such as HDD/CDD swaps and HDD/CDD calls and puts; coal, traded over-the-counter but also in NYMEX; and forced outages, for which insurances play a dominant role (Eydeland A. and K. Wolyniec, 2003).

In Italy, energy derivatives are traded on IDEX (Italian Derivatives Energy Exchange), a segment of Italian market of derivatives (IDEM), managed by Borsa Italiana.

Electricity futures are currently trading on IDEX and are cash settled; they can have a maturity of one month, three months, one year. Being futures, they are most of times liquidated before maturity, but their expiration date is however important to predict the spot price, according to the convergence assumption that will be explained in the next paragraph. In the IDEX, futures are described by some characteristics: underlying factor (electricity), unit of measure (€/MWh), maturity, volume, limits on price movements. Futures contracts may be negotiated in three alternatives modes: interbank order, where the counterparty is a predetermined operator; internal order, where the counterparty is the operator itself; block trades, applying to interbank and internal orders when the number of contracts exceeds certain limits, that differs from the former ones, because the price is not included between the best purchase purpose and the best sale purpose.

To favor a higher liquidity of derivatives, Borsa Italiana may hire the so-called *market makers*, operators in charge of listing from time to time the futures, though the

constant communication of offer and demand prices, associated to a certain number of contracts (www.borsaitaliana.com).

In conclusion, energy companies recur to the markets to face two risks: one is related to the quantity of commodity, the other one to its price. While the former is hedged through *weather derivatives*; the latter is covered with *energy derivatives*.

This thesis will focus on the **energy derivatives**, as the financial instruments to hedge against the commodity price risk.

### 4.2. Introduction to derivatives

Energy companies are among the most active users of derivatives. There is a sophisticated market for *energy derivatives*, traded in official markets or over-the-counter, and this is the main topic of this thesis, but to understand how do they work, a brief introduction about derivatives must be provided.

*Derivatives* are financial instruments whose value is derived from the performance of underlying market factors, such as commodities, stocks, bonds, interest rates and currencies. In practice, it is a contract between two parties that specifies conditions (especially the dates, resulting values and definitions of the underlying variables, the parties' contractual obligations, and the notional amount) under which payments are to be made between the parties (Hull, 2006). They can be traded over-the counter (OTC) or through exchanges or specialized derivatives exchanges, called exchange traded derivative contracts (ETD).

They can serve mainly three purposes: hedging, speculation or arbitrage.

Hedgers use derivatives to reduce and mitigate the risks deriving from the exposure to market factors: this is what energy companies do to protect themselves from the risk of commodity price fluctuations. Speculators use them by assuming a position on the market: they beat that an underlying price will rise or fall. Finally, derivatives may be used to make a profit by exploiting arbitrage opportunities. Hedging, which is the main use of derivatives from the energy companies, is the most interesting purpose for the aim of this work.

Now, we will have a look at the most common derivative contracts.

## 4.2.1. Forwards

Forward contracts are used to buy or sell an activity at a certain price, in a certain date, in the future. They are negotiated between two parties: the buyer has a *long position*; the seller takes a *short position*. The price that is agreed is called *delivery price*. The *payoff* of a long forward is given by the difference between the spot price (S, the price at maturity) and the delivery price (K), (Fig.4):

$$P_L = S - K$$

On the other side, the payoff of a short forward is equal to the difference between the delivery price and the spot price (Fig. 5):

$$P_s = K - S$$



#### Fig. 5 Long forward

Fig. 6 Short forward



As we can see from the graphs, forwards value is zero when they are signed; then, they may have a positive or negative value. *Marking to market* process is important for financial institutions in order to evaluate the contract day by day.

In practice, at the negotiation day, the forward price is assumed to be equal to the delivery price: then, what changes is the spot price, that may become positive or negative, while the delivery price is contractually fixed (Hull, 2006).

#### 4.2.2. Futures

Similarly to forwards, futures are agreements between two parties to buy or sell an activity at a certain price, in a certain date in the future, but they are traded in formal markets (the most important are Chicago Board of Trade and Chicago Mercantile Exchange); on the contrary, forwards are negotiated among private individuals. Futures prices are calculated on a daily basis.

Most of futures are not effectively delivered at maturity, but they are paid before the expiration date. Nevertheless, price is determined in function of delivery, since it is the link between spot price (price of the immediate delivery before maturity) and futures

price. Futures price and spot price tend to converge as term to maturity is expiring: this is the convergence assumption, used to derive the spot price that varies with term to maturity.

In the oil market, it has been observed that Brent crude oil futures prices decrease as maturity increases: it is an "inverted market" (Hull, 2006).

Hedgers use futures to preserve from a risk, that may be related to a commodity price, such as oil, to an exchange rate, and so on. The most important feature of hedging is the basis risk, given by the difference between the spot price of the underlying and the futures price of the contract. The basis risk should be equal to zero at maturity, since spot price and futures price will converge. Before maturity, basis rises when spot price increases more than futures price; and vice versa.

## 4.2.3. Options

Options differ from forwards and futures because they give the right, but not the obligation, to buy or sell an activity before a certain date, at a certain price.

*Call options* give the owner the right to buy an asset; while *put options* allow to sell it (Fig. 6).

The price of the option contract is called *exercise price* or *strike price*; the date is called *expiration date* or *maturity*. The most known categories are the *European options* that may be exercised only at maturity; and the *American options*, to be exercised at any time before the expiration date. Less known are the Exotic options.

Another difference respect to futures and forwards is that options are bought at a premium, while the other mentioned derivatives can be bought without any costs.

Fig. 7 Call and Put Option



In the graph, we have assumed to take a long position for a call and for a put, but it is possible to take a short position, as well. So, whether the party decides to buy or sell the option, we can have a *long put*, a *long call*, a *short put*, or a *short call*. In the table, the payoffs for each kind of European options are summarized:

Payoffs	Long	Short
Call	max (S - K, 0)*	min (K - S, 0)
Put	max (K - S, 0)	min (S – K, 0)

\*S= spot price; K= strike price

Spreads, straddles, strips, straps, strangles are some operating strategies investors use through the combination of an option and an underlying factor. Derivative strategies are applied for energy derivatives as well, and some examples will be provided in the following paragraphs.

#### 4.2.4. Swaps

Swaps are important derivative contacts in the over-the-counter market, because they are private agreements between two parties about an exchange of payments at given dates in the future, on the basis of market variables (interest rates like the London Interbank Offer Rate, better known as Libor; exchange rates, etc.).

While swaps payments are established at many different dates; forwards are paid in only one date, indeed they can be viewed as simple swaps.

The two main types of swap are: interest rate swaps and currency swaps.

The most common interest rate swap is called "plain vanilla", where there are two counterparties: the first one is committed to pay a fixed rate on the basis of a *notional principal* to the second one, paying a variable interest rate on the same capital, for the same number of periods.

A swap where a fixed rate is exchanged with a variable one can be also viewed as a bond portfolio, whose value ( $V_{swap}$ ) is given by the difference between the fixed rate bond ( $B_{fix}$ ) and the variable one ( $B_{fi}$ ):

 $V_{swap} = B_{fix} - B_{fl}$  [Hull, 2006]

Currency swaps are built on the same logic, but what is exchanged is the capital in a currency against the capital in one other currency.

Other types of swaps include *commodity swaps*, that can be viewed as a series of forward contracts, at different maturities but with the same delivery price, whose underlying is a commodity (Hull, 2006). If we imagine the underlying commodity to be oil, gas or electricity, we may figure out energy swaps conception.

## 4.3. Energy derivatives classification

As far as we know derivatives definition, we may define energy derivatives as derivative contracts based on an underlying asset, such as natural gas, crude oil or electricity. They include exchange-traded contracts (futures and options) and over-the-counter ones, such as forwards, swaps and options. According to an alternative classification (Fig. 7), they may be divided into options and contracts without "optionality", such as forwards, swaps and futures (Burger, 2007).

Fig. 8 Energy derivatives classification (Source: Burger, 2007).



## 4.4. Energy forwards, futures and swaps

Forwards, futures and swaps are hedging instruments for risk management, without "optionality", the main reason why they differ from options. They are the most liquid types of derivatives and are easier to use and to price than options (Burger, 2007).

### 4.4.1. Energy forwards

Since they are private agreements between two parties, forward contracts are traded in the OTC market. In the case of commodity, they consist in bilateral agreements to purchase or sell a certain amount of a commodity (oil, gas, electricity) on a fixed delivery date at a predetermined contract price. They are usually paid at maturity.

In some regions, there exists a liquid market for standardized forward contracts for some commodities, such as crude oil or electricity. On the other hand, forwards are characterized by the credit risk, that is the risk of insolvency of the counterparty.

The main uses of energy forwards are essentially three: hedging the obligation to deliver or purchase a commodity at a future date; securing a profit from a commodity production; speculating on commodity prices fluctuations when a liquid futures market is missing (Burger, 2007).

To evaluate a contract, we assume a delivery of a commodity at some future month in exchange of a fixed payment (fixed price forward contract). Since forwards are not traded in a formal market, we assume the same price and expiration of a futures contract. The value at time t of the fixed-price forward contract for a party that at delivery pays a fixed price X and receives one unit of commodity is:

$$V(t, F_{t,T}) = e^{-r(T-t)}(F_{t,T}-X)$$

Where r is the risk free rate (Eydeland A. and K. Wolyniec, 2003). This is based on the *convergence assumption*, that is the assumption of the convergence of futures and spot prices at the futures expiration date, according to which:

In electricity market, forward contracts are the majority of instruments used for risk management. Supposing a complex energy structure whose uncertainty is related to *n* random factors, if we want to hedge, we must be able to find a set of forward contracts dependent on the same *n* factors.

#### 4.4.2. Energy futures

Energy futures are quite similar to forwards, that is why their prices are used to estimate forward contracts value. Their advantages respect to forwards are related to the elimination of the credit risk, that is guaranteed by stock exchanges, and the reduction of transaction costs, because of the contract standardization. Furthermore, the daily trading allows an easy market-to-market evaluation, respect to forwards and swaps.

The main element of commodity futures are: volume, price, delivery location, delivery period, last trading day or settlement date (Eydeland A. and K. Wolyniec, 2003). Futures are traded on NYMEX and other exchanges. *Electricity futures* were introduced in NYMEX in 1996, then in other locations and exchanges. After some years, investors lost interest in futures, and moved to OTC forward contracts, so that electricity futures were delisted from NYMEX and some other official markets. Gas futures are currently traded on NYMEX and other markets, and they are about the delivery of commodity in some specific locations.

Hedging with futures is useful in order to prevent risk and losses deriving from price of commodities fluctuations. An interesting example is provided by Eydeland and Wolyniec (2003), who imagine a company committed to provide power to its clients during the summer, when the prices are supposed to be high. The risk is that of commodity price volatility and the solution could be that of locking the summer prices as early as possible. Indeed, the company decides to negotiate with an energy trading company, in order to achieve a fixed price in the power furniture, for one month. An energy future is signed: one party will deliver for one month a contracted power supply to the other one, committed to pay a fixed amount of money. In this way, the energy provider prevented the risk of price volatility during the summer. This very simple example is given to provide an idea about the usefulness of energy futures, in a highly volatile context like the energy one, where price fluctuations are very common. In this case, the risk is suffered also from the other side company, who is facing the obligation of supplying energy in a period where spot price is higher than the

contractually fixed one. The only way to continue to be profitable for the energy trading company is a dynamic hedging with futures during the preceding months, meaning that it would have had exploited the rise and fall of prices and accumulated a consistent positive margin, in order to be able to supply contractually fixed energy on the specified month to the counterparty, without suffering any loss.

A likely risk for energy companies is that of a failure to implement a correct hedging strategy, that is common to forwards and futures contracts. Indeed, hedging strategies need to be supported by methodologies taking in consideration the possibility of failure for different scenarios.

## 4.4.3. Energy swaps

Swaps in energy markets are very similar to swaps in financial markets, and very close to forwards, that can be seen as "one period swaps". They are traded OTC, very flexible and customizable, and suitable for hedging. They usually imply the payment from a party to a counterparty of a fixed amount, in exchange of payments related to a variable index (commodity spot price, for example). Swaps have the advantage, respect to forwards and futures, to be flexible, versatile and never rigid, so that they are an indispensable tool for energy risk management. In fact, there is a diversity of swap structures in the energy OTC market.

Plain Swap is the basic swap contract involving an exchange of cash flows or commodities, where one party pays a fixed price in a sequence of payments. A company may use swaps to protect itself from upside price fluctuations: for instance, it may pay a predetermined price (swap price) and receive in exchange a given amount of commodity, although the index prices exceed the swap price. In this way, when prices are high, it receives extra cash flows, but it cannot exploit downside price fluctuations. There are other types of swaps: a differential swap is built on the difference between the prices of two assets; a participation swap allows the holder to participate to the benefit of advantageous price movements; a Swaption is an option on a swap, and so on. (Eydeland and Wolyniec, 2003).

## 4.5. Energy options

After futures, forwards and swaps, calls and puts are the most common risk management instruments. In energy markets, a *call option* is the right, but not the obligation, to buy energy at a predetermined strike price, and a *put option* is the right, but not the obligation, to sell energy at a predetermined strike price (Eydeland and Wolyniec, 2003). There is wide diversity of traded options in energy market: calendaryear, quarterly, and monthly physical options; daily options and cash options; hourly options; and then, various types of exotic options, such as spreads. Among the plain-vanilla options, which are the basic types of calls and puts, there are power and natural gas options, according to a commodity classification. For instance, the owner of a power call option may have the right, but not the obligation, to call on the seller of the option to deliver a X amount of power in a peak hour, during a specific month. Furthermore, there are financially settled options, that are exercised against a financial index, such as FERC for gas, whose payoffs are the already mentioned ones in the table above; and physically settled options, traded without a financial index, whose pricing is based on the average of commodity spot prices.

Daily options are exercised every day as well as cash options, whose strike price is fixed or linked to a floating index, set at the beginning of the month (Gas daily index, for example). This kind of options is very common in energy risk management, since it allows to price risk on a daily basis. Hourly options exist only in power market to manage power price risk: they are settled against real-time hourly prices.

The main issue of options in energy markets, especially in the power market, is that the spot price cannot be traded. Since power cannot be stored, the one purchased on one day cannot be resold on another. It means that it is not possible to replicate the portfolio, unless you use other derivative contracts, such as forwards. Options are used for hedging when no other instruments are suitable to prevent a risk. A common application is that of an extraordinary rise in spot power price: "an option is used as an insurance against extraordinary events" (Eydeland and Wolyniec, 2003), events with

low probability of occurring but devastating effects. They are suitable for capturing downside and upside exposure, as well.

Spreads and spread options are included in exotic options: they are relevant in energy markets to manage complex risk structures. They are used to stabilize cash flows, to mitigate geographical and calendar risks, to arbitrage market inefficiencies. A spread is a "price differential between two commodities": between different grades of oil, for instance (intercommodity spread or quality spread); between prices in two different locations (geographic spread); between different futures prices of different expiration (time or calendar spread), and so on (Eydeland and Wolyniec, 2003).

A spread option is very common as well: it is call or a put option to enter into a forward or a spread contract, where the underlying is a two-commodity portfolio (for ex. the spread between forward prices of power and natural gas).

Swings, recalls and nominations are volumetric options that give holder the right, but not the obligation, to adjust volume of received or delivered commodity.

## 4.6. Valuing energy derivatives

Energy derivatives are traded at a price, that is not randomly set: in this paragraph, some models for valuing and pricing the main tools of risk management for energy companies will be illustrated.

Each model starts from the forward curve, the most elementary representation of commodity prices, and then extends the result of this analysis for pricing other derivatives. Indeed, if we are able to understand its trend, we will have a good basis for pricing all the other derivatives, as well.

The interest in analyzing the behavior of the energy forward curve and which are its determinants has been averted in literature: "A model of the dynamics of the evolution of the forward curve is an essential building block of any energy trading and risk management methodology" (Blanco and Stefiszyn, 2002). Furthermore, forward curve is a starting point for pricing OTC derivatives, such as Swaptions, or strike options and swings.

In order to estimate forward prices, it is necessary to start from futures ones but, since futures are often traded only for few days, you need to combine several contracts to get a time series of forward prices. As a result, you need to run a very complex calculation of several correlated variables and volatilities on NYMEX.

The multi-factor model was developed in 1999 for forward price curve, but also to price a wide range of energy derivatives: it may be considered a general framework for the risk management of energy derivatives. It was developed by Clewlow and Strickland (1999), who followed an alternative approach respect to the traditional one, relying on a stochastic process for spot prices. They preferred a more practical approach and synthesized the evolution of the forward curve in the following equation:

$$\frac{dF(t,T)}{F(t,T)} = \sum_{i=1}^{N} \sigma(t,T) dz(t) ,$$

where F(t, T) is the forward price at time t for maturity T and  $\sigma$  (t, T) are volatility functions associated with the independent Brownian motions z (t).

The model assumes that *n* sources of uncertainty drive the evolution of the forward curve, and each of them is associated with a volatility function, determining in which direction and how much the curve moves, after the arrival of new information related to a source of uncertainty. Integrating this model with the volatility functions found in literature for single factor models, it is possible to obtain a generalization for the spot price process:

$$\frac{dS(t)}{S(t)} = \left[\frac{\partial \ln F(0,t)}{\partial t} + \alpha \left(\ln F(0,t) - \ln S(t)\right) + \frac{\sigma^2}{4}(1 - e^{-2\alpha t})\right]dt + \sigma dz \mathbf{1}(t)$$

In this way, spot prices are consistent with the initial forward curve.

This equation is useful not only to define the trend of the forward curve, but also to price European options, by deriving the spot price. In fact, volatilities and correlations of forward prices may be estimated from the market (oil and gas futures from NYMEX,

for instance) and incorporated into the model in order to price a wide range of energy derivatives. Of course, the model needs to be integrated with methodologies such as Monte Carlo simulation and variance covariance matrix, that will be illustrated in the next chapter. Furthermore, by using trinomial trees for the spot prices, it is possible to price American options, as well. The model was also applied to Swaptions and European Caps pricing (Clewlow and Strickland, 1999).

A very simple type of multi-factor model was provided some years later by Blanco and Stefiszyn (2002), the so-called Principal Component Analysis (PCA), consisting in identifying only a very small number of components contributing to the variability of the data. Nevertheless, there is a trade-off between the ease of use of a model and the accuracy of results that you can obtain including more variables: the cost is complexity. In fact, if you include only the principal components, you come out with a very simple model but, on the other side, you are losing some of the accuracy of data that you would provide by including more variables in your analysis, despite complexity.

To one year ago, literature still confirmed the efficacy of multi-factors models. According to Blanco and Pearse (2012), some of the key features of energy forward price behavior are:

- Time-to-maturity effect: as the maturity is closer, the forward contract volatility and the correlations with other forward contracts often break down.
- Complex forward curve dynamics: the forward curve has a complex trend, that cannot be captured by simplistic models.
- Seasonality: since the variability of futures contracts is highly seasonal, the forward curve exhibits larger changes as well.
- Limited time series of contract behavior: it is not easy to build a forward curve from futures price, because they trade only for few days before delivery. As a result, many stories of a series of contracts need to be combined to build a continuous series of forward prices (forward curve).

Given the complexity of forward curve behavior, multi-factors models result to be more suitable than some others to capture all components of risk, but they need to be implemented with more sophisticated risk methodologies. The opportunity to use different risk metrics and methodologies, such as Monte Carlo simulation, to deal with risk exposure, has been already discussed in the last chapter, with reference to Valueat-risk and alternative methodologies.

Modeling the evolution of the forward curve may be useful for the pricing and risk management of a portfolio of energy derivatives (Clewlow and Strickland, 1999b).

## 4.7. Numerical techniques to value derivatives

At the end of the last paragraph, it has been mentioned the process that companies practically follow to price energy derivatives. The multi-factor model is nowadays the one that best approximates the evolution of the forward curve, used to price other derivatives, as well. However, it is the end of a process based on some assumptions implying the use of some methods, that need to be explained.

The models for pricing derivatives take origin from the Black-Scholes-Merton modeling approach (BSM). This method starts from the option valuation and assumes that it is possible to perfectly replicate options by continuously trading the underlying asset. This approach is unrealistic in the energy market because, as already told, spot electricity cannot be stored (Clewlow, Strickland, 2000). However, using futures to replicate options, the risk-neutrality assumption can be kept. Another important assumption of BSM is the mathematical description of how asset prices evolve: the Geometric Brownian Motion (GBM), included in the above mentioned forward curve model, assumes that proportional changes in the asset price (S) have a constant drift ( $\mu$ ), and a volatility, ( $\sigma$ ), such that they are described by the stochastic equation:

### $dS = \mu S dt + \sigma S dz$ [Clewlow, Strickland, 2000]

The Black-Scholes formulas introduced in the first chapter are valuable tools to evaluate the options but, their main drawback, that is also the reason why they have been replaced by VaR for risk measurement, is the assumption of constant volatility. This issue has been partially corrected by using the so-called "implied volatility smiles", that try to adjust the volatility in Black-Scholes formula for options through statistical methods. However, it is not always possible to price derivatives with closed formulas such as the Black-Scholes ones for call and put options. This is the reason why multi-factor models, defined in the third chapter as the most applied, replaced the stochastic ones. They are supported by numerical techniques that have been referred to be discussed in this section: the trinomial method and the Monte Carlo simulation.

### 4.7.1. The trinomial method

The trinomial method descends from the binomial method, at the basis of the GBM. Introduced by Cox, Ross and Rubinstein in 1979, the binomial method is commonly used to represent and price the options, in particular the American ones, in a form of binomial tree. Nevertheless, many practitioners prefer to use the trinomial trees: Clewlow and Strickland, the authors referred in this section, believe they are more suitable than binomial trees for energy derivatives representation. Respect to binomial method, the trinomial one allows to represent the future assets movements in three dimensions instead of two, and to approximate better the future changes in a rapidly changing environment, like the energy one. As a result, it is a more flexible and easier to adopt method to price energy forwards and options.

The process is not much different respect to binomial tree: you need to assign three probabilities, whose sum is zero, instead of two to the asset price increase. The trinomial process for one period is extended from time to time to the further periods, to form a tree (Fig. 9).



Fig. 9 A trinomial tree model of an asset price (Source: www.sciencedirect.com)

The tree may be used, for instance, to describe the energy spot price behavior: at each node, there is the spot price. Once each node of the tree has been built, it can be used to price options and other derivatives. Imagining to price an option, the procedure is "backward looking", because you are interested to know the value at maturity, but this is related to the values of the stages before (computed imagining to have exercised it before). The process is particularly interesting for American options, since it helps to find out the most convenient time to exercise the option.

## 4.7.2. Monte Carlo simulation

Monte Carlo simulation is implemented to support one-factor model but also multifactors ones, because it can include many sources of uncertainty in its simulations. Thus, it may be used to value options and derivatives depending on two or more energy prices, as well.

Introduced by Boyle (1977) to value the options, the Monte Carlo method simulates the possible paths that the prices, as well the payoffs, can undertake until the option maturity. So, the evolution of spot prices, expressed by the GBM, is simulated through random samples from a standard normal. For instance, if we wish to simulate the

energy spot prices evolution, we need to divide the time period into N intervals and repeat the simulation process N times. In this way, we can obtain the possible path of the spot price. At the end of the process, we calculate the option price with the Call or Put formula. If we are applying a multi-factor model, in order to price the option by simulation, we need to generate random samples for each variable and find the correlations, too. This process can be easily achieved through the generation of the standard normal variables, a part taking about 30% of the total execution time of a Monte Carlo simulation (Clewlow, Strickland, 2000).

Although the simulation can take much time, it has the advantage of reducing the variance.

As already mentioned, one of the identified characteristics of the spot prices is the seasonality. Monte Carlo simulation has the advantage of incorporating the seasonal volatility into the model: the property has been tested by Clewlow and Strickland (2000) for one-factor model, but it can be extended to multi-factors models, as well.

## 4.8. Techniques for hedging energy derivative positions

It has been widely explained how and why energy derivatives are used to offset the risks coming from the energy markets. Nevertheless, when companies own a complex portfolio of derivatives, they also need to care about the related risks. Thus, a risk management of portfolios containing energy derivatives is a subject that cannot be ignored discussing about energy risk management.

Energy companies are constantly increasing their trading of forwards, futures, swaps, options, such that they have to face the problem of managing the risk of these positions. Value-at-risk measures have been described as the tools to compute the risk related to market factors, but also to energy derivative positions. The next step is offsetting the risk related to these positions: delta, gamma and vega hedging are some techniques used to solve this issue. They all have in common the fact of being part of the dynamic hedge, that is more suitable than the static one to energy derivatives risk management. Static hedge means offsetting a position, for instance buying a long call

to hedge against a short call sold, and never changing this strategy. The result may be not sufficient to hedge perfectly the risk, especially when lots of changes in spot prices are expected, that is what generally happens in the energy markets.

The dynamic hedge tries to completely offset the risk, by making the derivative portfolio immune to small changes in the underlying energy price in the next small interval of time: this process is called *delta-hedging*. In this way, the position will be kept delta-neutral for the next small period, after which the hedge will be rebalanced. *Gamma-hedging* is based on the same principle, but it aims to make the portfolio insensitive to large changes in energy prices. *Vega-hedging* differs because offsets the risk related to changes in the volatility of the energy (Clewlow and Strickland, 2000).

Let's try to illustrate the use of the three hedging techniques starting from the example of the "delta profile for two at-the-money European call forward options on NYMEX crude oil with maturities of three months and six months on an underlying forward with nine months to maturity" (Clewlow, Strickland, 2000). It is interesting to observe how delta varies with the forward price: when it is low respect to the strike price, the delta of the option is close to zero, because the option is not likely to finish in the money; when it is high, the delta rises given the high probability of the option to finish in the money. The value of the delta corresponds to the number of long or short positions in futures contracts that the option writer should take to hedge its position. If the delta trend is very close to the futures prices, it means that it has well performed. As already mentioned, delta succeeds in offsetting only short term changes in energy prices; later, it has to be rebalanced. There is not a specific time to rebalance it: it depends on how much the underlying price has moved and on a cost-benefit analysis between the risk reduction and the trading costs, since the hedging strategies are not costless. Delta strategies become inefficient when the underlying prices move in large amounts from the hedge that was established. The problem derives from the fact that while the delta value is a linear function, the option is non-linear. Therefore, as the underlying price changes by larger amounts, the position required to obtain a deltaneutral changes too. Delta is not fixed, but it is sensitive to changes in the underlying asset: this is the real problem of delta-hedge. To correct this drawback, the sensitivity

of delta to changes in the underlying price, called *gamma*, has to be neutralized. Gamma can be computed with the second derivative of the option price respect to the underlying price: the higher is gamma, the more frequent has to be delta rebalancing. In order to neutralize gamma, the hedger has to use another option, since gamma of a forward or futures contract is zero (the sensitivity of delta to the underlying price was referred to options).

Gamma hedge is proved to perform better than delta, since the error is smaller for a wide range of futures prices, and the rebalancing needs to be less frequent: that is why it has the effect of hedging for longer periods. Despite its effectiveness, gamma hedging is more expensive than delta one, because trading options costs more than trading futures. One more time, there is a trade-off between the additional benefit of gamma hedge and the additional costs of the options market.

Further to the risk of change in prices, another source of risk comes from changes in volatility, that is a key variable to value derivatives. Volatility can be hedged through *vega*, calculated in a similar way of gamma, but focusing on the changes in volatility instead of prices. By taking a position in an option, the hedger makes that the vega of the hedging option offsets the vega of the original derivatives portfolio.

A trader can decide to use the three techniques at the same time, to hedge against delta, gamma and vega, or he may hedge against two or only one of them.

Applying a multi-factor model, you need to compute the changes in the value of the portfolio between the shift of the forward curve for each factor. You come up with a system made by multiple equations, to hedge with different forward contracts for each factor. The logic behind is the same: your aim is offsetting the risk of a derivatives portfolio through delta, gamma or vega techniques.

In the last chapter, energy derivatives appeared as a way to protect energy companies from the market risk factors they are constantly exposed to; thus, they were defined as the principal tools of risk management, especially due to their hedging purpose.

In this chapter, energy derivatives seemed to be a source of risk, as well. Quantitative tools, as VaR and its alternatives, as statistical techniques to compute volatility, are

used to measure and control risk not only coming from market factors, but especially related to a portfolio of energy derivatives.

To wrap up, if on the one hand energy derivatives may be seen as an opportunity; on the other hand, they are not risk free and imply a threat of adding risk to the portfolio. This criticism is generally moved to many kinds of derivatives, whose use is often accompanied by a certain amount of risk, especially those which are part of a complex portfolio of derivative positions.

For this reason, risk management and energy derivatives are strictly interrelated: it is not possible to look at them as at two separated entities. In fact, the use of the quantitative tools of risk management here shown helps to constraint the risk associated to a portfolio of energy derivatives, and to exploit the benefit related to them, that is hedging against commodity risk factors.

In particular, if well applied, the last mentioned delta-gamma-vega techniques may offset the risk associated to a portfolio of energy derivatives. Thanks to the quantitative tools illustrated till now, from VaR to hedging techniques, it becomes possible to exploit the benefits of the hedging property of energy derivatives in energy commodity markets, managing at the same time the risk of the portfolio.

In conclusion, to the criticism that one could move to energy derivatives of adding risk instead of offsetting it, the correct application of the methodologies of this chapter may be opposed.

## **Chapter 5**

## Hedging against energy risk

#### 5.1. Methodology

The methodology of this thesis has followed a logical process, integrating theoretical and practical aspects of the main topic. Energy derivatives and risk management have been studied on their essential parts and they have been integrated by practical examples, when necessary. Qualitative information prevailed on quantitative one, available in a minimal part. It has been collected mainly from academic publications, but also from companies' websites and publicly available sources. The academic research of publications, that has been at the basis of this work, has been preferred to the case study methodology essentially for two reasons. Firstly, risk management practices are applied by different companies in different manners, such that studying them on a single or few subjects, would not have allowed to extend the conclusions to other subjects, as well. Secondly, not all the relevant information about risk management, and especially about energy derivatives, are published by the companies, and they are not likely to disclose more than what has been collected to write the paragraph called "Empirical observations", contained in the second chapter. However, these chapters satisfy the need to provide an answer to the research

question that has driven this thesis. To be clear, the goal of this research has been that of showing the benefits of risk management and of energy derivatives for the energy companies. The reason of the focus on the energy sector relies on the multiplicity of risks that characterize this industry, and that make necessary the use of instruments to manage them and to protect the firms operating in.

Regarding to the structure, the chapters 1, 3 and 4 have been written to provide a theoretical knowledge, respectively, of risk management practices, quantitative tools and energy derivatives. On the other hand, the chapters 2 and 5 have a more practical approach: while the former contains the practical applications of risk management practices that actually have been observed in firms; the latter includes practical

applications of energy derivatives for hedging purpose, with some numerical supports, when required.

The preceding chapters have been focused on the description of the main risk management tools and methodologies, with a particular mention to energy derivatives. It has been explained why risk management is important for firms, and more specifically for energy companies, and which are its main instruments. Some well-known risk management users have been mentioned, and the tools they can use to fight with risk, as well. Nonetheless, one final step has to be done, if the aim of this work is that of showing the relevance of risk management, and more specifically of energy derivatives, for the companies operating in the energy sector. A very useful research of this final chapter is that of finding and showing some applications of energy derivatives, in order to prove the benefits that its users can achieve thanks to their use. Since the focus has been from the beginning on the hedging purpose, arbitrage and speculation aims will be left out from this analysis.

In order to provide a complete overview of the topic "hedging against energy risk", the mechanism will be illustrated for each of the main commodities (oil, gas, electricity), and mentioning some case studies will complement the analysis with some practical examples.

The first example is about oil hedging on NYMEX, the fundamental market where oil transactions take place. After a brief description of how the New York Mercantile Exchange system works, the paragraph offers a simple numerical example about hedging. It is practically shown how an oil producer may hedge through futures the risk of declining oil price. Despite its simplicity, the example is very useful, since it demonstrates through numbers how concretely oil producers may enjoy a cash flow stability thanks to futures. The application of oil futures "in numbers", regarding the positive effects achieved by hedging, is followed by a historical case study widely debated in literature, that is that of MetallGesellSchaft. In this case, energy derivatives were seen, on the contrary, to produce the negative effect of huge losses. Nonetheless, a historical simulation demonstrates that a correct application of derivatives would have provided the beneficial effects seen in the preceding

paragraph. After a historical case, a current one is provided, that is that of airline companies, hedging oil day by day to run their business. The case is important to show how this practice may be essential for the survival of a business indirectly related to oil, but funding its success on the benefit of hedging oil, as well. In fact, without fixing the jet fuel price, for an airline company, it would not be easy even to sell tickets.

Further to the cases about oil, the discussion about *hedging against energy risk* moves to another commodity, that is electricity. As for oil, a numerical example of short hedge is provided. Two scenarios of falling and rising electricity prices are prospected, and the net sales revenues in both cases are computed. They seem to be equal in both cases: it means that the objective of the cash flow stability is achieved, even though it is not possible to exploit the upside price fluctuations, but this is the hedge cost. Till now, hedging oil and electricity seem to be very similar, but a big difference exists and it is observed in the cases of the Nordic Power Exchange and of Texas electricity market. Since electricity cannot be stored and moved worldwide as oil, its demand and price are widely influenced by the local needs. Both cases confirm the expectation that models for pricing and hedging with power derivatives need to be adapted to local factors, if they want to be successful.

Despite the usefulness of oil and electricity examples to understand how energy derivatives are concretely used for hedging purpose, the discussion would not be complete without mentioning gas as commodity and options as energy derivatives. Futures are very diffused and immediate instruments, but options have a role in hedging against energy risk as well, especially in highly volatile markets. The example proposed in the paragraph, called *Gas hedging with options*, shows empirically how these instruments may offer a downside protection in a highly volatile market, like the gas one, affected by transportation issues.

Finally, the chapter comes to an end with a discussion about pros and cons of energy derivatives. If on the one hand the mentioned cases show their advantages; on the other hand, the criticism is supported by historical cases of epic failures and real danger of increasing exposure instead of reducing it.
#### 5.2. Oil hedging on NYMEX

To go back to the origins of the New York Mercantile Exchange (NYMEX), it is necessary to recall one of the peculiarities of the energy industry: high degree of uncertainty, leading to high volatility. From here, the necessity do hedge against the risk of adverse price exposure, through futures and options, the financial instruments listed on the NYMEX.

NYMEX is the world's largest physical commodity futures exchange, made by two divisions. In the NYMEX Division, oil financial contracts are traded, and they are used as pricing benchmarks in energy markets worldwide, as well (NYMEX, 2013).

A brief description of NYMEX working may be useful to provide a concrete idea about how energy transactions take place.

Energy futures and options are traded on the Exchange's electronic trading system, called NYMEX ACCESS<sup>®</sup>, and this is common to oil, gas and electricity.

A transaction can last some seconds and it is concluded by matching asking and bidding parties. The exchange works if on the market there are both private speculators and commercial hedgers. A customer usually calls a broker and orders to buy or sell contracts. The broker sends the order to the firms on the trading floor, via telephone or computer. On the one hand, the sellers compete with each other by offering lower prices; on the other hand, buyers compete rising prices. The difference between the prices is called *bid-ask spread*. When the highest bid and the lowest offer meet, the trade is concluded and it is registered on an index card, filled with the contract details (NYMEX, 2013).

Futures fulfill a great part of NYMEX; they are traded in standardized units and they are very widely dispersed. To be traded in a futures form, the commodity must have the following characteristics: volatility, presence of many buyers and sellers, interchangeability (possibility to be shipped and stored). Since oil fulfills these requirements, it is commonly traded through futures. In particular, futures are adopted to hedge against oil price risk. Futures have the advantages to be standardized and liquid, so that they are cost-efficient and quickly disseminated at the

same time. Even though they allow the trader to be anonymous, the counterparty credit risk is eliminated, because transactions are regulated by the Exchange, a very safe and fair system.

Let's introduce one hedging example through futures traded on NYMEX.

#### Example – Crude Oil Producer's Short Hedge

The case of a crude oil producer, committed to sell a given amount of oil at specific dates, is an example of short hedge, that is applied to protect the seller from a likely oil prices decline, through the futures market. At the opposite, a long hedge is the purchase of a futures contract to protect against price increases in the future. Symmetrically to the short hedge case, in a long hedge, futures are purchased by those who have a commitment to buy in the cash market. It is generally of interest of those who produce refined oil products.

Going back to our example, let's imagine a crude oil producer committed to sell, for the next 6 months, 30.000 barrels a month of petroleum at spot prices. At the deal date, price is equal to \$20,50, but it is expected to decline. In order to protect himself from losses, the producer decides to make a short hedge. He hedges his production for the six months ahead by selling futures contracts at the following prices for each month:

February  $\rightarrow$  \$20 ; March  $\rightarrow$  \$19,75 ; April  $\rightarrow$  19,50 ; May  $\rightarrow$  19,50 ; June  $\rightarrow$  \$19,25 ; July  $\rightarrow$  \$19.

An overview of the possible prices scenarios (slowly and rapidly declining) is summarized in the following tables (cash market column). Furthermore, the tables include how the net price received may vary when the oil producer decides to hedge the risk on the futures market. The *futures result*, that may be positive or negative, depending on the difference between the price at which the hedger sells and buys contracts, has to be summed to the spot price in order to obtain the *net price received* month by month. Intuitively, if the net price received is higher than the spot price, the oil producer will have taken advantage from its transactions in the futures market (Fig. 10 and 11). Fig. 10 Slowly declining prices scenario (Source: NYMEX 2013)

Dates	Cash market	Futures market	Futures result	Net price rec	eived
jan-01	\$21	Buys back Feb contracts at 20,50\$	20\$-20,50\$= <b>-0,50\$</b>	21\$-0,50\$= <b>\$</b>	20,50
feb-01	\$20,50	Buys back Mar contracts at \$19,75	19,75\$-19,75\$= <b>0</b>	20,50\$-0= <b>\$2</b>	0,50
mar-01	\$20	Buys back Apr contracts at \$19	\$19,50-\$19= <b>0,50\$</b>	20\$+0,50\$ <b>=\$</b>	20,50
apr-01	\$19,50	Buys back May contracts at \$18,50	\$19,50-\$18,50= <b>1\$</b>	19,50\$+1\$= <b>\$</b>	20,50
may-01	\$19,50	Buys back June contracts at \$18,75	\$19,25-\$18,75= <b>0,50\$</b>	19,50\$+0,50\$	\$ <b>=\$20</b>
jun-01	\$20	Buys back July contracts at \$19,50	\$19-\$19,50= <b>-0,50\$</b>	\$20-\$0,50= <b>1</b>	9,50\$
Average				Average	
Unhedged	\$20,08			Hedged	\$20,25

Fig. 11 Rapidly declining prices (Source: NYMEX 2013)

Dates	Cash market	Futures market	Futures result	Net price rec	eived
jan-01	\$20	Buys back Feb contracts at 19,50\$	20\$-19,50\$= <b>0,50\$</b>	20\$+0,50\$= <b>\$</b>	20,50
feb-01	\$19,50	Buys back Mar contracts at \$18,75	19,75\$-18,75\$ <b>=1\$</b>	19,50\$+1\$= <b>\$</b>	20,50
mar-01	\$19	Buys back Apr contracts at \$18	\$19,50-\$18= <b>1,50\$</b>	19\$+1,50\$ <b>=\$</b> 2	20,50
apr-01	\$18,50	Buys back May contracts at \$17,50	\$19,50-\$17,50= <b>2\$</b>	18,50\$+2\$= <b>\$</b>	20,50
may-01	\$18,50	Buys back June contracts at \$17,75	\$19,25-\$17,75= <b>1,50\$</b>	18,50\$+1,50\$	5 <b>=\$20</b>
jun-01	\$19	Buys back July contracts at \$18,50	\$19-\$18,50= <b>0,50\$</b>	\$19+\$0,50= <b>1</b>	9,50\$
Average				Average	
Unhedged	\$19,08			Hedged	\$20,25

We can estimate the benefits of the short hedge of oil producer for both scenarios, in terms of increased cash flows, respect to the base case of *unhedged* production. These results can be easily calculated multiplying the gap between the average oil prices achieved with and without hedging, times all the barrels of production:

Scenario 1: (\$20,25 - \$20,08) x 180 000 barrels = **+ \$ 30 600** Scenario 2: (\$20,25 - \$ 19,08) x 180 000 barrels = **+ \$ 210 600** 

In both cases, a positive result is achieved by hedging. Of course, the increase in cash flows is much higher in the scenario of rapidly changing prices. The great drop in oil prices hypothesized in the second table would have impacted very negatively on oil producer's cash flows if he did not have hedged the risk, but even in a slowly declining prices scenario, hedging is proved to be convenient and to have enhanced cash flows. This very simple example has been useful to provide an idea about the benefits that companies dealing with oil may achieve by hedging, in terms of avoided losses. In this case, the oil producer succeeded in protecting his revenues from the expected declining market. The near-by contract mechanism has been applied and it is commonly used by oil producers to hedge the current production: in practice, futures contract of the next month is used to hedge the production of the current month.

Hedging effectiveness has been studied in literature. In particular, the case of NYMEX crude oil futures was analyzed by Ripple and Moosa (2007), who tested hedging effectiveness for different futures contract maturities. Finally, they came out with the result that near-month contracts (those applied in the example) are more effective than longer maturity ones (six months). This is why the correlation between spot prices and near-month futures prices is higher than that with more distant futures prices. A final remark of the paper is about transaction costs: investor must be aware that near-month futures involve more transactions than six months ones. Thus, he has to compare the superior benefits of near-month contracts respect to their alternatives, with the higher transaction costs they have.

### 5.3. The case of MetallGesellSchaft

Metallgesellschaft (MGS) is a very discussed case of use of energy derivatives in literature. It is one of the most famous examples of companies experiencing losses from derivatives. MGS used oil futures and similar contracts with speculative aims, but it did not have a correct hedging strategy in case of adverse events (Oldani, 2012). When the oil price fell suddenly, the loss was huge. All those who wrote about MGS agree that mismatching maturities and scarce knowledge of the financial instruments have to be considered the causes of the epic loss.

A part of the research has been focused on the Refining & Marketing division of the company, called MGRM, as unit of analysis to find out the mistakes in the hedging

strategy of MGS as a whole. If on the one hand, some authors define it as a successful case of implementing oil price risk reduction; on the other hand, some others argue that, instead of reducing its exposure, the company actually increased the risk because of an oversized hedge. A further contribution to this analysis was provided by Wahrenburg (1996), who proved how effective would have been the strategy pursued by the company in a long time horizon, lasting all the contract length, that is a 1:1 hedge strategy.

At the beginning, MGRM started its hedging activity by establishing long term OTC contracts with customers. It was committed to sell refined oil products at a fixed price, each month, for the following five or ten years. Then, given the scarcity of long term contracts in the market, the company decided to look for short term futures and OTC swaps.

MGRM's hedging strategy has been analyzed and it has been found to work at best when the hedge ratio is 1:1. It means that the number of derivatives contracts is such that they can cover all the commodity exposure. There must be a perfect correspondence between the risk to hedge against and the contract object. Applying 1:1 hedge ratio, we assume that all the risk coming from oil price fluctuations will be eliminated.

Assuming a constant basis B, the futures price at time (t+1), and the spot price at time t are linked by the following equation:

## F = S + B

Similarly to the basic example provided in the last paragraph, the cash flow resulting from the hedging oil activity will be equal to: x(S-F).

In order to verify the effectiveness of this strategy, the author of the mentioned paper (Wahrenburg, 1995) ran a historical simulation to calculate not only the payoffs of MGRM's oil hedging program, but also the possible outcomes of alternatives hedging strategies. The payoffs are calculated in terms of cash flows, but the regression takes in consideration volatility, as well. In practice, the historical simulation aims to find out which is the best performing hedge ratio in terms of risk and return at the same time. The conclusions of the study are the following: a "no hedge" strategy would have provided to the company the worst result in terms of volatility and return; on the contrary, the 1:1 hedge performs at best for the return, associated to one of the lowest volatilities, as well. Indeed, 1:1 hedge results to be the winning strategy from the historical simulation.

Since 1:1 was capable to substantially reduce MGRM's commodity price risk in the long run, this case is a concrete example to prove the benefits that hedging through futures in the oil market may provide to oil companies.

Nonetheless, MGS experienced one of the largest losses from derivative instruments among oil companies, such that what said in the last sentence could not sound well. Actually, the pitfall found in MGRM's strategy is related to the time mismatching of its short term instruments to hedge long term commitments. This mistake caused a "funding risk", that is "the risk that a position profitable in the long run can bankrupt a company in the short run when negative cash flows are mismatched with positive cash flows" (Carter, Rogers, Simkins, 2004). However, this negative event does not mean that, if the strategy was well applied as Wahrenburg proved, MGS would not have benefited from hedging its exposures. On the contrary, the historical simulation on payoffs supports the thesis of the benefits of hedging for oil companies.

The lesson to learn from MGS is that if a company wants to use derivatives it needs to know them, in order to enjoy from them. Otherwise, it will have a counter producing effect, translated in a loss.

#### 5.4. The case of the airline industry

The NYMEX division is not only a market and a benchmark for oil prices, but also for similar products. One famous example of commodity hedged using heating oil futures contracts traded on NYMEX as a proxy, is the jet fuel, because of a chemical similarity and a price correlation.

Hedging against jet fuel price risk is a common practice in the airline industry, especially after the industry deregulation, that increased the price-based competition. Actually, translating the fuel price increase on customers is no more allowed, if the aim is competing on price. Furthermore, jet fuel is the second largest cost invoice for an airline company, and now that profitability depends on controlling costs, this cost needs to be accurately managed (Carter, Rogers, Simkins, 2004).

One well-known case of fuel hedging in the airline industry is that of Southwest Airlines, the American company which started this activity as a result of fuel price increases, to preserve its competitive advantage gained from pursuing a low cost strategy.

Fuel price risk management techniques began to be adopted in the airline industry around 1989. As already suggested, derivative instruments in this sector are based on crude oil, heating oil, or jet fuel, products that share similar characteristics and, as a result, have highly correlated prices. Many times, jet fuel is not directly traded and companies prefer to hedge more basic products, because they are more liquid and traded on NYMEX (with the consequent elimination of the credit risk), while jet fuel may be traded only OTC. Even when they trade futures on Exchange, they must be aware of the basis risk, that is the risk that the value of commodity hedged may not change in tandem with the value of derivative contract used. In the case of jet fuel, the *product basis risk* is higher than usual, because crude oil and jet fuel are two different commodities, very likely to differ. Then, the basis risk may also come from time, as in MGRM's case, and from a *locational basis*, when the price differs from a location to another one, not unlikely in the case of airlines (Carter, Rogers, Simkins, 2004).

The most commonly used hedging contracts by airlines are: swap contracts, call options, collars, futures contracts and forwards contracts.

Swap contracts include: plain vanilla, differential and basis swaps.

In all swap contracts, the airline is usually the fixed-price payer to a counterparty (floating-rate payer): in this way, it can hedge fuel price fluctuation risk. To give an example, using a plain vanilla jet fuel swap in OTC market, the parties agree a volume and the airline buys fuel on the market for the length of the contract, but the swap

makes that it continues to pay a fixed rate even when price moves, because the counterparty pays the floating, usually calculated monthly. Fuel hedging through swaps may also be arranged on the organized exchanges using highly liquid contracts, such as the NYMEX New York Heating Oil Calendar Swap. To eliminate basis risk, given by the difference between two commodities (heating oil and jet fuel, for instance), the airline can use an additional swap contract, to hedge the risk that jet fuel prices will increase more than heating oil prices.

Energy options may be very expensive for airlines, given the high volatility of the sector. However, they are used to hedge against the average monthly fuel price, in the case of lack of liquidity of the market. To eliminate the premium cost, they often prefer to hedge with a "zero-cost collar", to protect against upward prices. This strategy allows to establish a minimum and a maximum price for fuel, so that the company can be sure to pay not more than a given amount (Carter, Rogers, Simkins, 2004).

Finally, airlines adopt forwards and futures enjoying a similar increase in cash flows of that observed in the first example. As already told, futures are traded on NYMEX for more basic products such as crude oil and heating oil, that airlines use to substitute the more refined and less liquid jet fuel price risk.

The case of the airline industry has been useful not only to illustrate the characteristics of oil hedging in a different context, but also how the use of energy derivatives may bring benefits to companies whose business is not strictly oil based. The airline one is an industry of services, whose business is indirectly related to oil, but even in this case, hedging the risk of this commodity may result essential to control costs, profitability, and even to compete in the market, although jet fuel is an oil derivate and only one of the cost invoices for airlines.

The conclusion is that risk management techniques and oil derivatives should be used not only by companies whose business is oil-based, but also by firms that can be indirectly affected by oil price and would suffer some losses in case of "no hedge" decision. To provide an idea about it, it is sufficient to figure out how deterring for an airline company would be selling a ticket ex-ante without knowing the jet fuel cost; or

symmetrically for a passenger, paying an unexpected variable cost for the fuel the day before his departure. These intuitive examples help to understand how hedging is useful for day-by-day operations, and what would happen without it.

#### 5.5. Electricity hedging on NYMEX

The mechanism of trading oil futures on NYMEX is the same for electricity futures. Similarly to what has been already done for an oil producer in the first paragraph of this chapter, an example of an electricity producer who has to hedge against the risk of electricity price decline will be proposed as follows.

Let's assume that an independent power production company is risking that a drop in prices will reduce its profitability: with a short hedge strategy in the electricity futures market, it will stabilize its cash flow.

Given an excess of power and the attractive prices for the months of April, May, June, the producer decides to sell 10 futures contracts for each of the three months, at the following prices: \$ 23, \$ 23.50, \$ 24, respectively. The following sales are registered:

April: 10 contracts x 736 Mwh x 23 \$ = \$ 169 280

May: 10 contracts x 736 Mwh x 23.50\$ = \$ 172 960

June: 10 contracts x 736 Mwh x 24 \$ = \$ 176 640

At the end of March, the April contracts, originally sold at 23\$, are now valued at 22\$. This leads the producer to a gain equal to:

(23\$-22\$) x 10 x 736 Mwh = **\$7360**.

As in the oil example, the producer will receive the sum in the cash market, plus the futures gain, for a net amount of:

(10 x 756 Mwh x 22\$) + \$7360 = **\$ 169 280** (NYMEX, 2013).

Imagining to have lower prices on cash market than futures market for the next three months, the hedge results are summarized in the following table (Fig. 12):

Dates	Cash mkt	Futures market	Futures gain	Net sales revenue
Mar. 27	\$22	Buys back Apr contracts at 22\$	(23\$-22\$)x10x736= <b>\$7360</b>	(22\$x10x736)+\$7360= <b>\$169 280</b>
Apr. 26	\$23	Buys back Mar contracts at \$23	(23.50\$-23\$)x10x736= <b>\$3680</b>	(23\$x10x736)+\$3680= <b>\$172 960</b>
May. 26	\$23,25	Buys back Apr contracts at \$23,25	(24\$-23.25\$)x10x736= <b>\$5520</b>	(\$23.25x10x736)+\$5520= <b>\$ 176 640</b>

Fig. 12 Electricity prices short hedge for falling prices (Source: NYMEX, 2013)

One could ask what would happen if electricity prices in the next three months grew, instead of falling. If on April electricity price rises to 24\$, while futures contracts have been sold at 23\$, the producer should buy back them at a higher price, realizing the following futures loss:

(23\$-24\$) x 10 x 736= - **\$ 7360** 

This sum has to be subtracted from the sale revenue on cash market, equal to:

\$ 24 x 10 x 736 = **\$ 176 640** 

Finally, the net amount received would be equal to **\$ 169 280**, the budgeted sum for April, as in the preceding case.

In the following table (Fig. 13), the short hedge strategy results for the next three months in case of rising prices are summarized. The difference with the last table is that, instead of summing a gain from futures market to the sales revenue on cash market, here we need to subtract a loss to the revenue realized in the spot market.

Fig. 13 Electricity prices short hedge for rising prices (Source: NYMEX, 2013)

Dates	Cash mkt	Futures market	Futures loss	Net sales revenue
Mar. 27	\$24	Buys back Apr contracts at 24\$	(23\$-24\$)x10x736= ( <b>\$7360)</b>	(24\$x10x736)-\$7360= <b>\$169 280</b>
Apr. 26	\$24,50	Buys back Mar contracts at \$24,50	(23.50\$-24.50\$)x10x736= <b>(\$7360)</b>	(24.50\$x10x736)-\$7360= <b>\$172 960</b>
May. 26	\$25	Buys back Apr contracts at \$25	(24\$-25\$)x10x736= <b>(\$7360)</b>	(\$25x10x736)-\$7360= <b>\$176 640</b>

It is important to notice how the net sales revenues in the two tables are the same. This is because, while in the case of falling prices, lower revenues in the cash market have been compensated by the gain in the futures market; in the second case, producer cannot exploit the case of superior spot prices to rise its revenues more than the budgeted ones, because of a loss on the futures market. Since the net sales revenues are equal in the two cases, the electricity producer does not need to worry about risk, because futures allow to reach a certain amount of cash flows even for a negative price trend. On the other hand, it will be no more possible to exploit unexpected upward price fluctuations, but this is the hedging cost, with whom the producer is comfortable, since it has been already set by the risk management committee. What is really important for a hedger is stabilizing cash flows and avoiding to incur in losses when prices move adversely. Hedger is not a speculator: he buys futures to hedge against downside risk and not to exploit and take advantage from the upside. As a consequence, energy futures worked well in both cases, because they allowed the producer to reach the budgeted net sales revenues for the next three months, in each case.

Finally, it is worthwhile to remind that "a hedge strategy is an evolving process" (NYMEX, 2013). Indeed, risk management targets may be revalued from time to time, as market movements vary. In the mentioned case, if prices were expected to grow, net sales revenues targets would need to be risen.

The electricity producer example has been very useful to understand the importance of risk management tools (in this case electricity futures) to stabilize cash flow. Without using this kind of instruments, an electricity producer in bad times would risk to incur in huge losses. Instead, using these instruments, he knows that, even in adverse market conditions, his sales revenues will not be affected and he will be able to continue to operate as usual.

#### 5.6. The case of the Nordic Power Exchange

"Electricity may be considered a flow commodity", since it is characterized by limited storability and transportability (Lucia and Schwartz, 2002). As a result, it cannot be carried worldwide like other commodities, such as oil, for example, that is globally traded. Indeed, we can imagine how electricity spot prices are highly dependent on local supply and demand conditions. This is the reason why it is interesting to study

how electricity hedging works in a local market, in order to observe how this mechanism is affected by local factors.

The first case I will refer to study this phenomena is that of the Nordic market of electricity, where this commodity is traded on the Nordic Power Exchange, also known as Nord Pool.

The Nordic Market of electricity knew a deregulating process, followed by the introduction of competitive electricity markets, where power derivatives were traded OTC and on official exchanges.

The Nord Pool includes now all Scandinavian countries, and it is divided into two markets: a physical market, called *Elspot*, and a financial market, *Eltermin* and *Eloption*. On Elspot, the physical delivery of power is traded: each contract refers to a load of an amount of MWh, to release at a given hour. The price (*System Price*), that is fixed on the basis of the balance between demand and supply, is used as reference in the financial market, as well (Lucia and Schwartz, 2002).

Eltermin and Eloption financial markets allow to trade forward and futures contracts. They do not imply a physical delivery, but they are settled in cash. Delivery periods may be of one day, one week, or one season, up to three years in advance. A separate business area, called Nordic Electricity Clearing (NEC), offers clearing services for standardized OTC bilateral contracts registered in the market (Lucia and Schwartz, 2002).

As mentioned at the beginning of this paragraph, electricity prices are strongly influenced by the local needs. It is important, in each market, to distinguish between *on-peak* and *off-peak* situations, or among seasons, because they affect power derivatives price. Studying how the behavior of the spot prices is driven by these variables allows to identify a kind of predictability of the valuation models, in the local market. These systematic effects are included in a deterministic component in the models to evaluate power derivatives.

It has been found that "[...] at least some of those regularities, especially the seasonal pattern, play a central role in explaining the shape of the term structure of futures

prices at the Nord Pool" (Lucia and Schwartz, 2002). The volatility, as well, has been observed to vary in cold and warm seasons.

Adjusting the models for the local variables may allow to extend the conclusions about the Nord Pool to other electricity markets, as well.

The importance of Nord Pool case study relies in observing how oil and electricity commodity differ, because the latter is affected by local factors that cannot be ignored in trading and pricing power derivatives. As a consequence, before trading electricity derivatives in a market, is recommended to be aware of the local variables impact. Intuitively, the fact that Scandinavian countries have less sun hours than Mediterranean ones, is surely a big gap that plays a role in comparing the two electricity markets.

#### 5.7. The case of the Texas electricity market

We are now aware about the fact that electricity markets are characterized by a dependence to local energy demand including a strong seasonal component; indeed, standard financial models are not suitable for them.

Data about the Texas market, known as ERCOT (Electric Reliability Council of Texas), confirm this expectation. Hedging models need to take into account the relationship existing between energy demand (load), following a seasonal pattern, and price. This analysis has been extended with a "spike regime", in which the price-to-load relationship also reflects extreme market conditions, to include jumps in the spot price trend (Coulon, Powell, Sircar, 2012).

In influencing electricity prices, short term and long term variables have been found. The primary short term driver is load; while longer term effects are those coming from the fuel prices. Seasonal or weekends peaks are load drivers. These variables have been included in the models to price derivatives, and to be used for hedging, as well. This is what has been done in Coulon, Powell and Sircar's paper (2012), who proposed a model for Texas electricity market, that is suitable for energy companies, as well.

As in the last case, the complexity of electricity market requires to consider numerous different components. Although the models should be tailored for different electricity markets, because local market conditions vary from region to region, the process may represent a draft for other markets, if the local components are captured.

The case of the Texas electricity market is one more example, found in literature, of how models of electricity, given the complexity of this commodity, need to be locally adapted. Without deepening the mathematical peculiarities of the models proposed in these two papers, they do not differ in their general assumptions. Despite the difference between Nordic and Texas market, the two publications both agree on the necessity to include seasonality peaks and local effects in the energy demand. They both try to include a sort of predictability in the models, provided by historical prices, influenced by the above mentioned factors. In this way, pricing and hedging power derivatives will result easier for energy companies, that cannot ignore local factors using these financial instruments.

## 5.8. Gas hedging with options

To this point of discussion, oil and electricity forms of hedging have been widely described, capturing similarities and differences. For both, futures have been taken as sample hedging instruments, although they are not the only ones. As NYMEX demonstrates, there exist a lot of energy derivatives and strategies that companies may use to protect themselves from the energy risk. Some of them will be illustrated below, using natural gas as a commodity, because it has not been still mentioned in this chapter.

Let's take the case of a natural gas producer whose aim is hedging against a warm winter. Given the volatility of the market, he knows that, even in a normal winter, a price increase in unlikely. Indeed, he prefers put options to futures. Furthermore, he does not want to spend much for an *at-the-money put* (to buy at 2,20\$ with 0,15\$ premium): he finally decides to hedge against the highly volatile market purchasing an *out-of-the money put* (to buy at 1,95\$ with 0,05\$ premium), because he knows he will

have cash flow problems for a lower price than \$ 1,85 (NYMEX, 2013). In this way, he may spend less for the option: the condition is that of being confident that the prices will go above a certain limit, so that it becomes convenient to have a downside protection. The breakeven point has been calculated for both cases of at-the-money and out-of the money put options. Furthermore, the breakeven level between the two alternatives has been computed as the higher strike less the difference in the premiums.

Futures price	\$ 2,20		
At-the-money put premium	\$ 0,15		
Out-of-the money premium	\$ 0,05		
Break even at-the-money	\$ 2,20 - \$ 0,15 = \$ 2,05		
Break even out-of-the money	\$ 1,95 - 0,05 \$ = \$ 1,90		
Break even between the two	\$ 2.20 - (\$ 0,15 - \$ 0,05) = \$ 2,10		

Fig. 14 Hedging with Put options (Source: NYMEX, 2013).

From the table, we can see how convenient is to buy an out-of-the money put option in this case, respect to an at-the-money one. If the producer thinks that prices are likely to go above the breakeven (\$2,10), but he still wants a downside protection because of cash flow problems in highly volatile market, the out-of-the money put is the recommended choice. On the contrary, the more expansive at-the-money should be recommended to exploit upward price fluctuations, but this is not the case.

The example above shows how, many times, decisions about purchasing options are influenced by the cost of these instruments that, contrarily to futures, are bought at a premium.

To reduce the options cost while enhancing revenues, a *collar* strategy is often applied. It involves the purchase of a call, offset by the sale of a put, or vice versa.

Supposing that the same natural gas producer wants to hedge without bearing the option premium costs, he may set a collar. This strategy would allow him to make that the gain and loss of the put and call offset each other (NYMEX, 2013).

Hedgers are free to decide the strategy that best is adapted to their market positions. This kind of strategies, especially those described in this paragraph, are suitable for markets characterized by high volatility, where a producer wants to be sure to keep its profits above a certain limit, even in case of adverse conditions. Upward and downward limits, that only derivative contracts may ensure, are given to grant a cash flow stability.

The case of the natural gas producer has been useful for two purposes: to illustrate a potential hedging strategy for gas commodity, affected by transportation issues, thereby with a particularly volatile market; to show how options and more complex strategies, not depth here, may be used for hedging.

#### 5.9. Energy derivatives: pros and cons

Practical cases and concrete examples of hedging through derivatives were provided to give an idea about the usefulness of these instruments to preserve energy companies against the commodity risk. Energy derivatives have been defined as essential instruments of risk management to accomplish this purpose. Despite their positive contribute to the stability of cash flows, that has been shown in simple cases of producers of oil, electricity and gas, they have been often criticized for increasing risk, instead of reducing risk. In this paragraph, energy derivatives will be viewed from a double perspective, counterbalancing the point view of those who believe them "performance- enhancing", against that of those who find them dangerous.

The cases of this chapter demonstrate that hedging and energy derivatives benefits are several: they allow to lock prices in advance and to reduce the potential loss; they reduce the commodity price exposure by making possible to take an opposite position in the market; they exploit the convergence between cash prices and futures prices to adapt the strategy day by day and to obtain better results than an unhedged position (NYMEX, 2013).

For all these reasons, the hypothesis of a positive relationship existing between hedging and value creation for firms has to be considered. Thereby, a debate in literature was focused on the contribution that hedging may have on firm value. Although Modigliani-Miller theorem teaches us that hedging activities should have no

impact on firm value, some others argue that they have the property of reducing cash flow variability, and as a consequence of contributing to the value creation. The positive effect of hedging on firm value is supposed to be indirect, such that its effectiveness has been tested by Lookman (2004), who verified this hypothesis on a sample of oil and gas producing firms. The conclusions of his study were that: hedging grants a premium especially to diversified firms, those who hedge commodity as a secondary risk, while this effect is not so evident for those who hedge it as a primary one. This conclusion was then confirmed by a study on the same phenomena conducted about the airline companies, hedging commodity risk as a secondary one, since the cost of fuel is only one of their cost invoices, even if consistent. Airline companies have been observed to reach a consistent gain from hedging, because they actually succeed in reducing cash flow variability and in meeting their obligations with less difficulties when they hedge against the fuel price risk. If on the one hand a positive relationship emerged between firm value and hedging, it does not mean that the more they hedge the higher is their worth. Hedging is valuable until the investment opportunities they want to process, through purchasing future jet fuel hedged, are valuable. If no good investment opportunities are valuable, hedging has no sense (Carter, Rogers, Simkins, 2006).

Till now, only positive words have been spent for energy derivatives, because the focus of this work is on their correct use for hedging. Nevertheless, most of criticism considers derivatives, in general, as dangerous instruments at the basis of the current crisis. To be honest, derivatives are not dangerous as they are: it is their misleading use at the origin of financial disasters. In fact, many investor think that there are activities with low risk and high return, but this is absolutely false: as return grows, risk rises as well. This wrong overconfidence led the banks to assume too much risk, and derivatives, originally thought as instruments to preserve from risk, actually increased the exposure (Oldani, 2012).

One case of incorrect use of derivatives in the energy sector is the famous Enron's one. The management of the American company, giant in the energy sector, acted aggressive speculative actions on the market and carried losses out-of-balance, with

the aim of boosting the performance. This is a clear case of moral hazard, where the interest of the company has been disregarded, by using fraudulent means, in favor of the benefits of few managers. In order to avoid that such conducts could retake place, a stricter regulation followed up, but this is not enough to avoid that companies take too much risk, because the magnitude of derivative instruments is not always totally known. This is the reason why the analysis of energy derivatives has been accompanied by that of risk management methodologies, such as VaR, very important to provide a statistical risk quantification. Monitoring risk by means of VaR and similar methodologies is something that should move in tandem with the energy derivatives application. Nevertheless, some derivative strategies can become so complex that these means may lose the control of them. Thus, preferring simple derivatives strategies to more complex ones, may help to constraint the risk exposure.

To be effective, risk management should be part of a "risk governance" (Oldani, 2012), such that best practices are shared across all the business areas; risk is monitored *exante* and *ex-post*; information flows and "risk culture" is diffused in an integrated context. Risk identification, mitigation and monitoring should be interrelated phases of a continuous integrated process. This need becomes more and more urgent in the energy sector, riskier than many others. By managing the risks and reducing volatility, the influence of energy derivatives to the offer side is positive, because prices are generally driven down. This becomes possible when these instruments are used in the right way and for hedging purpose. Speculation is not the core business of energy companies, and to think about doing it is misleading and may lead firms to temporarily gain but to gradually increase their exposure because, as already stated, activities with high return and low risk do not exist.

# Conclusions

As this work had the aim of showing the relevance of risk management and energy derivatives for the energy companies, the goal has been achieved.

The energy risk, caused by the commodity price fluctuations, is the source of risk this thesis has focused on, to whom energy companies are exposed. In order to protect themselves from it, they often recur to hedging strategies, but they are only a part of risk management.

Risk management has been defined as a process made by more phases, such as risk identification, evaluation and control, where hedging is only an eventual tool, because having a risk does not necessarily imply that it should be hedged. As sustained by Damodaran (2007), the main difference between risk hedging and risk management is that: while the former considers the risk as a threat; for the latter, it may be a threat, but also an opportunity. This is the reason why in some situations, it may be convenient to exploit a risk or to accept it, and to do hedging only if necessary. The only way to evaluate these contingencies and the opportunity to hedge for a company, is to have a risk management system, that is called Enterprise risk management (ERM). The ERM becomes necessary when a company has several risks, deriving from several sources, that is what happens to the energy companies. A system of ERM allows them to develop a framework (like COSO, 2004), where risk is identified, evaluated and monitored. After it has been classified according to its probability of occurrence and severity of impact, it may be accepted, shared or transferred, avoided or mitigated, according to the risk response matrix resolutions (Dafikpaku, 2011). Hedging applies only if the mitigation strategy is pursued, and energy derivatives are the hedging tools for energy companies. It is important to remark that ERM succeeds when it is applied in an integrated way overall the organization, that is when the risk management practices are shared across departments. As the purpose of this work was to show the relevance of risk management for the energy companies, successful cases of ERM

implementation have been part of the research, so that case studies and empirical observations came out as evidence of its application. The former support, coming from case studies, made clear how energy companies actually find useful to develop frameworks to deal with risk, and disclosed the necessity of the energy sector "to shift from an avoid risk culture to a think risk culture" (Clarke, Varma, 1999), given the high volatility of the business. The latter support, provided by the empirical observations of energy companies adopting risk management, confirms the expectations that, dealing with many risks, they take a great advantage from the implementation of ERM. These systems are more or less developed from firm to firm: some of them even hired a Chief Risk Officer (ex. Enel); others are planning to do that; all of them are aware about the fundamental role played by risk management within the organization.

Dealing with energy risk, companies necessarily need to put in practice financial instruments to hedge against it, when required. Energy derivatives are the hedging instruments for energy companies and they have been studied to provide several benefits to the users: possibility to take an opposite position to that of the risk in the market, so to reduce the exposure; possibility to lock prices in advance, with the result of avoiding losses and ensuring a cash flow stability; contribution to the performance improvement and to the value creation. These benefits, already guessed in the fourth chapter from energy derivatives technical description, have been practically shown with concrete hedging examples. The cases proposed confirmed the expectation that hedging, whatever are the commodities, the derivatives, or the markets, may provide the mentioned advantages, assuming to apply them in the correct manner.

In fact, some criticism argues that, in many cases, derivatives have contributed to increase the exposure and to take too much risk, instead of reducing risk. Enron and MetallGesellSchaft cases (Oldani, 2012) provide the evidence that a misleading use of these instruments may cause losses instead of benefits. Nonetheless, these cases should not deviate the attention from the positive effects achieved from hedging through energy derivatives, when they are correctly applied. On the contrary, they should encourage to adopt these instruments with more care, in order to take advantage from their use.

From the analysis conducted in this work, it comes out that one way to adopt energy derivatives while controlling the exposure, is that of using them in tandem with metrics able to predict the risk involved in a portfolio of derivatives, such as VaR and Monte Carlo simulation, and in an integrated ERM framework, where risk is constantly monitored. Furthermore, simpler strategies of derivatives are less risky than more complex ones. Finally, as Enron case demonstrates, using derivatives to carry on speculative actions is counter producing for energy companies, whose core business is not a financial activity. If energy companies use energy derivatives for hedging purpose and integrated in a risk management framework, they are more likely to gain from them the above mentioned advantages.

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