Abstracts for the conference on "Energy and Commodity Risk Management and hedging of Commodity Derivatives"

Wolfgang Pauli Institute, Vienna

September 17-19, 2012

Invited speakers

René Aid, Electricité de France

Title: **One step towards a high-dimensional probabilistic investment model in electricity generation**

We present an investment model in electricity generation that takes into account electricity demand, cointegrated fuel prices, carbon price and random outages of power plants. It computes the optimal level of investment in each generation technology, considered as a whole, w.r.t. the electricity spot price. This electricity price is itself built according to a simplified structural model. In particular, it is a function of the random processes as well as the installed capacities. An efficient probabilistic numerical algorithm combining dynamic programming, Monte Carlo simulations and local basis regressions is used to solve the problem formulated as a nonstationary optimal multiple switching problems in infinite horizon. The evolution of the optimal generation mix is illustrated on a realistic numerical problem in dimension 8, i.e. with 2 different technologies and 6 random processes. This talk is based on a joint work with Luciano Campi, Nicolas Langren and Huyen Pham.

Ole E. Barndorff-Nielsen, Aarhus University

Title: **Energy and Ambit Stochastics**

Ambit stochastics is a general framework for probabilistic modelling. The talk will briefly outline this framework and indicate some of the questions regarding the further development of the theory of ambit stochastics. Ambit stochastics has found applications in a variety of areas, in particular in finance and in turbulence. In both areas volatility, or intermittency as it is called in turbulence, has key roles, and the talk will focus on these as they relate to energy.

Michael Coulon, Princeton University

Title: **New Challenges in Electricity Price Modeling: Emissions, Renewables and Market Coupling**

Many electricity markets have recently undergone and continue to undergo various fundamental changes linked to new regulations and technological developments. These include the role of emissions markets, the growth of renewables and ongoing cross border integration (particularly in Europe) via a mechanism called market coupling. Such key changes provide major obstacles for traditional reduced-form models of power price dynamics, particularly as price histories become unreliable for parameter estimation during periods of structural change. Recent examples include reductions in spike frequencies, the prominence of negative prices and the high occurrence of identical hourly prices in neighbouring countries (for example, in about 65

Matt Davison, Kyloe Energy and University of Western Ontario

Title: **Designing market incentives to promote wind-storage hybrid systems**

The nondispatchability of wind power has an increasing impact on the power grid as wind power penetration increases. We present some interesting data from the Ontario electricity market to show one possible consequence of wind power on electricity systems. Engineering research developing storage technologies to buffer wind variability has greatly exceeded work on economic incentives to deploy these systems. We present a solvable dynamic programming model providing optimal bidding and storage use rules for a wind turbine/storage unit facility given a penalty for undelivered power. We fit the parameters of this model to real data and draw policy conclusions.

Emmanuel Gobet, Ecole Polytechnique, Paris

Title: **Expansion formulas applied to option pricing in energy markets**

Financial contracts in energy markets are often written in terms of average or spread of different assets: for instance, call option on the average of daily delivering forward contracts, clean spark spread based on gas, electricity and carbon. Even in log-normal models, deriving closed analytical formulas is out of reach. Alternatively, we develop a proxy based approach that can handle the case of average or spread options, in general local volatility models. It provides explicit and tractable approximation formulas which accuracy are very good on realistic examples.

Rüdiger Kiesel, University of Duisburg-Essen

Title: **Model Risk for Energy Markets**

Recently, model risk in particular parameter uncertainty has been addressed for financial derivatives. During this talk we will review these concepts and apply the methods to energy markets. In particular, we will discuss parameter uncertainty for spread options and implications for power plant valuation. (Based on joint work with Karl Bannr, Anna Nazarova and Matthias Scherer).

Kevin Kindall, ConocoPhillips

Title: **A quants view of the energy business: why certain problems remain unsolved**

Even though energy related products have been traded for quite some time, certain challenges remain. This presentation will introduce a sample of problems from the front, middle, and back office that many practitioners face with some emphasis on price discovery. Characteristics of effective solutions will be discussed for certain types of problems, and a few ideas offered for the illiquid option pricing problem.

Delphine Lautier, Paris-Dauphine University

Title: **Systemic risk in energy derivative markets: a graph theory analysis**

Considering it as a necessary condition for systemic risk to appear, we focus on integration in energy derivative markets, through a three-dimensional approach: observation time, space and the maturity of futures contracts. Such a method indeed makes it possible to investigate prices shocks in the physical as well as in the paper markets. In order to understand the underlying principles and the dynamic behavior of our prices system, we select specific tools of the graph-theory. Among others, we use minimum spanning trees as a way to identify the most probable path for the transmission of prices shocks. We study the organization of the graphs and their dynamic behavior. Examining three categories of underlying assets (energy and agricultural products, as well as financial assets), we find that crude oil stands at the heart of the system, and that energy markets are becoming more and more integrated.

Brenda Lopez-Cabrera, Humboldt University Berlin

Titlte: **State price densities implied from weather derivatives**

A State Price Density (SPD) is the density function of a risk neutral equivalent martingale measure for option pricing, and is indispensable for exotic option pricing and portfolio risk management. Many approaches have been proposed in the last two decades to calibrate a SPD using financial options from the bond and equity markets. Among these, non and semi parametric methods were preferred because they can avoid model mis-specification of the underlying and thus give insight into complex portfolio propelling. However, these methods usually require a large data set to achieve desired convergence properties.

Despite recent innovations in financial and insurance markets, many markets remain incomplete, and there exists an illiquidity issue. One faces the problem in estimation by e.g. kernel techniques that there are not enough observations locally available. For this situation, we employ a Bayesian quadrature method because it allows us to incorporate prior assumptions on the model parameters and hence avoids problems with data sparsity. It is able to compute the SPD of both call and put options simultaneously, and is particularly robust when the market faces the illiquidity issue. As illustration, we calibrate the SPD for weather derivatives, a classical example of incomplete markets with financial contracts payoffs linked to nontradable assets, namely, weather indices.

Esteban Tabak, Courant Institute, New York

Title: **Constrained density estimation in the commodity market**

A methodology is proposed for non-parametric density estimation, constrained by the known expected values of one or more functions. Examples in the commodity market include prescribing the mean of a conditional distribution to enforce the martingale condition of the risk-neutral measure, and constraining this measure by the available option prices. The problem is addressed through the introduction of a family of maps that transform the unknown density into an isotropic Gaussian, while adjusting the prescribed moments of the estimated density. Joint work with Peter Laurence

Peter Tankov, University of Paris 7

Title: **Quadratic hedging in Markov models with jumps. Applications to electricity markets**

We first review our recent theoretical results for the computation of the quadratic hedging strategy in incomplete markets modeled by Markov processes with jumps. Using the Hamilton-Jacobi-Bellman approach, the value function of the quadratic hedging problem can be related to a triangular system of parabolic partial integro-differential equations (PIDE), which can be shown to possess unique smooth solutions. The first equation is non-linear, but does not depend on the pay-off of the option to hedge (the pure investment problem), while the other two equations are linear. We next propose convergent finite difference schemes for the numerical solution of these PIDEs. In the final part of the talk, our results are illustrated with an application to hedging options on futures in electricity markets, where time-inhomogeneous pure jump Markov processes appear in a natural manner. Work in collaboration with Carmine De Franco (OSSIAM) and Xavier Warin (EDF).

Xavier Warin, Electricité de France

Title: **Valuing and hedging gas contracts**

In the gas market, the most widely used specific contracts are gas storage contracts, and swing index gas contracts. In order to assess the risk due to these contracts, practitioners often use for example cash flow at risk measure. In order to evaluate these cash flow generated, they have to take into account the dynamic hedge they will follow. We first recall what are gas storage, index swing contract and how we can valuate them accurately. We then explain how to calculate the dynamic hedge associated to these contacts and we show its efficiency on some examples.

Contributed speakers

Stefan Ankirchner, University of Bonn

Title: **Hedging forward positions: basis risk versus liquidity costs**

Consider an agent with a forward position of an illiquid asset (e.g. a commodity) that has to be closed before delivery. Suppose that the liquidity of the asset increases as the delivery date approaches. Assume further that the agent has two possibilities for hedging the risk inherent in the forward position: first, he can enter customized forward contracts; second, he can acquire standardized and liquidly traded forward contracts. We assume that purchasing customized forwards perfectly eliminates the risk, but entails high liquidity costs charged by the counterparty. The standardized forwards can be acquired at considerably lower costs, but do not perfectly match the agent's risk and hence entail basis risk. By means of stochastic control we show how to obtain an optimal trade-off between liquidity costs and basis risk. To this end we reduce the hedging problem to a family of stopping problems. In two case studies we consider simple liquidity dynamics for which optimal hedging strategies can be calculated explicitly.

Sara Ana Solanilla Blanco, University of Oslo

Title: **Forward prices in power markets as a moving weighted average of the spot**

Given a Lévy semistationary model of the energy spot price

$$S(t) = \Delta(t)\exp\left(\int_{-\infty}^{t} g(t,s)\,dL(s)\right),$$

where Δ represents a seasonal function, we have explicitely available the following pricing formula of forwards

$$f(t,T) = h(t,T)\exp\left(\int_{-\infty}^{t} g(T,s)\,dL(s)\right),$$

where T represents de time of maturity and h involves the market price of risk θ. We investigate how to recover the path $X(t,T) = \int_{-\infty}^{t} g(T,s)\,dL(s)$ in the forward price from the spot price. To reach our goal first we will change the variables into a Musiela paramatrization so that we will work with the time to maturity $x = T - t$ instead of the time of maturity T. Afterwards, we will introduce some useful computations involving the Laplace transform of the path $Y(t) = \int_{-\infty}^{t} g(t,s)\,dL(s)$ in the spot to express the path of the forward as a moving weighted average of the observed spot. Finally, we will see some applications of this theory in models of gas and electricity prices.

Mireille Bossy, INRIA Sophia Antipolis

Title: **Two pricing approaches for carbon emission allowances**

We study the CO2 emission allowance prices, according to a given sector's players aggregation : the electricity producers. We consider first the European trading scheme. We model the indifference price for an individual producer that can dynamically switch between coal, gas or hydro power plants, and/or buy/sell emission allowances. We discuss the numerical computation of the indifference prices and indifferent price sensitivities for the needs of market designs Second, we consider a N-producers game and a cap-and-trade scheme style. We construct a CO2-emission-prices dynamic, induced by a Nash equilibrium between players on the electricity market.

Simon Eberle, Verbund Trading AG

Title: **Practical implementation of the energy forward curve modeling in the framework of the non-Markovian approach**

We present a practical implementation of the energy forward curve modeling in the case when the risk-neutral dynamics of the positive and negative energy spot prices with upward and downward spikes are given by the Non-Markovian process introduced earlier by Kholodnyi. The parameters of this process, as proposed earlier by Kholodnyi, are calibrated by means of an optimization problem so that they minimize, in a suitable sense, the differences between the market and model energy forward/swap prices. The resulting risk-neutral spot price process, among other things, allows for the interpolation and extrapolation of the market forward curves, the Monte Carlo simulations of the spot and forward/swap prices, analytical and numerical pricing of contingent claims on spots and forwards/swaps, as well as the extraction of the forward-looking market-implied risk-neutral probability distributions for the spot and forward/swap prices. We consider practically important examples of power, gas, oil, coal and carbon markets. Joint work with Valery Kholodnyi.

Pascal Heider, E.ON Energy Trading SE

Title: **Spread volatility of co-integrated commodity pairs**

There are many typical commodity pairs, for which the commodities are linked together by a fundamental production relationship. A typical example is the burning of fossile fuel to produce energy. The dynamics of the commodities are influencing each other, which results in certain feed-back effects and has impact on the spread dynamics of the two commodities. In the talk we introduce a simple model to study the joint dynamics of a driving and a driven commodity. We obtain explict formulas for the terminal variances of the commodities and their spread. We apply the model to study the dynamics of the coal-power pair and the Brent-gasoil pair. Joint work with Rainer Döttling

Asma Khedher, Technical University in Munich

Title: **Stationarity of Ornstein-Uhlenbeck processes with stochastic speed of mean reversion**

When modelling energy prices with the Ornstein-Uhlenbeck (OU) process, it was shown in Barlow, Gusev, and Lai [1] and Zapranis and Alexandridis [2] that there is a large uncertainty attached to the estimation of the speed of mean-reversion and that it is not constant but may vary considerably over time. In this paper we generalised the OU process to allow for the speed of mean reversion to be stochastic. We suppose that the speed of mean-reversion is a Brownian stationary process. Then, we show the stationarity of the mean and variance of the OU process when the average speed of mean-reversion is sufficiently larger than its variance. We further compute the chaos expansion of the generalised OU process and show that the kernel functions converge in norm as time tends to infinity. (Joint work with Fred Espen Benth)

References

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Thomas Kruse, University of Bonn

Title: **Optimal trade execution under price-sensitive risk preferences**

We consider the problem of how to close a large asset position in an illiquid market in such a way that very bad outcomes are unlikely. To this end we introduce a discrete time model that provides a simple device for designing and controlling the distribution of the revenues/costs from unwinding the position. By appealing to dynamic programming we derive semi-explicit formulas for the optimal execution strategies. We then present a numerical algorithm for approximating optimal execution rates as functions of the price. We provide error bounds and prove convergence. Finally some numerical experiments illustrate the efficiency of the algorithm.

Alexander V. Kulikov, Gazprom Export LLC

Title: **Hedging volumetric risks using put options in commodity markets**

Let us consider an energy company that sells fluctuating volume V of energy units at random price S per unit and obtains the income $X = VS$. Markets today do not provide simple instruments that can be used for hedging volumetric risk. A short survey of current literature for the volumetric risk hedging problem and optimal hedging results using forwards, call and put options for the utility-based optimization framework can be found in [4].

Traditional measure of risk which is widely used in practice is VaR. We consider the problem of VaR minimization in incomplete markets using put options. We try to find the optimal startegy in $h \in \mathrm{R}$ that solves the following problem:

$$VaR\left(V * S + h((K-S)^{+} - EP(K))\right) \to \min_{h\in \mathrm{R}, K \in \mathrm{R}_{+}}$$

Unfortunately, due to incompleteness of commodity markets we could not make a perfect hedge. Also usually we can not use put options with many different strikes. In [5] this task is solved for the cases when price has lognormal distribution and volume takes no more than 2 values and strike is fixed.

Here we introduce the solution of finding optimal number of put options bought with strike K to minimize VaR in the case of some continuous distributions and prove the fact that if volume distribution has an atom in this minimum then there exists such λ_0 that for $\lambda < \lambda_0$ for minimizing VaR it is optimal to buy this minimum number of put options. Also we consider the task of finding the optimal strike of put option to buy in different models and make some numeric calculations.

However VaR has some drawbacks. So we also consider Tail VaR introduced in the paper [1] by Artzner, Delbaen, Eber and Heath. Since those papers, Tail VaR was used for many purposes. For the purpose of optimal hedging solution we can use the results presented in [2] and find the geometric or probability solutions of our task in terms of generator and risk-neutral measure. The results obtained for optimal hedging using put options are based on the optimal hedging strategy using Tail and Alpha VaR considered in [3].

References

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Nina Lange, Copenhagen Business School

Title: **Pricing energy market quanto options**

In energy markets, the use of quanto options have increased significantly in the recent years. The payoff from such options are typically triggered by a commodity price and a measure of temperature and are thus suited for managing energy risk. We price as option-type contract written on underlying furures contracts on natural gas and Heating Degree Days (HDD) and obtain closed form pricing formulas as well as hedging strategies for energy market quanto options in the case of log-normally distributed futures price. This includes both a bivariate GBM and the two-factor model by Schwartz-Smith (2000). We estimate NYMEX natural gas and HDD futures for New York and Chicago, calculate option prices and discuss the quanto options ability to manage extreme risks.

Marcus Nossman, KYOS

Title: **Pricing electricity swaptions under a stochastic volatility term-structure model with jumps**

This paper suggests a stochastic volatility term-structure model with jumps applied to pricing of electricity swaptions in the Nord Pool market. Our modeling framework is based on an alternative HJM-approach stated under the risk-neutral measure where we only model the swaps that are actually traded in the market. The volatility structure is specified as a product of a time-dependent function that handles the maturity effect, and a Cox-Ingersoll-Ross process that captures the volatility smile. The first contribution of the paper is to develop a Fourier based swaption pricing model with stochastic volatility and jumps. As a second contribution we perform an empirical analysis by calibrating the model to a data set consisting of more than 12000 implied volatilities corresponding to swaption prices from the Nord Pool market. In the empirical section we restrict ourselves to study a special case of the model where jumps are excluded. To our knowledge this is one of the first studies to use swaption data from the Nord Pool market. We show that our model outperform the log-normal benchmark model both in-sample and out-of-sample.

Matthias Ritter, Humboldt University Berlin

Title: **Minimizing geographical basis risk of weather derivatives using a multi-site rainfall model**

It is well known that the hedging effectiveness of weather derivatives is interfered by the existence of geographical basis risk, i.e., the deviation of weather conditions at different locations. In this paper, we explore how geographical basis risk of rainfall based derivatives can be reduced by regional diversification. Minimizing geographical basis risk requires knowledge of the joint distribution of rainfall at different locations. For that purpose, we estimate a daily multi-site rainfall model from which optimal portfolio weights are derived. We find that this method allows to reduce geographical basis risk more efficiently than simpler approaches as, for example, inverse distance weighting. Joint work with Oliver Musshoff and Martin Odening.

Carlo Sgarra: Politecnico di Milano

Title: **Historical and risk-neutral parameter estimation in a two-factor stochatsic volatility model for crude oil market**

In this work we analyzed spot prices and futures quotation data to get inference under the historical and risk neutral measure in commodity crude oil market (data are referred to WTI index which tracks the crude oil barrel price on NYMEX market). Most part of research and techniques in finance deals with the risk neutral modeling or with the model choice under the historical measure, in this work our goal was to study the estimation problem under both the measures at the same time, through a parametric choice of the Radon-Nikodym derivative. To conduct this estimation we resort to a recent technique in Bayesian inference field: the Particle Markov Chain Monte Carlo proposed by Andrieu, Doucet and Holenstein, in which Particle Filters algorithms are used to estimate the marginal likelihood for Markov Chain Monte Carlo inference. We used a stochastic volatility two factor model to model the spot prices, for which the futures prices are available in closed form. Two version of the original model, with and without jumps in prices, were taken into account and results were compared. Joint work with Gaetano Fileccia.

Kenichiro Shiraya, University of Tokyo

Title: **Pricing commodity derivatives under imperfect collateralization and CVA**

We develop a general pricing method for multi-asset cross currency options, whose underlying asset consists of multiple different assets, and the evaluation currency is different from the ones used in the most liquid market of each asset. Furthermore, We also evaluate CVA(credit value adjustment) of commodity derivaties by applying an asymptotic expansion method with an interacting particle method.

Che Mohd Imran Bin Che Taib, University of Oslo

Title: **Stochastic dynamical modelling of spot freight rates**

Continus time models are gaining traction in shipping economics. Freight rate dynamics can be characterised by non-trivial stochastic dynamics. In this talk, we propose a fairly rich continuous time stochastic freight rate dynamics. Our model can capture jumps, stochastic volatility and higher order autoregressive and moving average effects. Our empirical results suggest that our models captures important characteristics of the Baltic Capesize Index and the Baltic Panamax Index. We provide a VaR calculation to illustrate the economic relevance of our model.