Abstracts

Presenting author, *other authors* **Title**

Roberto Baviera*, Tommaso Santagostino Baldi*
Optimal Statistical Arbitrage in presence of Stop-Loss and Leverage

In this paper we develop a statistical arbitrage trading strategy with the introduction of two key elements in hi-frequency trading: leverage and stop loss. We consider the case when the security price follows a mean-reverting process with proportional transaction costs. We focus on repeated strategies as in Kelly (1956): the investment strategy is not realized only once but it is reproduced iteratively using a self-
nancing portfolio. For every given stop-loss level we derive analytically the optimal investment strategy consisting of optimal leverage and market entry/exit levels. First we show how to obtain the optimal strategy when the underlying log-price follows an Ornstein-Uhlenbeck (OU) process and in the case of an OU price process. Then we describe how to apply the strategy to a generic continuous mean-reverting process. Following industry practice of pairs trading we consider two examples of pairs in the commodity futures' market. We report in detail the analysis for two spreads on Heating-Oil and Gas-Oil futures in a one year sample of half-hour market prices.

Alvaro Cartea
Model Uncertainty in Electricity Interconnector Markets

We show how an investor takes positions in two locations that are joined by an electricity interconnector. The investor takes positions in the intraday market by continuously trading in both markets whilst accounting for the impact her trades have on electricity prices in both locations. Moreover, we also show how model uncertainty affects the optimal trading strategy.

Panagiotis Christodoulou*, Nils Detering, Thilo Meyer-Brandis*
Quadratic hedging with multiple assets under illiquidity with applications in energy markets

We propose a hedging approach for general contingent claims when liquidity is a concern and trading is subject to transaction cost. Multiple assets with different liquidity levels are available for hedging. Our quadratic risk criterion targets a tradeoff between minimizing the risk against uctuations in the stock price and incurring low liquidity costs. Following Cetin et al. (2004) we work in an arbitrage-free setting assuming a supply curve for each asset. In particular, in an incomplete market in discrete time, we prove the existence of a locally risk-minimizing strategy under mild conditions on the price process. Under stochastic and time-dependent liquidity risk we give a closed-form solution for an optimal strategy in the case of a linear supply curve model. Our results extend the work of Schweizer (1988) in two directions. First by considering a multidimensional asset price. Second by accounting for liquidity costs. Finally we give an application of our hedging method in energy markets where futures with different maturity are available for trading. The futures closest to their delivery period are usually the most liquid but depending on the contingent claim not necessary optimal in terms of hedging. In a simulation study we investigate this tradeoff and compare the resulting hedging strategies with the classical ones.

P. Falbo, *A. Bersani, L. Mastroeni*
Impact of Emission Trading on the Energy-mix

We consider an aggregate model of the optimal energy-mix problem. The power system is composed by producers, that manage short term generation decision in a competitive way. On the contrary the long term energy-mix decision is taken in a cooperative way, which is equivalent to a monopolist decision aiming at maximizing the expected long run profit of the entire electricity sector. The initial investment is distributed on three technologies: one based on a renewable energy source, and two polluting (e.g. coal and gas). Long term demand is random and determines the level of production and emissions. An emission trading system place the obligation to producers to buy emission certificates in a number equivalent to their emissions. The energy-mix problem is therefore directly affected by the cost of the certificates, since the preference for the green technology over the polluting ones can largely offset such environment cost. We analyse both theoretically and by means of a numerical application.

Flavio Giannantonio
Commodity risk control modelling in the energy sector

Monitoring commodity risks affecting a company results and minimizing their exposure and impact, consistently with business targets, have become more relevant in the last years. Commodity risk is characterized by market price risks related to power/fuel prices volatility and volume risks due to fluctuation of resources availability (e.g., wind, water). By considering the netting effect among total price and volume risks, a global Key Risk Indicator (KRI) is determined. According to the different nature of risk exposures, deriving both from the company industrial core business and from the trading activities, different risk metrics are applied. For industrial books, Profit at Risk (PaR) is used to give indication of the difference between yearly expected profit (gross margin) and minimum profit achieved at a given confidence interval. For trading books, Value at Risk (VaR) is applied to capture the maximum potential portfolio value loss at a given level of certainty, and based on the assumption that all net positions will be closed within a certain period of time (the so-called holding period).

Luigi Grossi, *Fany Nan*
Robust SETARX models for electricity price forecasting

In the present paper we suggest to use a version of threshold autoregressive models (SETARX) where parameters are estimated robustly to the presence of spikes. Differently from what has been done in the literature so far, we are not interested in modelling spikes, but we want to focus the attention on the influence that spikes can have on the estimated coefficients. If non robust estimators are applied, coefficient could be very badly biased and even non-spiky observations, which are the very large majority, could not be properly modeled and forecasted. Moreover, we suggest a completely robust approach to modelling and forecasting electricity prices which embed robust estimation of a SETARX model, robust tests for unit root and nonlinear components and robust information criteria. A Monte Carlo study is carried out in order to select the best weighting function for GM-estimators of SETAR processes. Grossi & Nan (2015) have started to address the above points through a Monte Carlo experiment which compares the performances of classical SETAR estimator and robust estimator using different weighting functions. The main insights obtained from that preliminary work are confirmed in the present paper where a more extensive simulation experiment is carried out. The results obtained from the simulation experiment are used

to estimate the parameters of SETAR models on the Italian electricity price data (PUN, prezzo unico nazionale). The model is enriched by the introduction of exogenous regressors which improve the forecasting performances. Crucial variables in predicting electricity prices are dummies for the intra-day seasonality, predicted demanded volumes and predicted wind power generation (Gianfreda & Grossi, 2012). The application of the procedure to the Italian electricity market reveals the forecasting superiority of the robust GM-estimator.

Carlo Mari, *Carlo Lucheroni*
Stochastic systemic LCOE: integration of non-dispatchable renewable power sources in the LCOE theory

Computing the levelized cost of electricity (LCOE) of intermittent nondispatchable energy resources in an otherwise dispatchable resources based power system cannot be done in the straightforward usual way, without neglecting costs which come from constraints imposed by the system to the intermittent resources sector itself. This paper introduces the systemic LCOE theory for energy planning and policy analysis, extending the way the LCOE for dispatchables is computed by keeping into account system constraints. Based on previous work on the stochastic extension of LCOE, used to include assessment and optimization of fossil fuels and CO2 prices risk in the LCOE theory, the paper studies systemic intermittent resources LCOE computations also in their stochastic systemic version, in order to include price risk into the theory. Coherently with given renewable energy target policies, the systemic LCOE theory allows to plan optimal generation portfolios which integrate in an efficient way the non-dispatchable energy available in a given power system. As a side result, it is shown how the stochastic systemic LCOE theory can be used to quantify and optimize CO2 emissions reduction due to cost risk aversion when wind resources are added to a power system.

Loretta Mastroeni, *Pierluigi Vellucci*
"Butterfly Effect" vs Chaos in Energy Futures Markets.

In this paper we test for the sensitive dependence on initial conditions (the so called "butterfly effect") of energy futures time series (heating oil, natural gas), and thus the determinism of those series. These series have also been studied by Adrangi et al. (2001) and Chwee (1998). For a distinction between "chaos" and "butterfly effect", we refer to celebrated book by Devaney et al. (1989). Unlike previous studies (see Benedetto et al. (2016)) we test for the time series for sensitive dependence on initial conditions, employing a coefficient that describes the determinism rate of the series and that represents its reliability level (in percentage). This coefficient has been introduced by Kaplan and Glass (1992). The introduction of this reliability level is motivated by the fact that time series generated from stochastic systems also might show sensitive dependence on initial conditions. The reliability level obtained for the NYMEX energy futures considered here is always approximately 50% and this means that the stochastic component and the deterministic one turn up approximately in the same proportions. Such a tangible presence of a stochastic component does not warrant strong evidence of chaotic behaviour.

Giorgia Oggioni, *Elisabetta Allevi, L. Boffino, M.E. De Giuli*

Evaluating the impact of political risk in the external natural gas supply to the Italian market

Natural gas covers a significant quota of the energy mix of many of the European countries with a share of 24% in the Total Primary Energy Supply (see Holz et al., 2014). Many of the European natural gas imports originate from unstable regions and suppliers exposed to the risk of supply failure due to political instability. The political instabilities of Northern Mediterranean area and the disturbances between the European-Russian relationship in the last years has increased the concerns on security of supply in the European natural gas market. Among the European countries, Italy is one of the largest gas market in Europe that mainly rely on natural gas imports to cover its demand since the national production is very low. As for other European countries, Italian natural gas imports mainly come from Russia, followed by Algeria, Libya, the Netherlands, Qatar, and Norway. In this paper, we analyze the political risk associated with the natural gas imports of the Italian gas market. We develop an equilibrium model that describes the natural gas supply chain where producers, mid-streamers and consumers can sell and buy natural gas. Furthermore, we assume that consumers are subdivided into residential/commercial users, energy-intensive industries, and power companies. In addition, we model both the supply of natural gas with pipelines and the Liquefied Natural Gas (LNG) that is transferred through tankers. Mid-streamers who buy natural gas and LNG are assumed to be exposed to the political risk associated to the imports from foreign countries. They defines the amount of gas and LNG to import not only on the basis of the production and transportation costs, but also on the political risk associated with the countries from which the gas originates. The political risk of external gas and LNG supply is measured by the means of an indicator that has been constructed as in Le Coq and Paltseva (2009). The equilibrium problem is transformed in complementarity condition form. This approach has been already applied to the study of the natural gas market (see Egging and Gabriel, 2006; Egging et al. 2008).

Jan Palczewski, *John Moriarty*

Energy imbalance market call options and the valuation of storage

The utilisation of energy storage in electric grids is increasing and, with it, the importance of operational optimisation from the twin viewpoints of cost and system stability. In this paper we assess the real option value of balancing reserve provided by an energy-limited storage unit. The contractual arrangement is a series of American-style call options in an energy imbalance market (EIM), physically covered and delivered by the store, and purchased by the power system operator. We take the EIM price as a general regular one-dimensional diffusion and impose natural economic conditions on the option parameters. In this framework we derive the operational strategy of the storage operator by solving, iteratively, a pair of optimal stopping problems: when to purchase energy to load the store (to provide physical cover for the option) and when to sell the option to the system operator. Assuming that the store is used only for provision of balancing services, i.e., options are offered back-to-back, we give necessary and sufficient conditions for the finiteness and positivity of the value function (the total discounted cash flows generated by operation of the storage unit) as well as its fixed point characterisation. The latter allows us to design a straightforward procedure for the numerical evaluation of the optimal operational strategy (stopping regions, i.e., sets of prices when power should be purchased) and the value function. Interestingly, our developments sidestep differential characterisation of the value function favouring instead a purely probabilistic approach. Theoretical results are illustrated with an operational and economic analysis using data from the German Amprion EIM.

Filippo Petroni, *Guglielmo D'Amico, Robert Adam Sobolewski*
Optimal provision of a dispatchable energy source for wind energy management: dependence on the wind energy model

The share of wind energy is continuously increasing in time but there are still relevant problems that affect this industry. The most important limitation concerns the variability of the wind speed phenomenon. Solutions are mainly based on energy storage systems or by insurance contracts. Assume that a firm produce energy by means of gas and wind and should furnish a given quantity of energy K. An low production of energy causes a cost due to penalties. An excess of production is lost. Then, the firm needs to determine an optimal quantity of energy to be produced with gas that added to the uncertain wind energy production maximize its profit. The problem is solved under different hypothesis on the wind energy model: a simple sequence of i.i.d. random variables, a Markov chain model, semi-Markov based models of wind energy. The results show the dependence of the optimal policy on the different models of wind energy and therefore highlight the importance of using an appropriate model of wind energy. The application is performed on real data of energy produced by a wind turbine E-48 ENERCON of rated power 800kW.

Enrico Piccin, *Elisa Scarpa, Francesco Giuseppe Sitzia*
Multivariate gas and power spot prices process with NIG innovations: an application to spread option pricing

With the rapid growth of renewables in Europe during the last decade traditional generation margin declined sensibly. Trading and hedging on the forward curve doesnt guarantee any more sustainable revenues for operators hence the attention shifted from forward to spot markets. Flexibility represents now the majority of assets and contracts value. In our work, we jointly model gas and power spot market dynamics: firstly via estimating a mean reverting process with Normal Inverse Gaussian (NIG) innovations and secondly fitting a copula function for the multivariate distributions. The NIG process is able to capture the typical characteristics of power and gas markets such as kurtosis and heavy-tailed distributions while the copula guaranteed to capture co-movements and tail dependence. The model is estimated on Italian Gas (PSV) and Power (PUN, Zonal Prices) markets and finally price paths, via Montecarlo simulation approach, are generated in order to show an application of spread option pricing.

Marco Piccirilli, *Fred Espen Benth, Tiziano Vargiolu*
Additive energy forward curves under the HJM framework

In energy markets the most traded products are usually forward contracts. Generally, these can be of two types: in our terminology, forward and futures. As, for instance, in stock markets, the former consist of an agreement to buy a certain underlying at a fixed price to be given at a fixed date, whereas who sells a futures contract commits to deliver, say, the power over a fixed period. This implies that abitrage-free futures prices consist of (in our continuous time setting, integral) averages of forward prices. Our purpose is to design a Heath-Jarrow-Morton framework, both for forwards and futures, which exhibits the following features. Firstly, the dynamics of the processes are additive and mean-reverting: the additivity property generally allows to find closed-form formulae and suitable calibration procedures for average based contracts, while mean reversion can be empirically observed. Furthermore, we want to preserve the Markovianity of the modeling stochastic processes. Finally and most importantly, in a market model consisting of contracts of any maturity date or delivery period, we require that no arbitrage opportunities are possible. This forces

us to find a change of measure that turns into martingales the forward and futures prices of any maturity or delivery. We consider the forward prices for each maturity that can be represented as affine functions of a universal source of randomness. In the Brownian setting, we are able to completely characterize the models which allow for the above mentioned martingale property. We discuss the possibility of introducing a Lévy component either as stochastic driving factors, or in the role of stochastic volatility.

Rossana Riccardi, *Elisabetta Allevi, Antonella Basso, Francesca Bonenti, Giorgia Oggioni*
Efficiency valuation of Green stocks and portfolio construction: a two stage approach

Nowadays, beside classical financial aspects, new relevant social requirements are perceived as important and need to be included in the construction of an investment portfolio. In particular, the environment is rapidly becoming a factor as relevant in an investment decision as more traditional financial elements such as liquidity or competition, since investors mandates involve contributing to public policy goals, and one of the most important among these is climate mitigation. Many initiatives are born around the climate change mitigation of investors portfolios and this is one of the main theme identified by the sustainable finance literature. In this paper, we evaluate and manage a green investment portfolio that integrates classical financial tasks with some environmental issues. We first propose two synthetic indicators of environmental sustainability which effectively inform financial agents on the greenity of their investments. These alternative indicators could serve as an overall measure of environmental sustainability; they will also overcome the drawback that limits the evaluation of green investments to the measurement of CO2 emissions. Then, we propose alternative integrated methods for portfolio optimization that involves decisions on stock screening, stock selection, and capital allocation. A two steps approach is adopted: in the first step a wide set of relevant stocks are screened in order to find a group of potential investment targets that are simultaneously profitable and green. For this selection procedure we use a suitable data envelopment analysis (DEA) model with different selection methods. In the second step we apply an ad-hoc Mean-Variance portfolio optimization model to determine the allocation of capital to each stock in the final portfolio. The analysis is carried out on a sample period of five years (taking as benchmarks the STOXX All Europe 100 and EURONEXT indices), using a moving window approach to construct a green portfolio and evaluate its performance with periodic rebalance of the portfolio.

Maren Diane Schmeck
The role of mean reversion when pricing options on forwards in energy markets: the case of stochastic volatility and jumps

Consider the problem of pricing options on forwards in energy markets, when spot prices follow a geometric multi-factor model in which several rates of mean reversion appear. In this paper we investigate the role played by slow mean reversion when pricing and hedging options. In particular, we determine both upper and lower bounds for the error one makes neglecting low rates of mean reversion in the spot price dynamics in a jump diffusion setting. When including stochastic volatility as well as time dependent mean reversion into the model, we quantify a bound for the maximum error one makes.

Carlo Sgarra, *Ying Jiao, Chunhua Ma, Simone Scotti*
A Branching Process Approach to Power Markets

Energy markets, and in particular, electricity markets, exhibit very peculiar features. The historical series of both futures and spot prices include seasonality, mean-reversion, spikes and small fluctuations. Very often a stochastic volatility dynamics is postulated in order to explain their high degree of variability. After the pioneering paper by Schwartz, where an Ornstein-Uhlenbeck dynamics is assumed to describe the spot price behavior, several different approaches have been investigated in order to describe the price evolution. A comprehensive presentation of the literature until 2008 is offered in the book by F.E. Benth, J. Salthythe-Benth and S. Koekebakker. High frequency trading, on the other hand, introduced some new features in commodity prices dynamics: in the paper by V. Filimonov, D. Bicchetti, N. Maystre and D. Sornette evidence is shown of endogeneity and structural regime shift, and in order to quantify this level the branching ratio is adopted as a measure of this endogenous impact and a Hawkes processes dynamics is assumed as a reasonable modelling framework taking into account the self-exciting properties. The purpose of the present paper is to propose a new modeling framework including all the above mentioned features, still keeping a high level of tractability. The model considered allows to obtain the most common derivatives prices in closed or semi-closed form. Here with semi-closed we mean that the Laplace transform of the derivative price admits an explicit expression.

Bartosz Uniejewski
Automated variable selection and shrinkage for day-ahead electricity price forecasting

In day-ahead electricity price forecasting (EPF) variable selection is a crucial issue. Conducting an empirical study involving state-of-the-art parsimonious expert models as benchmarks, datasets from three major power markets and five classes of automated selection and shrinkage procedures (single-step elimination, stepwise regression, ridge regression, lasso and elastic nets), we show that using the latter two classes can bring significant accuracy gains compared to commonly used EPF models. In particular, one of the elastic nets, a class that has not been considered in EPF before, stands out as the best performing model overall.

Maria Teresa Vespucci, *Diana Moneta, Paolo Pisciella, Giacomo Viganò*
Optimal operation of power distribution networks with RES generation and storage devices

The operation of power distribution networks is going to change as a consequence of the large penetration of distributed generation, i.e. power plants (wind, photovoltaic, micro-CHP,...) directly connected to distribution networks. Distribution networks will host both dispatchable power plants (e.g. thermal), for which the production schedule is determined one day ahead by the plant's owner on the basis of load and price forecast, and non-dispatchable power plants (wind, photovoltaic), for which in advance only production forecasts are available, on the basis of weather forecast (wind speed, solar irradiance). As power generated by non-dispatchable plants is partially unpredictable, imbalance between load and generation is very likely to occur. A new operator, the Distribution System Operator (DSO), will be in charge of operating the distribution network, in order to compensate generation-load imbalances, while guaranteeing technical feasibility, i.e. constraints on currents in lines (security) and voltages at nodes (power quality). Internal (owned by DSO) regulation resources will be electricity storage devices and onload tap changers. DSOs external regulation resources (owned by third parties) will be exchanges of active and reactive power with the high voltage

transmission network and dispatch of active and reactive power of generation plants. Costs associated to the use of internal regulation resources reflect device deterioration; costs associated to the use of external regulation resources have to be defined by the Regulator, so as to allow a technically efficient operation of the network. We develop a nonlinear programming model for operating a medium-voltage AC network with distributed generation and storage devices where initial set points are assigned in each period of a given time horizon on the basis of load, price and weather forecasts. A set point in a time period is defined by modules and phases of voltages in all nodes, active and reactive powers, on load tap changer transformation ratio and loads. When the realized values of loads, prices and renewable generation differ from forecasts, new set points are determined so as to minimize distributors redispatching costs while satisfying security requirements and ensuring service quality (nodal balance of active and reactive power, current transits on lines and transformers for security). Storage devices are modeled by means of constraints that relate adjacent time periods. The optimal set points are computed by an ad-hoc algorithm that exploits the problem structure in order to minimize the computational time.

Andreas Wagner
An Integrated Electricity Spot and Forward Model

A framework for the consistent modelling of electricity spot and forward prices is introduced. It builds upon ideas from structural and financial models. The crucial concept is a separation of trading and delivery time in the electricity price process and the introduction of the abstract electricity price. Moreover, the electricity forward price is defined as an expected value of the abstract price conditioned only on the evolution of certain model components representing the forward dynamic. This enables the model to account for hedgeable and unhedgeable components in the electricity market. Applications focus on the pricing of electricity derivatives.
Within this framework, a concrete model is proposed, which relies on the model for residual demand and a two-factor forward dynamic. It is capable of replicating the electricity forward price term-structure and partially the volatility term-structure of European options on electricity forwards. The practical problem of delivery periods in forward products is accounted for. Calibration procedures are described in detail and some applications are discussed. The model is assessed in a case study on the German market.

Rafał Weron
Day-ahead electricity price forecasting with high-dimensional structures: Univariate vs. multivariate models

Conducting an extensive empirical study on short-term electricity price forecasting (EPF), involving state-of-the-art parsimonious expert models as benchmarks, datasets from 12 power markets and 32 multi-parameter regression models estimated via the lasso, we show that using the latter shrinkage approach can bring statistically significant accuracy gains compared to commonly used EPF models. We also address the long-standing question on the optimal model structure for EPF. We provide evidence that despite a minor edge in predictive performance overall, the multivariate modeling approach does not uniformly outperform univariate models across all datasets, seasons of the year or hours of the day, and at times is outperformed by the latter. This may be an indication that combining advanced structures or the corresponding forecasts from both modeling classes may bring a further improvement in forecasting accuracy. Finally, we also analyze variable selection for the best performing multivariate and univariate high-dimensional lasso-type models, thus provide guidelines to structuring better performing forecasting model designs.

Posters

- A. Balata, *J. Palczewski*

  Regress Later Monte Carlo for controlled diffusions

- *Clementina Bruno,* Anna Menozzi

  CEO turnover in the European energy market

- Angelica Gianfreda, *Giacomo Scandolo*

  New VaR and ES Requirements: Comparing Risk Metrics in Electricity Markets via Conditional Autoregressive Models

- Martino Grasselli, *Katja Ignatieva*

  Nonparametric Estimation of Commodity Price Dynamics

- *Paolo Guiotto,* Andrea Roncoroni

  How Firms Should Hedge Non-Tradable Risk?

- Wieger Hinderks

  An Extension of Arithmetic Factor Models

- Takashi Kanamura

  A Financialization Model of Crude Oil Markets

- Alberto Santangelo, *Anna Coppola, Gianluca Fusai*

  Gas storage valuation using a temperature dependent gas price model

- Yuying Sun, *Xun Zhang, Yongmiao Hong, Shouyang Wang*

  Threshold effects in interval-valued models: A new approach to analyze the impact of speculation on crude oil prices

- *Massimiliano Caporin, Fulvio Fontini,* Elham Talebbeydokhti

  Testing Persistence of WTI and Brent Long-run Relationship after Shale oil Supply Shock