Financial Risk – MSA400

On the Topic of Energy Risk Management

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Abstract

Energy markets are bounded with a set of certain typical features, such as seasonality, mean reversion and storage costs. These attributes make risk management significantly different from the common capital markets, making the day of risk manager just a little bit more problematic. In this paper we give an introduction to the typical risks encountered, along with methods used to overcome and hedge against it. The report was written jointly by the authors in close cooperation.

1. Introduction

Energy market deals with the trading of energy, which is an essential importance for many different companies. This includes businesses involved throughout the whole production chain, ranging from oil producers like Shell to electricity suppliers as Vattenfall or large energy intensive industries in line with Stora Enso. All these industries have a tendency to be sensitive to market risk or more precisely – to price risk, which is a consequence of high volatility in energy markets. Energy company managers can more easily deal with other sources of risk, through up-to-date effective tools, insurances or similar tools. However, these tools are not as effective when it comes to managing price risk, particularly with regard to electricity. This assessment deals with energy market risk in general, with power markets in particular. The latter branch of energy markets inherit a certain set of interesting characteristics, which make handling and hedging of electricity price risk specifically tough. Pilipovich (2007) lists a couple of these, amplifying the importance for the use of different methods for risk handling compared to the common capital markets. These are presented in the subsequent section. This paper aims to give an introduction to energy markets, the price risk related to these and an overview of how to handle it. There are notably many other sources of risk apparent, such as functional overload or political risk, that could not fit into this report.

2. Energy markets' characteristics

Seasonality

The demand and supply of energy in general, and power in particular, tends to be highly affected by seasonality. In this way energy markets are comparable to some other markets of commodities, such as the harvesting seasons or likewise. Consider for instance the importance of temperature for the demand of heating oil, which drives up prices in winter months whilst lowering them in the summer where there is little need for it. The prices of electricity can be even far more seasonal, which has since the wave of de-regulation evolved into a highly volatile market (Cartea et al 2005). The prices depend not only on season, but on whether it is a working day or holyday. In some extreme cases one might even experience *jumps* in prices during the course of day, making power prices highly sensitive. The importance of seasonality is largely but not entirely dependent on temperatures. The prices are also affected by severe weather conditions or the amount of rainfall/solar hours, just like in the case of crops and harvesting seasons. The capital markets are on the other hand obviously unaffected by a fall in temperature. Seasonality is thereby one of the most important issues for how to model and understand energy markets.

Sensitivity to location

Trading centers and other financial institutions are usually gathered together in one location, i.e. London/New York, which implies that financial markets tend to be *centralised* when it comes to location. Energy suppliers and energy users are in contrast usually "spread around" with regard to their location, therefore energy markets are said to be *decentralised*. This becomes a problem because when an energy company signs a future contract in, for example, New York, the energy price is still dependent on the location of the energy company. The price can actually be very different from the local market price that we wish to hedge. The fact that energy markets are *decentralized* introduces us to a new risk – "geographical risk". In the common capital markets, one unit of some currency holds equal value everywhere, otherwise obvious arbitrage opportunities would arise. This is simply not possible in energy markets, for numerous reasons, like the limits of capacity of the power grid. The price of energy is thereby relative not only to the model parameters, but to the locational one as well.

Mean reversion

Energy markets, electricity markets especially, are infamous for exhibiting a high degree of mean reversion. Whilst the occurrence of price spikes, or price events are common, in contrast to equity markets, they also die out quickly. The market moves around the equilibrium price, but one should take further notice of a higher persistence of positive events compared to negative ones (Cartea et al 2009). Thus to make things even more complicated we have to deal with an inhomogeneous level of mean reversion, differing between spikes and between up-s and down-s. One can compare this characteristic to other financial markets, which generally tend to experience few but highly persistent price events (Pilipovich 2007). The different situation for energy market can be explained by its sensitivity to changes in supply and demand. These occur due to some news making events, for example a war, high rainfall or natural catastrophes.

Impact of storage

The energy supplier could manage the price risk by producing or purchasing the energy, e.g. oil/gas/uranium, in the current period and storing it for later. One disadvantage with this approach is the cost of storage, which drives up the forward/future contract prices. Another more pressing concern is the inability to store electricity[1]. The storage limitations are thus contributing to the high volatility of energy prices. This issue applies distinctively to power, further increasing the level of volatility of prices. In comparison, in the money markets you can easily store your contract, which usually is a piece of paper or an electronic document.

"Split personality"

Energy markets can be compared to the two-faced Janus, one face for the short term perspective and one other for the long term. As stated above, energy prices are highly affected by the storage limitations present this underlines the differences between short-term and long-term forward/future prices. The short term forward contracts are concerned with produced energy supply for today or up to the next couple of months. Long-term contracts, for more than six months or similar has to incorporate the issue of future possible supply of energy, which might differ heavily from today or last year. One can thereby argue that there exists a split personality for modeling of forward prices in energy markets.

Relatively new market

A further important discrepancy between the money and energy markets, are that the

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[1] Purely theoretically one can of course also store electricity, generally however at a cost that does not make it an alternative.

latter are relatively newer. The common financial markets have been around for quite some time, hence there is a lot more research done on these compared to the other. One can of course argue that the world is constantly changing, financial markets no exception, and there is always the need and use of improvements. Still the strategies for equites/bonds have been refined for many more years than what is the case of energy. Whilst many of the "mysteries" of energy markets have been uncovered, there are still a lot of flaws and a comparatively higher level of uncertainty for modeling purposes than in other markets. Whether or not these comparative issues will remain even in the future is difficult to tell, given the fact that energy markets are far more complex.

Complex derivative contracts

All financial markets evolve, energy and equity markets included. Consistently the hedging, trading and risk quantification abilities have developed to become more refined and complex. Whereas the plain vanilla options still play a significant part in money markets, one might question their use for energy. These markets demand a more refined sort of derivative, for speculative or hedging purposes. The derivatives used might range from more commonly known "Asian" or "Barrier" options, to far more complicated weather derivatives. With more complex derivatives come bigger problems of effectively pricing these derivatives. One aspect that further emphasis this issue is the lack of an underlying asset to use for hedging purposes. No surprise the derivatives used here are called "exotic derivatives".

3. How to model energy price risk

In the previous section the specific characteristics of the energy markets were outlined, why and how these markets differ from other financial markets. Needless to say, one might experience some rather nasty consequences when applying money market modeling techniques to energy. What we need is to take into account the mean-reversion, the sudden jumps in prices and the seasonality. Applying the common model for equities, which are usually thought to be log-normally distributed, will therefor render skewed results (Pilipovich 2007). Instead consider the fact that there tends to be a large seasonal up-ward jump in winters, we need to keep this in mind when we try to predict prices. The most common approach would be to include a seasonal component, obtained from historical data. One should though recognize, that this course might be problematic for certain electricity markets, such as Nord Pool, where the supply side is heavily dependent on the amount of snow fallen in the winter (Cartea et al 2009). Likewise markets dependent on fossil fuels or nuclear power, are highly dependent on prices and availability on other markets too. If we consider the sudden hikes in electricity prices, which might occur for numerous reasons (such as technical failure), these should probably be modeled by some jump-diffusion process (Cartea and Figueroa, 2005). Most commonly one assumes the jumps occur according to some homogenous (Geman and Roncoroni, 2006) or inhomogeneous Poisson process (Benth et al 2007), with an intensity parameter estimated from historical data. An alternative to try and capture the price spikes on average is proposed by Nomikos and Soldatos (2008). The authors instead suggest using a regime-switching model, allowing for periods of high and low water levels in the Nordic reservoirs. Cartea et al (2009) extends on the framework, adding the regime-switching component accounting for periods of high level of price spikes, originating from available forecasts. Janzcura and Weron (2010) provide a more throughout oversight over these models, establishing supremacy of three-regime over two-regime models in terms of empirical fit.

When we know the dynamics of price behavior, we sure like to find some easy way to model and quantify the risk we are exposed to in order to hedge our bets. Most appropriately we would like to make a

Value-at-Risk (VaR), Profit-at-Risk (PaR) or Earnings-at-Risk (EaR) assessment to decide on possible losses and buy insurance to deal with that. For VaR our interest is the expected losses on our portfolio, for PaR is sheer profits from all our operations and for EaR we are concerned with overall earnings from our operations. Generally whilst the portfolio-manager has most use of VaR, one can argue that the other methods are more appropriate for energy markets (Lemming, 2004). We will here stick to the VaR-concept, being the most commonly known and applied, for which there are parametric, semi-parametric and non-parametric methods (Chan and Gray, 2006). Despite the known limitations of VaR, particularly for energy markets, in comparison to suitable alternatives, i.e. Profit-at-Risk or Earning-at-Risk, it is still widely used (Lemming, 2004). The non-parametric approach typically involves using "historical simulation" (HS), i.e. taking a certain quintile of the historical distribution and call that the VaR. Semi-parametric approaches typically aim to combine the approach with auto-regressive (AR) modeling, to preserve the "distribution free" HS-method allowing for trends. For the fully parametric approaches, one typically specify some variant of a GARCH-model combined with some assumption of the underlying distribution, as normal, student-t or extreme value distribution. When models are compared by Chan and Grey (2006) using an EGARCH specification, the authors find that the EGARCH-EVT and, surprisingly, HS models tend to perform best. One should take notice though that the normality assumption in all cases tends to produce rather biased VaR-estimates, although GARCH-t mostly give VaR almost in line with the EGARCH-EVT-model.

4. Managing energy price risk

A derivative, in its common form is a financial instrument or a contract, with a valued derived from an underlying asset. In the common financial markets the underlying asset is a stock or bond, with a defined value, non-storage cost and well defined path. Such is not necessary the case in energy markets, which like in commodity markets, are associated with far more complex characteristics. The derivatives may range from simple forward contracts on oil/gas to more sophisticated weather derivatives, earning a pay-out if and only if the temperature surpasses a certain defined level. These financial instruments are commonly used to hedge the risk, which was derived in the previous chapter. In contrast to the money markets, diversification and long-term fixed-price contracts cannot really be applied (Pilipovich, 2007). The classes of derivatives used can be divided into categories of forwards/futures, options and swaps. Of which the futures, swaps and exotic options are the most important in energy markets. All these contracts are often traded Over-The-Counter (OTC) rather than using some exchange, given the demand for non-standardized products (Pilipovich, 2007).

Energy futures (in contrast to forwards) are standardized derivatives, traded on an exchange. The most common is that one uses a future or forward contract on a delivery of oil, gas or any similar energy source including some storage costs. By the use of these contracts the future price is stabilized, reducing price uncertainties and securing future deliveries. The future spot prices become thereby less volatile with the use of future contracts. Whilst futures can be settled both in physical deliveries and cash, swaps on the other hand always concern cash. Swaps for energy markets are an exchange of cash flows between counterparties, paying the difference between contract price and market price. Swaps do not involve any energy transfers or physical deliveries, just cash. The exotic stuff most commonly employed are Asian and Barrier options, along with complex weather derivative on temperature, rainfall or snowfall that might affect energy prices. An Asian is designed to pay the average over its "lifetime", a Barrier option becomes active once price of the assets fall (rise) below (above) some specified threshold. These options thereby provide an additional reduction in the spot price volatilities, due to the ability to set floors and ceilings by these options. The options in question are thus said to be path-dependent, as the pay-off don't only depend on price of the closing day (He, 2007). Weather derivatives are relatively new contracts with a weather index as the underlying asset. The purpose of this financial tool is to hedge against high-probable changes in the weather, e.g. changes in average temperature or snowfall. Let us consider the case of an energy company purchasing a weather derivative to hedge against the risk of extra-ordinary cold weather in the winter, which tends to produce spikes in Nordic power prices (Cartea et al 2009). If the winter then becomes a really harsh one, then the company has effectively managed this risk as the issuer of the derivative will compensate the company for deviances from the average (James, 2007).

5. Conclusions and own opinion

Energy markets are bounded by lots of specific properties, which essential leads to a major problem – complicated price behaviour. Regardless if one look at the oil price or the electricity price, all these tend to have a complex pricing structure. In comparison to equities, similar to commodities, energy is essentially traded for the purpose of the end-user. One should take notice though that it is becoming more common for general speculative and hedging aspects as well, although the markets are not essentially designed for this. The increased de-regularisation of and trading in the (especially power) markets, has led to the evolvement of a prominent "price-risk. In addition to already existing instances of risk in energy markets described, such as mean reversion and seasonality, this has made situation even more complex. The companies no longer simply sell what they produce, but it is traded as any other commodity on open energy exchanges, e.g. Nord pool. One now generally rather sell and purchase all the energy to be delivered to the end user through these markets separately from production, which has given rise to the need for every company operating here to handle these issues. It is every company's responsibility to be able to deal with the price risk, in order to keep supplying the customers with the energy and its shareholders with return on their investment. To achieve this, the company's risk manager must adequately be able to deal with risk through mathematical modelling of prices accounting for numerous troublesome aspects. Something that is easier said than done, whereas the optimal modelling for electricity, the most complex business of energy, typically needs to account for the specific characteristics to predict prices. This in turn has implications for the method for calculating the risk and the need for hedging, be it VaR, PaR and EaR that is used. Once this has been done, we can "easily" hedge our position using derivative contracts.

One should recall that energy markets are yet young, modelling techniques still suffer to a large extent from childhood diseases. Whereas the practice of taking the known models of capital markets and blindly applying them to energy is gone, there is still need for a continuous improvement and adaption to obtain a better fit to the markets. In case we fail to adequately mimic the traits and circumstances, we will rely on misfits which might give rise to huge losses. Likewise with energy markets approaching other financial markets, new market participants will enter for speculative, hedging or diversification purposes. Evidently this will like in the commodity markets amplify the need to adapt to a changing environment, where energy is not solely a commodity but also a form of investment. We would argue that in order to reduce risk in the future, whether as an energy producer or trader we should be aware of this and keep it in mind. While on the one hand, it adds liquidity to the market on the other hand, it might contribute to speculative bubbles and in that sense increase the level of volatility. Given that energy markets are crucial for many parts of society, reduction of price spikes and high level of volatility is a matter of high public interest. One can argue therefore in favour of regulations, in order to cope with and deter from high levels of speculation in the markets.

From a more mathematical perspective the need must lie with improvement of models to fit reality, to make these become more overarching. The deviation from unrealistic assumptions of convenience, e.g. normality or log-normality, is a step taken in the right direction. In a similar fashion the development of alternative risk-measures that could more appropriately model the company specific risk, than the typical VaR for instance could be advantageous. Arguably, the application of PaR and EaR-models are attempts to better fit an adjusted risk-measure to the circumstances of energy markets. Yet one must not forget the importance of understanding and interpreting the models. If models developed become too complex, the numbers derived will be difficult to interpret to anyone but the highly skilled practitioner, constituting a major issue. It is highly likely in such a case that the model might be neglected for being too ambiguous, regardless of the plausibility. Equally fatal could be a blind belief in the numbers produced by models, omitting any fundamentals that could be of even higher significance. A good closing example of such could be the oil crisis of 1973, as your predictions of the oil price would all have been rendered obsolete by political factors.

Further readings

A reasonable introduction to energy markets, the pricing and most notable characteristics of these are presented in Pilipovich (2007). The book is simply a good introduction, but that is also all that it is and to dig deeper one has to search elsewhere. Janzcura and Weron (2010) provide a reasonably good oversight of the recent developments in modelling electricity prices, concluding with an evaluation of different models. The paper furthermore includes a rich list of references, from where the curious might find much of interest. For VaR and similar assessments, the literature is scarce and also more case-specific. Chan and Gray (2006) evaluate different techniques for the electricity price, Marimoutou et al (2010) provides a similar evaluation comparing EVT with standard methods and Aloui and Mabrouk (2009) extend the VaR-analysis to gas markets. For an overview of derivatives used in energy markets, He (2007) gives an interesting description of such and use of the non-vanilla contracts.

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