CRACOW UNIVERSITY OF ECONOMICS

EFC17 Partner

Polskie Sieci Elektroenergetyczne

Energy Finance Christmas Workshop (EFC17)
13-15.12.2017, Kraków (Cracow), Poland

Under auspices of the Rector of the Cracow University of Economics

Abstracts

Clemence Alasseur, FiME / EDF R&D, France
Imen Ben Tahar, FiME / EDF R&D, France
Anis Matoussi, FiME / EDF R&D, France

Grid with distributed generation and storage

We consider a stylized model for a power system with distributed local energy generation and storage. This system is modelled as a grid connecting a large number of nodes, where each node is characterized by a local electricity consumption, has a local electricity production (e.g. photovoltaic panels), and manages a local storage device. Depending on its instantaneous consumption and production rates as well as its storage management decision, each node may either buy or sell electricity, impacting the electricity spot price. The objective at each node is to minimize energy and storage costs by optimally controlling the storage device. In a non-cooperative game setting, we are led to the analysis of a non-zero sum stochastic game with N players where the interaction takes place through the spot price mechanism. For an infinite number of agents, our model corresponds to an Extended Mean-Field Game (EMFG). In a linear quadratic setting, we obtain and explicit solution to the EMFG, we show that it provides an approximate Nash-equilibrium for N-player game, and we are able to compare this solution to the optimal strategy of a central planner.

Derek Bunn, London Business School, UK
Stefan Kermer, Technical University Vienna, Austria

Statistical arbitrage and information delays in electricity balancing markets

In this paper we analyse the effects of market participants responding to price incentives for spillage and shortage positions in a single price electricity balancing market. We consider real-time positions by speculative agents based upon forecasts of the conditional distribution of the imbalance and examine the effects of time delays for the consequent statistical arbitrage positions. We apply this to the Austrian imbalance settlement process. Results suggest that permitting additional intraday flexibility from a physical or a non-physical player can be beneficial for agents, the system operator and market efficiency. This analysis raises questions about the desirability or otherwise of increased liberalization of balancing and settlement procedures.

Michael Coulon, University of Sussex, UK

Spread option pricing: implied volatility implied from implied correlation

Spread options are important derivative contracts in energy markets, closely linked to the valuation and operation of physical assets like power plants, refineries or storage facilities. While many techniques and approximations have been developed to price such options efficiently, very little attention has been paid to the key challenge of choosing the most appropriate volatility parameters calibrated to vanilla derivatives. Given observed implied volatility structures in each of the two legs of the spread, a so-called strike convention is required in order to make use of common approaches like Margrabe's formula and its many extensions. By means of Malliavin Calculus we construct an optimal linear strike convention for consistently pricing exchange options under stochastic volatility models. This convention allows us to minimize the difference between the model and implied correlations between the two underlying assets in the spread. Moreover, we show that this optimal convention does not depend on the specific stochastic volatility model, and can be linked to market observables instead. Numerical examples are given and demonstrate the strength of the approach under a variety of different settings.

Maria Flora, University of Padova, Italy
Alvaro Cartea, University of Oxford, UK
Georgi Slavov, Marex Spectron Ltd., UK
Tiziano Vargiolu, University of Padova, Italy

Optimal cross-border electricity trading

TBA

Angelica Gianfreda, University of Bolzano, Italy
Giacomo Scandolo, University of Bolzano, Italy

Model risk in energy markets

It has been recognized that model risk has an important effect on any risk measurement procedures, particularly in energy markets. We consider a normalized measure of model risk for the forecast of daily Value-at-Risk, combined with a model selection and averaging procedure based on the Bayesian Information Criterion. This allows us to restrict the set of plausible models on a daily basis, making the initial choice of competing models less crucial and yielding a more reliable assessment of model risk. Using AR-GARCH models with 9 different distributions, we assess the dynamics of model risk for different energy assets in the period 2001-2015.

Luigi Grossi, University of Verona, Italy
Lisa Crosato, The University of Milano-Bicocca, Italy
Fany Nan, Joint Research Center of the European Commission (Ispra), Italy

A new robust approach to volatility forecasting on electricity markets

Volatility of electricity prices has been often estimated through GARCH-type models. The bias of classical GARCH estimators in presence of extreme observations has been widely studied and robust estimators have been proposed to address the issue. Although the presence of spikes is a well-known stylized effect observed on electricity markets, robust volatility estimators have not been so far applied to the series of electricity prices. In this paper we try to fill this gap by suggesting a robust procedure to the study of the dynamics of electricity prices. The conditional mean of de-trended and seasonally adjusted prices is modeled though a robust estimator of SETAR processes based on a polynomial weighting function (Grossi and Nan, 2015), while a robust GARCH is used for the conditional variance. The robust GARCH estimator relies on the extension of the forward search (Crosato and Grossi, 2017) which is a general monitoring procedure originally developed in the linear model framework. The robust SETAR-GARCH model is applied to the Italian electricity markets using data in the period spanning from 2014 to 2016. Robust confidence regions are obtained which can be used to detect spikes and drops in the series of electricity prices and to get forecasted probability regions for prices.

Takashi Kanamura, University of Kyoto, Japan

Supply-side perspective for carbon pricing

This paper theoretically and empirically revisits carbon pricing from the supply-side perspective for carbon assets to solve the recent low price issue which may delay the development of emission reduction technologies in the sense of marginal abatement costs. We propose a carbon pricing model linked to crude oil prices, which has historically been employed in supply-side driven pricing of long-term contracts for early-stage energy trading. Since the model is designed to hold carbon prices between certain lower and upper boundaries using S-shaped carbon price linkage to crude oil prices, it can be useful to overcome a recent low carbon price issue. In addition, it is shown that the model can alleviate the difficulties of carbon derivative pricing in selecting market price of risk. Empirical studies using EUA and Brent crude oil futures prices estimate the parameters of the Brent crude oil-linked EUA price model. The comparison of EUA prices simulated from the model with historical EUA prices suggests that simulated EUA prices be kept relatively higher than historical EUA prices. This is preferable for accelerating carbon emission reductions in that it can make emission reduction technologies with high marginal abatement costs affordable. It may imply that EUA must be priced using a crude oil-linked carbon price model in the early stage of EUA trading until EUA markets are matured. This is a sharp contrast to current carbon markets employing premature market-based or supply and demand based pricing models. To show usefulness of crude oil-linked carbon pricing, we also give a numerical example of European carbon option pricing based on the Brent crude oil-linked EUA price model by using Crank-Nicolson finite difference method. Finally we discuss the relation between crude oil-linked carbon pricing and emission reduction risk. These studies may suggest carbon policy makers should take into account of crude oil-linked carbon pricing to tackle low price and low liquidity issues of carbon assets.

Rüdiger Kiesel, University of Duisburg-Essen, Germany

Modelling market order arrivals on the intraday power market for deliveries in Germany with Hawkes processes with parametric kernel

We analyse market order arrivals on the intraday power market for deliveries in Germany and Austria (IDM). Average market order arrivals per five minutes of a trading window reveal that homogeneous Poisson processes are not a suitable model. We show that non-homogeneous Poisson processes may also be ruled out. Therefore, we focus on whether parametrically estimated Hawkes processes are suited to model the dynamics. We take into consideration time dependence of the baseline intensity and different self-excitation kernels, specifically exponential, power law and Weibull. Given that the IDM exhibits some peculiarities such as iceberg orders with a minimum peak volume of 25~MW, we also consider an approach where the arrivals of groups of market orders are modelled separately but potentially impacting each other.

Maciej Kostrzewski, Cracow University of Economics, Poland
Jadwiga Kostrzewska, Cracow University of Economics, Poland

Bayesian pooling approach in forecasting electricity prices

This research is focused on forecasting electricity prices. We apply the Bayesian jump-diffusion models and the stochastic volatility models with jumps and exogenous variables. The Bayesian approach allows for the statistical inference of model parameters, latent volatility, jump occurrence times and their sizes. To produce probabilistic forecasts within the Bayesian approach we employ predictive distributions which – calculated under the Bayesian pooling approach – handle formally the uncertainty associated with parameters and model specification. Using the day-ahead electricity prices from the Nord Pool market we argue that the Bayesian models and Bayesian pooling approach can be used for the efficient modelling and probabilistic forecasting of electricity prices.

Sergei Kulakov, University of Duisburg-Essen, Germany
Florian Ziel, University of Duisburg-Essen, Germany

Modeling of the non-linear impact of renewable energy forecasts on intra-day electricity prices

It appears undeniable that energy collected from renewable resources constitutes a substantial part in the overall supply of electricity in many contemporary energy markets. The German EPEX SPOT SE is not an exception in this case. One of the major features of this exchange is that it establishes prices for a MWh of electricity multiple times a day. It is primarily done on day-ahead auctions and during intra-day trading. The latter tends to be conducted on the grounds of a more precise renewable energy supply data. The day-ahead auctions are, in turn, based on the respective forecasts. Needless to say, those forecasts tend to be erroneous. In this paper we demonstrate that the influence of forecasting errors on day-ahead prices is non-linear. That is, a wrongly calibrated forecast may exert different impact on electricity prices depending on a sector of a merit-order curve. To show this explicitly, we model intra-day prices given errors in the forecasts for wind and solar energy generation. In doing so, we exploit an empirical supply and demand curves approach as well as a non-linear optimization technique. We show that forecasting accuracy increases as long as we take non-linear effects into account.

Carlo Lucheroni, University of Camerino, Italy

Modeling electricity price series with vector Hidden Markov Models

Electricity price series display peculiar features, from daily periodicities and price spikes to long autocorrelation. Most of the discrete time econometric models that can support these kinds of features have no internal representation of them and limit themselves to mimick the phenomenology. In the seminar, a machine learning approach and its econometric equivalent will be presented, that allow for a nice reproduction of many important features of electricity series, but also help look at the data in a way that has a clear and direct interpretation in terms of classes of market days and high level representations of market features.'

Katarzyna Maciejowska, Wrocław University of Science and Technology, Poland

Operational decisions of a small utility: forecasting the difference between the spot and the balancing market prices

The recent regulations of the electricity markets in Poland abandoned the system of guaranteed prices and hence forced all RES utilities to trade in the market. Since the electricity can be sold on both the spot and the balancing market, producers may try to optimize their sales. In this study, an index of price differences is constructed, which takes values between –1 and 1. It indicates, which of these two electricity prices – spot or balancing – is predicted to be higher and hence helps to make rational decisions. A new evaluation method is proposed, which aims at comparing different indexes from the point of view of an electricity producer. The approach is illustrated and verified with recent data from Polish power market.

Grzegorz Marcjasz, Wrocław University of Science and Technology, Poland
Bartosz Uniejewski, Wrocław University of Science and Technology, Poland
Rafał Weron, Wrocław University of Science and Technology, Poland

On the importance of the long-term seasonal component in day-ahead electricity price forecasting with NARX neural networks

In day-ahead electricity price forecasting the daily and weekly seasonalities are always taken into account, but the long-term seasonal component was believed to add unnecessary complexity and in most studies ignored. The recent introduction of the Seasonal Component AutoRegressive (SCAR) modeling framework has changed this viewpoint. However, the latter is based on linear models estimated using Ordinary Least Squares. Here we show that considering non-linear autoregressive (NARX) neural network-type models with the same inputs as the corresponding SCAR-type model can lead to a yet better performance. While individual Seasonal Component Artificial Neural Network (SCANN) models are generally worse than the corresponding SCAR-type structures, we provide empirical evidence that committee machines of SCANN networks can significantly outperform the latter.

Jacek Osiewalski, Cracow University of Economics, Poland
Kamil Makieła, Cracow University of Economics, Poland

Cost efficiency analysis of electricity distribution sector under model uncertainty

This paper discusses a Bayesian approach to analyzing cost efficiency of Distribution System Operators (DSOs) when model specification and variable selection is difficult to determine. Bayesian model selection and inference pooling techniques are adopted in a stochastic frontier analysis to mitigate the problem of model uncertainty. All interesting specifications can now be jointly considered for analysis of cost-effectiveness. Adequacy of a given specification is judged by its posterior probability, which makes the benchmarking process not only more transparent but also much more objective and inclusive for the stakeholders. The proposed methodology is applied to one of Polish Distribution System Operators. We find that variable selection plays an important role and models, which are the best at describing the data, are rather parsimonious. They rely on just a few variables determining the observed cost. However, these models also show relatively high average efficiency scores among analyzed objects.

Michael Schuerle, University of St. Gallen, Switzerland
Florentina Paraschiv, NTNU, Trondheim, Norway

Valuation of the flexibility of power-to-gas facilities

Power-to-gas (P2G) is a technology that converts electrical power to gas fuels like methane for storage in the natural gas grid. Due to the low efficiency, the production of synthetic methane is only profitable if electricity is sufficiently cheap. However, P2G facilities are flexible consumers and can benefit from short-term price fluctuations on the electricity spot market. We use a real option approach to assess the profitability of an investment in a P2G facility, taking into account the uncertainty of power prices, gas prices and future investment costs.

Paulina Rowińska, Imperial College London, UK

A multifactor approach to modelling the impact of wind energy on electricity spot prices

One of the main challenges of the 21st century is reinforcing sustainable economic growth in order to tackle climate change. An important part of this task is a more effective use of renewable energy sources, such as wind power. From the economical point of view, these sources are notorious for being risky to invest in because of their unpredictability. This is due to their high dependence on the weather – and weather forecasts still do not reach a desirable accuracy. Inspired by this problem, we aim to improve existing models of prices of electricity contracts. Reliable models give energy providers invaluable information that facilitates the process of decision making as well as encourages new investments in renewable energy sources. We introduce a three-factor model of electricity spot prices, consisting of a deterministic seasonality and trend function as well as short- and long-term stochastic components, and derive a formula for futures prices. The long-term component is modelled as a Levy process with increments belonging to the class of generalised hyperbolic distributions. We describe the short-term factor by Levy semistationary processes: we start from a CARMA(2,1), i.e. continous-time ARMA model, and generalise it by adding a short-memory stochastic volatility. We further modify the model by including the information about the wind energy production as an exogenous variable. We fit our models to German and Austrian data including spot and futures prices as well as the wind energy production and total load data. Empirical studies reveal that taking into account the impact of the wind energy generation on the prices improves the goodness of fit.

Marco Piccirilli, University of Padova, Italy
Luca Latini, University of Padova, Italy
Tiziano Vargiolu, University of Padova, Italy

Mean-reverting no-arbitrage additive models for forward curves in energy markets

In this paper we present an additive no-arbitrage model for energy forward markets capable to exhibit mean-reversion. The model naturally incorporates term structures for both the mean-reversion level and the volatility of forward prices and it is able to reproduce the seasonalities empirically observed in gas and power markets. We also present a method to estimate the model parameters, based on quadratic variation/covariation for the volatility and on constrained maximum-likelihood estimation for the mean-reversion speed and level. We apply this technique to time series of Phelix Base forward products.

Tomasz Sikorski, Polish Transmission System Operator (PSE S.A.), Poland
Marcin Czupryna, Cracow University of Economics, Poland
Artur Świętanowski, Polish Transmission System Operator (PSE S.A.), Poland

Challenges in the energy markets – power system operator's perspective

We discuss the current challenges facing the power system operation and development. The talk concentrates on the impact of risk and uncertainty on the selected business processes run by power system operator. We briefly discuss decision models and stochastic methods that support efficient and secure energy delivery to final costumers. We consider the consequences of increasing share of intermittent generation (solar and wind) and distributed generation as well as changing roles in the electricity market (prosumers and active load). The power grid development based on dynamic stochastic optimization methods and market management system based on locational pricing are presented as important examples of research and development. Finally, the concept of stochastic power reserve mechanism is discussed.

Neda Todorova, Griffith University, Australia
Dirk Baur, University of Western Australia

Automobile manufacturers, electric vehicles and the price of oil

This paper analyzes the oil price sensitivity of the world's largest automobile manufacturers. We identify two opposing effects: a fuel-cost negative demand effect and a global business cycle positive demand effect. Both effects have strengthened significantly since the Global Financial Crisis and also become more volatile both in the time-series dimension and in the cross-section of automobile firms. Tesla is the only company that displays a positive oil price sensitivity. The results indicate that the market is pricing the risk of a fundamental change of the industry towards more fuel-efficient and fully electric vehicles.

Stefan Trück, Macquarie University, Sydney, Australia
Lin Han, Macquarie University, Sydney, Australia
Chi Truong, Macquarie University, Sydney, Australia

Revisiting the directional volatility connectedness between crude oil and equity markets

The relationship between volatility in oil and equity markets has been investigated by numerous studies with conflicting results. While some authors find significant volatility transmission from oil to equity markets, others suggest that transmission effects are rather limited, with oil shocks only occasionally contributing to volatility in major equity markets. We replicate a recent study by Maghyereh et al. (2016) to investigate volatility spillover effects between oil and 11 global equity markets. While Maghyereh et al. (2016) suggest that oil-equity connectedness is significantly dominated by volatility transmission from oil to equity markets, our results indicate that the oil market is rather a spillover taker. Instead we find that major equity markets such as the US, UK and Germany are transmitters of volatility to the oil market and other global equity markets.

Bartosz Uniejewski, Wrocław University of Science and Technology, Poland
Rafał Weron, Wrocław University of Science and Technology, Poland
Florian Ziel, University of Duisburg-Essen, Germany

Variance stabilizing transformations for electricity spot price forecasting

Most electricity spot price series exhibit price spikes. These extreme observations may significantly impact the obtained model estimates and hence reduce efficiency of the employed predictive algorithms. For markets with only positive prices the logarithmic transform is the single most commonly used technique to reduce spike severity and consequently stabilize the variance. However, for datasets with very close to zero (like the Spanish) or negative (like the German) prices the log-transform is not feasible. What reasonable choices do we have then? To address this issue, we evaluate 16 variance stabilizing transformations (VSTs) within a comprehensive forecasting study involving regression models and 12 datasets from diverse power markets. We show that the probability integral transform (PIT) combined with the standard Gaussian distribution yields the best approach, significantly better than many of the considered alternatives.

Tiziano Vargiolu, University of Padova, Italy

Capacity markets and the pricing of reliability options

The growing penetration of non-dispatchable renewable sources, like solar and wind, introduced in the latest years market uncertainties in the quantity of electricity produced, which can possibly originate price spikes. Capacity markets have exactly the purpose of providing new potential capacity when that present in the market is already allocated and there is a sudden drop in supply (due for example to unexpected adverse weather events). In this talk we will present the different capacity remuneration mechanisms, and analyze in more detail the so-called reliability option, which is a call option sold by producers to transmit system operators. This option has the important advantage of shaving possible price peaks, but its correct pricing require non-trivial techniques.

Sjur Westgaard, NTNU, Trondheim, Norway

Forecasting price distributions in the German electricity market

Electricity price distributional forecasts are important input to energy risk management. In this chapter we compare a set of models w.r.t. predicting the price distribution in the German electricity spot market (the EPEX market) using various supply and demand variables. We apply static and dynamic quantile regression models and benchmark the forecasts with different GARCH and CAViAR type models. Since the aim is predicting, we select the subset of possible variables for each quantile and trading period such that the performance is maximized. Our findings highlight the importance of variable selection, and show that it in many cases it is just as important as the choice of the model itself. The empirical study indicates that exponential weighted quantile regression is the best model overall. It give consistently good forecasts across trading periods and quantiles, and performs particularly well in the outer tail quantiles. Hence, we this model capture the changing input mix of electricity production in Germany market. The CAViaR models are the best performing benchmarks, but their performance is not consistent over all quantiles and trading periods. The GARCH model captures clustering of exceedances the best, but it's performance is rather poor generally speaking. Based on these results we recommend exponential weighted quantile regression as a solid model for energy risk management in the German el-market. In addition, it is a model that is transparent, easy to implement and to communicate.

Florian Ziel, University of Duisburg-Essen, Germany

Mid-term electricity price forecasting using future data

Due to the liberalization of markets, the change in the energy mix and the surrounding energy laws, electricity research is a dynamically altering field with steadily changing challenges. One challenge is to provide reliable mid-term forecasts despite high variation in the time series of electricity prices. This issue is tackled in a promising and novel approach. By utilizing the high precision of econometric autoregressive models and the expectations of market participants reflected in future prices, we show that the forecasting performance can be vastly increased while maintaining hourly precision. We investigate the day-ahead electricity price of the EPEX Spot for Germany and Austria and setup a model which incorporates the Phelix future of the EEX for Germany and Austria. The model can be considered as an AR24-X model with one distinct model for each hour of the day. We are able to show that future data contains relevant price information for future time periods of the day-ahead electricity price. By implementing a fast and efficient lasso estimation approach we demonstrate that our model can outperform several other models of the literature.