

specification. The results obtained by means of the Bayesian and non-Bayesian methods are compared. Our empirical study is based on day-ahead electricity prices. We argue that the Bayesian models and Bayesian pooling approach can be useful for the modelling and probabilistic forecasting of electricity prices.

## Using tropical optimization techniques in multi-criteria decision problems

Nikolai Krivulin<sup>1</sup>

<sup>1</sup>*Saint Petersburg State University, , Russian Federation*

We consider problems of rating alternatives based on their pairwise comparisons according to several criteria. Given pairwise comparison matrices for each criterion, the problem is to find the overall priorities of each alternative. We offer a solution that involve the minimax approximation of the comparison matrices by a common (consistent) matrix of unit rank in terms of the Chebyshev metric in logarithmic scale. The approximation problem reduces to a multi-objective optimization problem to minimize simultaneously the approximation errors for all comparison matrices. We formulate the problem in terms of tropical (idempotent) mathematics, which focuses on the theory and applications of algebraic systems with idempotent addition. To solve the optimization problem obtained, we apply methods and results of tropical optimization to derive a Pareto optimal solution. As an illustration of the approach, we present a complete Pareto optimal solution for a general problem of rating alternatives in the case of two criteria used for comparisons.

## Distributionally Robust Inverse Covariance Estimation: The Wasserstein Shrinkage Estimator

Viet Anh Nguyen<sup>1</sup>, Daniel Kuhn<sup>1</sup>, Peyman Mohajerin Esfahani<sup>2</sup>

<sup>1</sup>*EPFL, , Switzerland*, <sup>2</sup>*Delft University of Technology, , Netherlands*

We introduce a distributionally robust maximum likelihood estimation problem with Wasserstein ambiguity set to infer the inverse covariance matrix of a  $p$ -dimensional Gaussian random vector from  $n$  independent samples. We prove that this estimation problem is equivalent to a semidefinite program, which is tractable in theory but beyond the reach of general purpose solvers for practically relevant values of  $p$ . In the absence of conditional independence constraints we show that the estimation problem has an analytical solution that is naturally interpreted as a nonlinear shrinkage estimator with several desirable properties: besides being invertible and well-conditioned even for  $p \gg n$ , it is rotation-equivariant and preserves the order of the eigenvalues of the sample covariance matrix. Finally, we develop a sequential quadratic approximation algorithm for efficiently solving the generic estimation problem in the presence of conditional independence constraints.

## Modelling a non-linear impact of renewable energy forecasts on intra-day electricity prices

Sergei Kulakov<sup>1</sup>, Dr Florian Ziel<sup>1</sup>

<sup>1</sup>*University of Duisburg-Essen, , Germany*

It seems 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. This 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 are prone to be erroneous. In this paper we demonstrate that the influence of forecasting errors on a difference between intra-day and 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 day-ahead data and 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.

## Estimation of risk neutral moments from WTI crude oil options.

Valeriy Kunst<sup>1</sup>

<sup>1</sup>*NTNU, Trondheim, Norway*

It is possible to estimate statistical distributions' moments that are based not on a historical data but are incorporated in derivatives' prices and are forward looking. Thus risk neutral moments, that are backed out from options with wide range of strike prices, can be advantageous for forecasting, risk management and policy analysis. In this work, risk neutral moments are calculated for WTI crude oil options with maturities of one and six months. Taking into consideration that observable strike prices are discrete and have relatively big increments, there is a need for interpolation. It is applied not directly on options prices but on implied volatilities with two methods: cubic spline smoothing and kernel smoothing. Furthermore, options with extremely low and high strike prices are not traded. Therefore risk neutral distributions' tails are extended by Generalised Extreme Value distributions. Moreover, tails of distributions are extrapolated using another approach: constant volatilities are attached to the left and right side of implied volatility. Consequently, estimated with these approaches, risk neutral moments are compared across time and two maturities of one and six months. Some analysis of potential of risk neutral moments describing major events is analysed as well.

## Is market surprised by the surprised?

Khine Kyaw<sup>1</sup>, Mojisola Olugbode, Barbara Petracchi

<sup>1</sup>*NTNU, Trondheim, Norway*

This paper investigates how investors respond to earnings surprises. We study over 9,000 annual earnings announcements made by US companies during the period 2002 through 2016. Each surprise is classified as either good, neutral or bad depending on whether firms meet analysts' expectations or not. Market reactions to the surprises are then explored using panel data models. We find that market reactions to the earnings surprises are asymmetric between positive and negative surprises. We also explore the effect corporate governance and market uncertainty have on the market reactions earnings surprises incite. We find that market reactions have changed during the global financial crisis.